

**IN THE UNITED STATES DISTRICT COURT
FOR THE WESTERN DISTRICT OF TEXAS
WACO DIVISION**

GENTEX CORPORATION and INDIGO
TECHNOLOGIES, LLC,

Plaintiffs,

THALES VISIONIX, INC.,

Involuntary Plaintiff,

v.

FACEBOOK, INC. and FACEBOOK
TECHNOLOGIES, LLC,

Defendants.

Case No.: 6:21-cv-00755-ADA

JURY TRIAL DEMANDED

**PLAINTIFFS' AMENDED DISCLOSURE OF
PRELIMINARY INFRINGEMENT CONTENTIONS**

Pursuant to the Court's Order Governing Proceedings, Plaintiffs Gentex Corporation and Indigo Technologies, LLC (collectively, "Gentex") hereby serve their amended disclosure of preliminary infringement contentions.

These infringement contentions are preliminary. Discovery has not yet begun, and Gentex's investigation is ongoing. The parties have not discussed proposed constructions for, and the Court has not yet construed, any of the asserted claims. Gentex specifically reserves its right to supplement these disclosures—including by asserting additional claims, accusing different or additional functionality, and accusing additional and/or different products—based on information obtained as the case progresses. Gentex also reserves the right to amend its infringement contentions and asserted claims based on any proceedings before the U.S. Patent & Trademark Office regarding the asserted patents.

I. CHARTS SETTING FORTH WHERE IN THE ACCUSED PRODUCT(S) EACH ELEMENT OF THE ASSERTED CLAIMS IS FOUND.

As set forth in detail in Gentex’s Complaint and the Exhibits attached thereto (Dkt. No. 1), Gentex alleges that Defendants Facebook, Inc. and Facebook Technologies, LLC (collectively, “Facebook”) have infringed and continued to infringe, directly and indirectly, literally or under the doctrine of equivalents, one or more claims of U.S. Patent Nos. 6,757,068 (the “’068 patent”), 7,301,648 (the “’648 patent”), 8,224,024 (the “’024 patent”), 6,922,632 (the “’632 patent”), and 7,725,253 (the “’253 patent”) (collectively, the “Asserted Patents”) by making, using, selling, offering to sell, and/or importing their Oculus Rift S, Oculus Quest, and Oculus Quest 2 products (collectively, with their respective related instructions, systems, services, and software, the “Accused Products”).

Gentex attached as Exhibits 1-5 to its October 22, 2021 Disclosure of Preliminary Infringement Contentions (“Preliminary Infringement Contentions”) claim charts identifying the manner in which the Accused Products infringe each element of the asserted claims. These claim charts are based on a reasonable investigation of publicly available information currently available to Gentex. These preliminary infringement contentions are intended to serve a notice function, and do not constitute an exhaustive explanation of all theories Gentex may present in this case. Gentex reserves the right to amend, revise, alter, or otherwise modify these charts as this case progresses, including to incorporate new information obtained during the course of discovery (such as information that is not currently publicly available).

Exhibit 1 sets forth Gentex’s preliminary contentions concerning Facebook’s direct and indirect infringement of claims 1-2, 4-5, 7-9, 11-20, 23-33, 35, 41, 45-48, 50, and 54-59 of the ’068 patent, including a chart setting forth where in the Accused Products each element of the aforementioned claims is found, to the best of Gentex’s current knowledge and information.

Exhibit 2 sets forth Gentex's preliminary contentions concerning Facebook's direct and indirect infringement of claims 1-5, 8-11, 16-18, 20-32, 35, 37-38, and 40-44 of the '648 patent, including a chart setting forth where in the Accused Products each element of the aforementioned claims is found, to the best of Gentex's current knowledge and information.

Exhibit 3 sets forth Gentex's preliminary contentions concerning Facebook's direct and indirect infringement of claim 1 of the '024 patent, including a chart setting forth where in the Accused Products each element of the aforementioned claim is found, to the best of Gentex's current knowledge and information.

Exhibit 4 sets forth Gentex's preliminary contentions concerning Facebook's direct and indirect infringement of claims 1-8, 11-26, 28-36, 44-45, 47-55, 57-61, and 66-69 of the '632 patent, including a chart setting forth where in the Accused Products each element of the aforementioned claims is found, to the best of Gentex's current knowledge and information.

Exhibit 5 sets forth Gentex's preliminary contentions concerning Facebook's direct and indirect infringement of claims 1-4 and 6-9 of the '253 patent, including a chart setting forth where in the Accused Products each element of the aforementioned claims is found, to the best of Gentex's current knowledge and information.

The Court has not yet conducted claim construction proceedings. Depending on any constructions by the Court as to the Asserted Claims, and/or positions that Facebook or its expert witness(es) may take concerning claim interpretation, infringement, and/or validity issues, the charts in Exhibit 1-5 and the disclosures referenced therein may be of greater or lesser relevance, and different disclosures relating to the Accused Products may be implicated. Given this uncertainty, the charts may reflect alternative applications of the claims to the Accused Products. Nothing stated herein shall be construed as an admission or a waiver of any particular construction

of any claim term.

II. THE PRIORITY DATE TO WHICH EACH ASSERTED CLAIM IS ENTITLED

Gentex contends that the Asserted Claims of the '068 patent are entitled to a priority date no later than January 28, 2000, the date of the filing of Provisional Application No. 60/178,797, to which the '068 patent claims priority.

Gentex contends that the Asserted Claims of the '648 patent are entitled to a priority date no later than January 28, 2000, the date of the filing of Provisional Application No. 60/178,797, to which the '648 patent claims priority.

Gentex contends that claim 1 of the '024 patent is entitled to a priority date no later than July 14, 2005.

Gentex contends that the Asserted Claims of the '632 patent are entitled to a priority date no later than June 13, 2001.

Gentex contends that the Asserted Claims of the '253 patent are entitled to a priority date no later than June 13, 2001.

Gentex's investigation is ongoing, and not all materials related to the conception and reduction to practice of the Asserted Claims are in its possession. Gentex reserves the right to amend its contentions regarding the priority dates of the Asserted Claims, including to identify and establish earlier dates, based on information learned as the case progresses.

III. DOCUMENTS EVIDENCING THE CONCEPTION AND REDUCTION TO PRACTICE FOR EACH CLAIMED INVENTION

Gentex produced a copy of the file histories for the Asserted Patents with its Preliminary Infringement Contentions. Gentex is concurrently producing certain documents evidencing conception and reduction to practice of the inventions claimed in the '024, '632, and '253 patents with Bates numbers GNTX0001534–GNTX0001604. Gentex is working with and will continue

to work with the relevant third parties to locate any additional documents evidencing conception and reduction to practice of the claimed inventions and to produce them promptly.

IV. A COPY OF THE FILE HISTORY FOR EACH PATENT IN SUIT

Gentex has produced a copy of the file histories for each of the Asserted Patents with Bates numbers GNTX0000031–GNTX0000904.

Dated: December 22, 2021

Respectfully submitted,

/s/ Adam D. Harber

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Exhibit 4

Gentex Corporation and Indigo Technologies, LLC (collectively, “Gentex”) presently contend that Facebook, Inc. and Facebook Technologies, LLC (collectively, “Facebook”) infringe claims 1-8, 11-26, 28-36, 44-45, 47-55, 57-61, and 66-69 (the “Asserted Claims”) of U.S. Patent No. 6,922,632, directly and/or indirectly, either literally or under the doctrine of equivalents. This chart sets forth Gentex’s preliminary infringement contentions relating to the Asserted Claims and the accused products, i.e., the Oculus Rift S, Oculus Quest, and Oculus Quest 2 (collectively, the “Accused Products”). In the event Facebook releases new products or services that infringe the ’632 patent, or further investigation reveals that other products or services infringe the ’632 patent, Gentex reserves the right to update these contentions as appropriate under the Order Governing Proceedings.

These contentions articulate the structure and acts that constitute direct and/or indirect infringement of the ’632 patent and identify specifically where each element of each asserted claim is found within each Accused Product. Exemplary references to publicly available information concerning the Accused Products is provided where appropriate. Exemplary references to specific Accused Products are not intended and should not be read to exclude Accused Products not exemplified. On information and belief, the Accused Products are materially the same with respect to the claims of the ’632 patent discussed below, except the contentions below regarding hand tracking, which is performed by the Oculus Quest and Oculus Quest 2, but based on present information, is not performed by the Oculus Rift S. This disclosure is not intended to describe all acts of direct, induced, or contributory infringement Facebook has and continues to commit by making, using, selling, providing, developing, installing, testing, deploying, and/or directing the use of the Accused Products by customers and end users. The parties have not engaged in any discovery. The parties also have not discussed proposed constructions for, and the Court has not yet construed, any of the claims of the ’632 patent. As a result, and consistent with the Order Governing Proceedings, Gentex reserves the right to modify, amend, or otherwise supplement these initial infringement contentions as discovery and the pre-trial phase of the litigation proceed and as additional information comes to light, including with respect to which claims Gentex is asserting, the infringement analysis for one or more of the claims, and whether and how limitations of one or more claims are met literally or under the doctrine of equivalents.

U.S. Patent 6,922,632	
Claim Limitation	Accused Products
Claim 1	
(1pre) A method for tracking an object comprising:	Facebook encourages, directs, or promotes users to use the Accused Products to carry out the claimed method, and Facebook performs the claimed method, as set forth below. For example, Facebook uses, and encourages users to use, a method for tracking an object (e.g., the user’s hand(s) and/or Oculus controller(s)). The Accused Products are especially adapted to carry out this method, which is a material part of the claimed invention, and have no substantial noninfringing uses. Further, on information and belief, Facebook conditions a user’s use of the Accused Products, and therefore the user’s receipt of the benefits of the Accused Products, upon this method and establishes the manner or timing of that use (e.g., through its software and/or user instructions, which have not been provided at this stage of the litigation).

See, e.g., *Compare Headsets*, <https://www.oculus.com/compare/?products=quest%2Cquest-2> (hereinafter “*Compare Headsets*”).



Oculus Quest
All-In-One VR Gaming

TRACKING

Six Degrees of Freedom

With 6DOF, the headset tracks the movement of both your head and body, then translates them into VR with realistic precision. No external sensors required.



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Oculus Rift S
PC-Powered VR Gaming

TRACKING

Six Degrees of Freedom

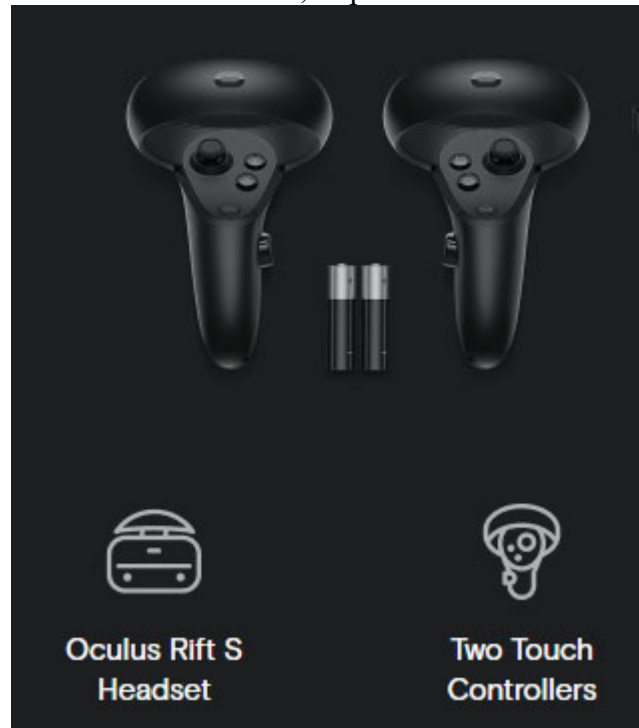
With 6DOF, the headset tracks the movement of both your head and body, then translates them into VR with realistic precision. No external sensors required.

See also Oculus Quest Features.

Two Oculus Touch VR controllers are shown against a dark background. The controllers are black with blue and purple accents. They have a curved, ergonomic design with a trackball and various buttons.

TWO TOUCH CONTROLLERS
Feeling is believing.
With Oculus Touch controllers, you can transport your hands and gestures right into the game. Your slashes, throws and grabs appear in VR with intuitive, realistic precision.

See also Oculus Rift S, <https://www.oculus.com/rift-s/>.



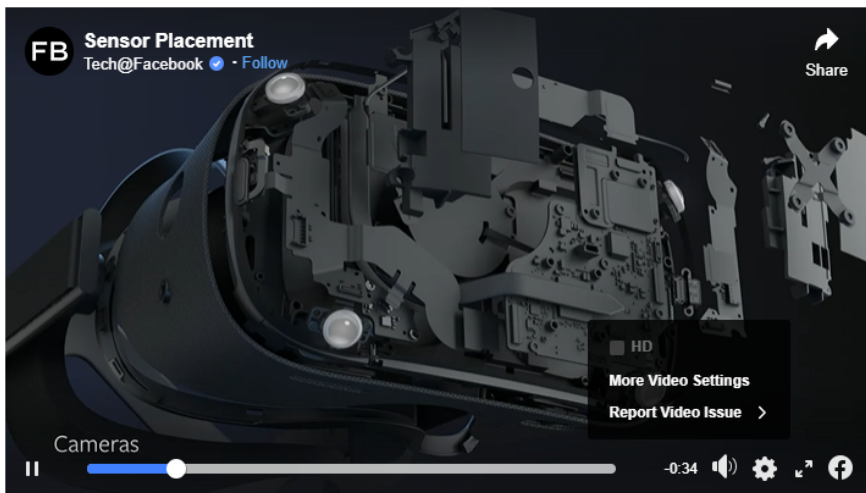
(1a) coupling a sensor subsystem to an estimation subsystem, said sensor subsystem enabling measurement related to relative locations or orientations of sensing elements;

Facebook encourages, directs, or promotes users to couple a sensor subsystem to an estimation subsystem, wherein the sensor subsystem enables measurement related to relative locations or orientations of sensing elements, and Facebook performs such step itself. For example, the Accused Products include a sensor subsystem (e.g., the cameras and/or inertial measurement units (“IMUs”), such as accelerometers and gyroscopes, within the headset, and/or the IMUs within the Oculus controller(s)) that is coupled to an estimation subsystem (e.g., the Oculus Insight tracking system). The sensor subsystem enables measurement related to the relative locations or orientations of sensing elements (e.g., the positions and orientations of the user’s hand(s) and/or the Oculus controller(s) relative to the headset). The Accused Products are especially adapted to carry out this method, which is a material part of the claimed invention, and have no substantial noninfringing uses. Further, Facebook conditions a user’s use of the Accused Products, and therefore the user’s receipt of the benefits of the Accused Products, upon this method and establishes the manner or timing of that use.


See, e.g., *Oculus Quest Features*, https://web.archive.org/web/20200901154027if_/https://www.oculus.com/quest/features/ (hereinafter “*Oculus Quest Features*”).



See also Tech@facebook, *From the Lab to the living room: The story behind Facebook's Oculus Insight technology and a new era of consumer VR* (Aug. 22, 2019), <https://tech.fb.com/the-story-behind-oculus-insight-technology/>, Sensor Placement at 0:15 (hereinafter "*From the Lab*").



See also Oculus Rift S.






oculus rift s

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- 
Improved Optics
 Improved optics deliver bright, vivid colors and reduced "screen-door" effect.
- 
Ergonomic Design
 The halo headband is redesigned with speed and comfort in mind.
- 
Oculus Touch Controllers
 Your slashes, throws and grabs appear in VR with intuitive, realistic precision.

See also Oculus Blog, *Powered by AI* (Aug. 22, 2019), <https://ai.facebook.com/blog/powered-by-ai-oculus-insight/> (hereinafter “*Powered by AI*”).

headset and controllers with respect to a 3D map that is generated and constantly updated by Insight. The data used for this process comes from three types of sensors built into the Quest and Rift S hardware:

1. Linear acceleration and rotational velocity data from IMUs in the headset and controllers are integrated to track the orientation and position of each with low latency.
2. Image data from cameras in the headset helps generate a 3D map of the room, pinpointing landmarks like the corners of furniture or the patterns on your floor. These landmarks are observed repeatedly, which enables Insight to compensate for drift (a common challenge with IMUs, where even tiny measurement discrepancies build up over time, resulting in inaccurate location tracking).
3. Infrared LEDs in the controllers are detected by the headset cameras, letting the system bound the controller position drift caused by integrating multiple IMUs.

See also id.

At last year’s Oculus Connect event we shared some details about [Oculus Insight](#), the cutting-edge technology that powers both Quest and Rift S. Now that both of those products are available, we’re providing a deeper look at the AI systems and techniques that power this VR technology. Oculus Insight marks the first time that fully untethered six-degree-of-freedom (6DoF) headset and controller tracking has shipped in a consumer AR/VR device. Built from the ground up, the Insight stack leverages state-of-the-art computer vision (CV) systems and visual-inertial simultaneous localization and mapping, or SLAM.

See also Oculus for Developers, Oculus Device Specifications, <https://developer.oculus.com/learn/oculus-device-specs/> (hereinafter “*Oculus for Developers*”).

Oculus Quest 2

- Panel Type: Single Fast-Switch LCD, 1832×1920px per eye
- Supported Refresh Rate: 72Hz (default), can be configured to 60Hz in some cases
- Default SDK Color Space: Rec.2020 gamut, 2.2 gamma, D65 white point
 - CIE 1931 xy color-primary values:
 - Red : (0.708, 0.292)
 - Green: (0.17, 0.797)
 - Blue : (0.131, 0.046)
 - White: (0.3127, 0.3290)
- USB Connector: 1x USB-C
- Tracking: Inside out, 6DOF

See also id.

3DOF vs 6DOF

The Oculus Go headset comes with 1 3 Degree-of-Freedom (DOF) controller to track controller orientations. However, the Oculus Go headset will not track controller positions in space. The Oculus Rift, Rift S, and Quest headsets are equipped with 2 6DOF controllers that support both orientation and positional tracking. The 6DOF capabilities allow you to integrate virtual hands to interact with VR environments.

See also Ben Lang, [Quest Teardown Shows How Oculus Crammed Cooling & Cameras Inside](https://www.roadtovr.com/oculus-quest-teardown-disassembly/) (July 17, 2019), <https://www.roadtovr.com/oculus-quest-teardown-disassembly/> (hereinafter “Lang”).



Image courtesy BadVR, Jad Meouchy

Around the mainboard we can also see the headset's four cameras mounted at very purposeful angles at the corners. The cameras are essential to enabling 6DOF tracking on both the headset and the controllers; their views are also merged together to allow a pass-through vision mode on the headset which is used to trace the boundary of your playspace.

See also Powered by AI.

To unlock the full potential of virtual reality (VR) and augmented reality (AR) experiences, the technology needs to work anywhere, adapting to the spaces where people live and how they move within those real-world environments. When we developed [Oculus Quest](#), the first all-in-one, completely wire-free VR gaming system, we knew we needed positional tracking that was precise, accurate, and available in real time — within the confines of a standalone headset, meaning it had to be compact and energy efficient.

See also Powered by AI.

Academic research has been done on SLAM techniques for several decades, but the technology has only recently become mature enough for consumer applications, such as driverless cars and mobile AR apps. Facebook previously released a version of [SLAM for AR on mobile devices](#) which uses a single camera and inertial measurement unit (IMU) to track a phone's position and enable world-locked content — content that's visually anchored to real objects in the world. Oculus Insight is the second generation of this library, and it incorporates significantly more information from a combination of multiple IMUs and ultra-wide-angle cameras, as well as infrared LEDs to jointly track the 6DoF position of a VR headset and controllers.

The Oculus Insight system uses a custom hardware architecture and advanced computer vision algorithms — including visual-inertial mapping, place recognition, and geometry reconstruction — to establish the location of objects in relation to other objects within a given space. This novel algorithm stack enables a VR device to pinpoint its location, identify aspects of room geometry (such as floor location), and track the positions of the headset and controllers with respect to a 3D map that is generated and constantly updated by Insight. The data used for this process comes from three types of sensors built into the Quest and Rift S hardware:

See also Powered by AI.

At last year's Oculus Connect event we shared some details about [Oculus Insight](#), the cutting-edge technology that powers both Quest and Rift S. Now that both of those products are available, we're providing a deeper look at the AI systems and techniques that power this VR technology. Oculus Insight marks the first time that fully untethered six-degree-of-freedom (6DoF) headset and controller tracking has shipped in a consumer AR/VR device. Built from the ground up, the Insight stack leverages state-of-the-art computer vision (CV) systems and visual-inertial simultaneous localization and mapping, or SLAM.

See also From the Lab.

"We wanted to create a system that lets you move and explore a VR world just as naturally and easily as you would in real life," says Kozminski.

Kozminski joined a team whose mission was to create the first full-featured "inside-out" tracking system for a consumer VR device. The technology would have to track the full range of a person's movements (known as six degrees of freedom) and be able to pinpoint the location of the two handheld controllers as well as the headset.

Previously, VR devices relied on external sensors to track these movements. These cameras attach to a PC, and while they work well, they make VR less portable and more complicated to set up.

"With inside-out tracking in the headset, VR becomes as easy as putting on headphones to listen to music," says Kozminski.

See also From the Lab.

Taking SLAM technology ...

The foundation of Oculus Insight's inside-out tracking is [simultaneous localization and mapping, or SLAM](#), which uses computer vision CV algorithms to essentially fuse incoming data from multiple sensors in order to fix the position of an object within a constantly updated digital map. SLAM has been used in robotics and in [AR camera effects](#) on smartphones and was demoed in the Oculus [Santa Cruz VR headset prototype](#) in 2016. But Oculus Insight required an unprecedented level of precision and efficiency, and that meant adapting the latest research on tracking and computer vision.

"A lot of these technologies really start in academia — inside the lab," Kozminski notes. It's no coincidence, then, that she's part of Facebook's Zurich-based team of engineers, many of whom came from [Zurich Eye](#) — a joint program from the prestigious [ETH University](#) and [University of Zurich](#) that researched self-navigating systems.

See also From the Lab.

There are other complications, too. The infrared LEDs in the two hand controllers drastically change appearance when they move closer or farther away from the headset as you swing a virtual sword or maneuver a virtual spaceship. Oculus Insight also uses other sensors, drawing acceleration and velocity data from the inertial measurement units (IMUs) located in the headset and controllers. The system must process all of these data points in real time and, in the case of Quest, on a mobile chipset.

See also From the Lab.

Previously, VR devices relied on external sensors to track these movements. These cameras attach to a PC, and while they work well, they make VR less portable and more complicated to set up.

See also Oculus Quest 2, <https://www.oculus.com/quest-2/>.



See also Compare Headsets,
<https://www.oculus.com/compare/?products=quest%2Cquest-2>.



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See also David Heaney, Oculus Firmware Reveals New Touch Controllers, Referencing Improvements to Tracking, Finger Sensing, Haptics (Apr. 16, 2020), <https://uploadvr.com/oculus-jedi-controller-driver-found/> (hereinafter “Heaney”).

More Precise Tracking

A function for infrared LED calibration exists, suggesting this controller is optically tracked in the same way as the current Touch— cameras on the headset follow the movement of the LED constellation, and this is fused with the accelerometer readings to achieve sub-mm precision.



Facebook's VR controllers are tracked via infrared LEDs under the plastic

See also Heaney.

The driver also reveals the series model number of the controller's inertial measurement unit (IMU)- the chip within all VR controllers which contains the accelerometer.

Teardowns and the FCC filings for the current Touch showed it uses TDK's ICM-20601 IMU from late 2015.

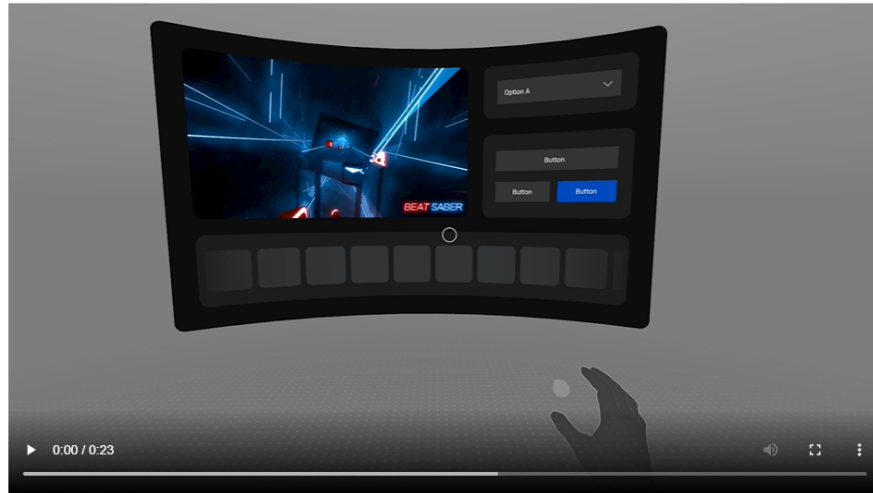


The IMU in the current Touch controllers for Rift S and Quest

See also ICM-20601 Specification.

	<p>FEATURES</p> <ul style="list-style-type: none"> • 3-Axis Gyroscope with Programmable FSR of $\pm 500\text{dps}$, $\pm 100\text{dps}$, $\pm 2000\text{dps}$ and $\pm 4000\text{dps}$ • 3-Axis Accelerometer with Programmable FSR of $\pm 4g$, $\pm 8g$, $\pm 16g$, and $\pm 32g$ • User-programmable interrupts • Wake-on-motion interrupt for low power operation of applications processor • 512 byte FIFO buffer enables the applications processor to read the data in bursts • On-Chip 16-bit ADCs and Programmable Filters • Host interface: 8 MHz SPI or 400k Hz Fast Mode I²C • Digital-output temperature sensor • VDD operating range of 1.71 to 3.45V • MEMS structure hermetically sealed and bonded at wafer level • RoHS and Green compliant
<p>(1b) accepting configuration data from the sensor subsystem;</p>	<p>Facebook encourages, directs, or promotes users to use the Accused Products to accept configuration data from the sensor subsystem, and Facebook performs such step itself. For example, the Accused Products can operate using both controllers, a single controller, or no controller at all, and the headset in the Accused Products is configured using the applicable configuration data of the sensors in use at a given time. As a further example, the Accused Products enumerate the sensing elements available in the sensor subsystem, including optical sensors (e.g., cameras) and inertial sensors (e.g., IMUs), and configuration data regarding these sensing elements, including the characteristics of these sensing elements, is accepted from the sensor subsystem. The Accused Products are especially adapted to carry out this method, which is a material part of the claimed invention, and have no substantial noninfringing uses. Further, Facebook conditions a user's use of the Accused Products, and therefore the user's receipt of the benefits of the Accused Products, upon this method and establishes the manner or timing of that use.</p> <p><i>See, e.g., Hand Tracking.</i></p> <p><small>The hand tracking feature enables the use of hands as an input method for the Oculus Quest device. It delivers a new sense of presence, enhances social engagement, and delivers more natural interactions with fully tracked hands and articulated fingers. Integrated hands can perform object interactions by using simple hand gestures such as pinch, unpinch, and pinch and hold.</small></p> <p><small>The hand tracking feature lets you operate with hands and controllers interchangeably. When you opt to use hands, the hand's pose drives a laser cursor-pointer that behaves like the standard controller cursor. You can use the cursor-pointer to highlight, select, click, or write your own app-level event logic.</small></p> <p><small>Hand tracking complements the Touch controllers and is not intended to replace controllers in all scenarios, especially with games or creative tools that require a high degree of precision. By opting-in to hand support, your app also needs to satisfy additional technical requirements specific to hand tracking in order to be accepted on Oculus Store. To submit an app to Oculus Store, the app must support controllers along with hand tracking.</small></p> <p><i>See also Designing for Hands.</i></p>

Designing for Hands



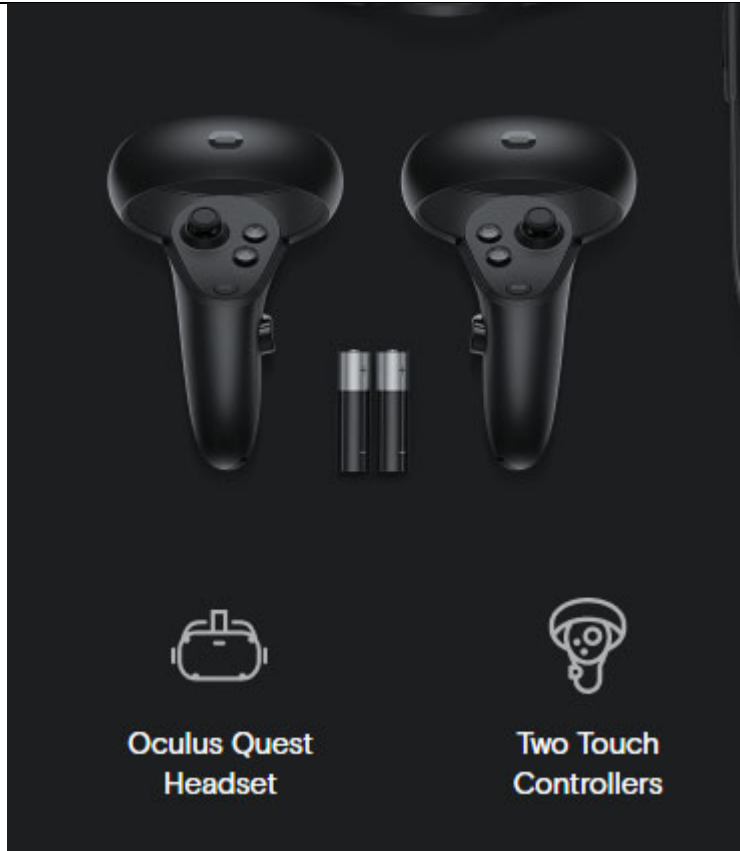
See also Hand Tracking Deep Dive.



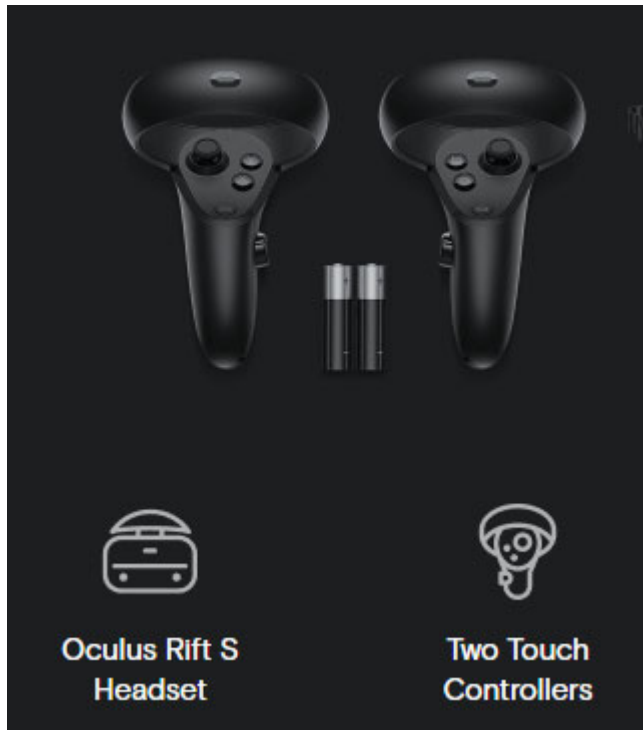
See also id. at 4:00–10:00.



See also Oculus Quest.



See also Oculus Rift S.



See also From the Lab.

There are other complications, too. The infrared LEDs in the two hand controllers drastically change appearance when they move closer or farther away from the headset as you swing a virtual sword or maneuver a virtual spaceship. Oculus Insight also uses other sensors, drawing acceleration and velocity data from the inertial measurement units (IMUs) located in the headset and controllers. The system must process all of these data points in real time and, in the case of Quest, on a mobile chipset.

See also From the Lab.

Taking SLAM technology ...

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"A lot of these technologies really start in academia — inside the lab," Kozminski notes. It's no coincidence, then, that she's part of Facebook's Zurich-based team of engineers, many of whom came from [Zurich Eye](#) — a joint program from the prestigious [ETH University](#) and [University of Zurich](#) that researched self-navigating systems.

To build a new, more advanced version of SLAM, the engineering team drew from Facebook's years of AI research and engineering work, building systems to understand the objects and actions that appear in videos and creating highly efficient computer vision algorithms that work well on mobile devices.

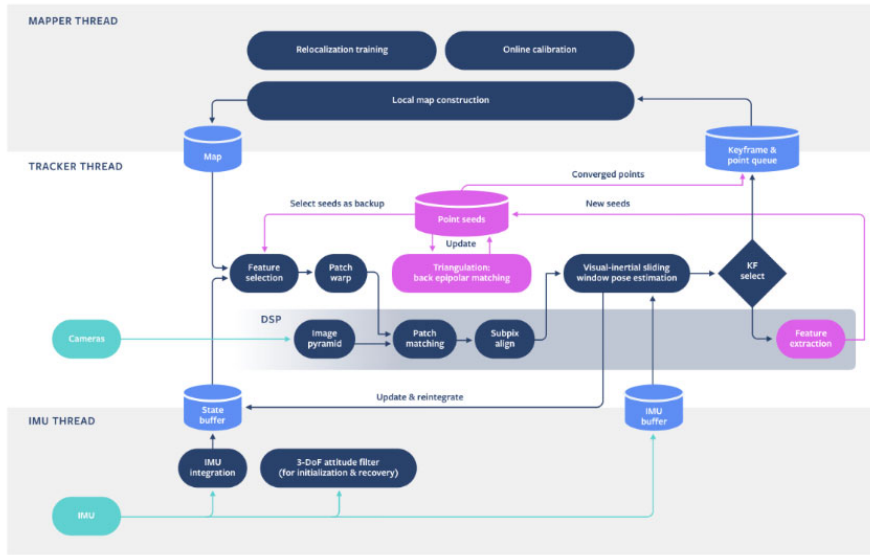
See also Powered by AI.

headset and controllers with respect to a 3D map that is generated and constantly updated by Insight. The data used for this process comes from three types of sensors built into the Quest and Rift S hardware:

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3. Infrared LEDs in the controllers are detected by the headset cameras, letting the system bound the controller position drift caused by integrating multiple IMUs.

See also id.

Headset tracking compute architecture



Oculus Insight processes multiple threads of data at once, in real-time — the mapper thread modifies the map, sending updated copies to the tracker thread, which uses camera frames to estimate poses in the mapper-provided frames, while the IMU thread uses measurements from the IMUs to update the latest SLAM state.

See also *From the Lab*, Sensor Placement at 0:23.



See also *From the Lab*, Sensor Placement at 0:30.



See also Heaney.

More Precise Tracking

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Facebook's VR controllers are tracked via infrared LEDs under the plastic

See also Does the Quest have a single controller mode for any games?, Reddit, https://www.reddit.com/r/OculusQuest/comments/clrwr1/does_the_quest_have_a_single_controller_mode_for/ (hereinafter “Reddit Single Controller Discussion”).

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See also Expert Mode at 2:36.



(1c) configuring the estimation system according to the accepted configuration data;

Facebook encourages, directs, or promotes users to use the Accused Products to configure the estimation system according to the accepted configuration data, and Facebook performs such step itself. For example, the Accused Products configure the estimation system (e.g., the Oculus Insight tracking system) based on the accepted configuration data (e.g., the configuration of the Oculus controller(s) and/or the available sensing elements). The Accused Products are especially adapted to carry out this method, which is a material part of the claimed invention, and have no substantial noninfringing uses. Further, Facebook conditions a user's use of the Accused Products, and therefore the user's receipt of the benefits of the Accused Products, upon this method and establishes the manner or timing of that use.

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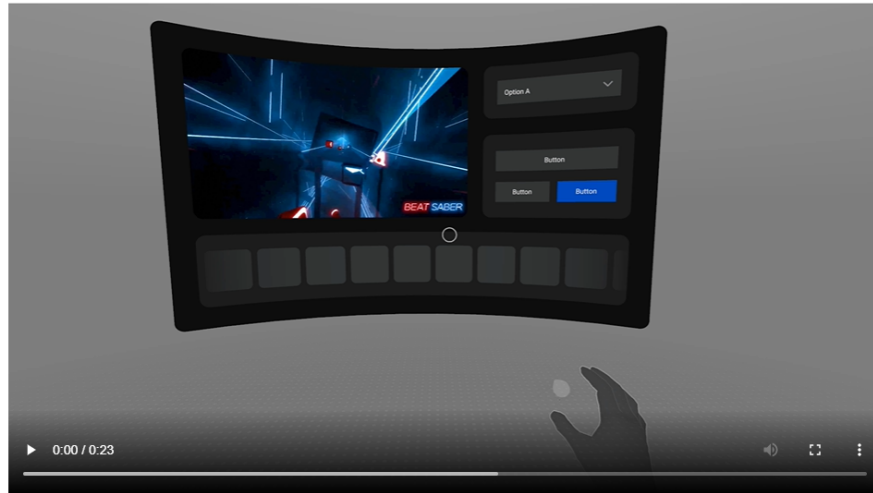
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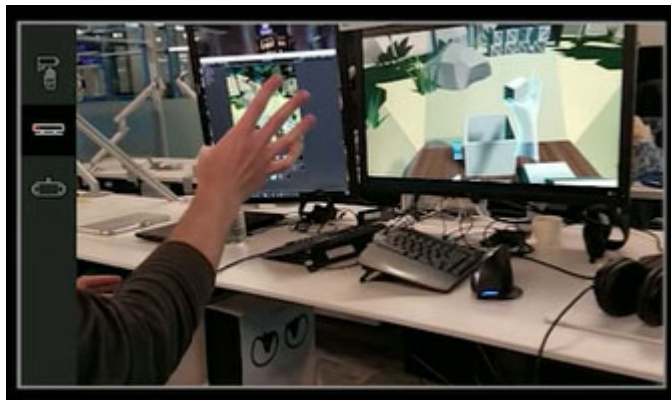
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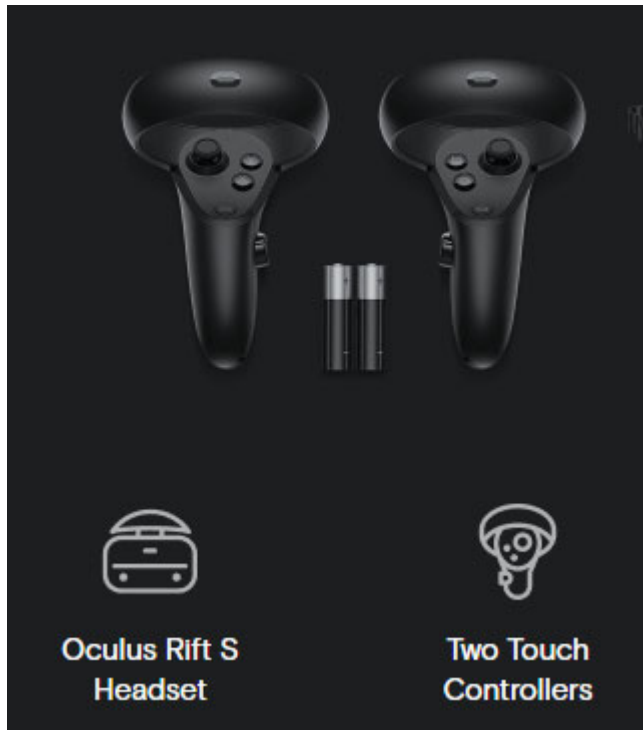
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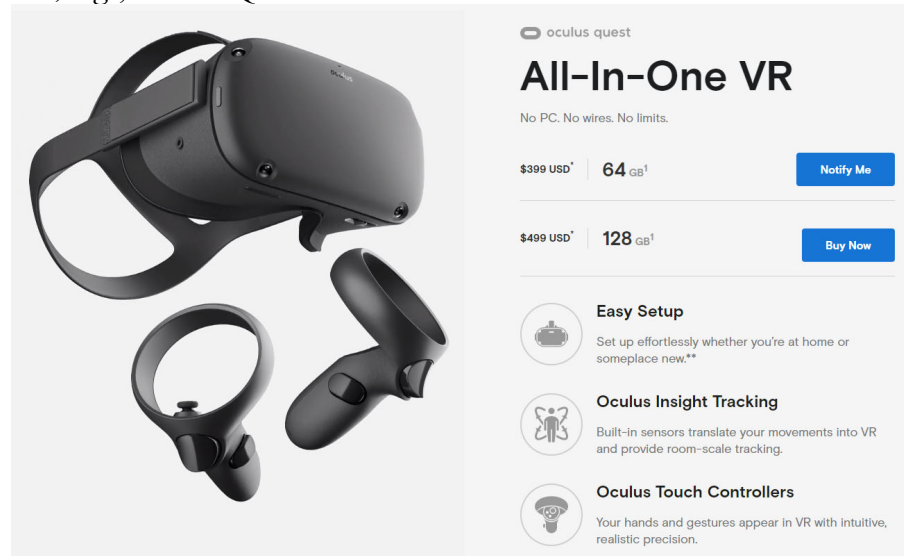
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(1d) repeatedly updating a state estimate, including accepting measurement information from the sensor subsystem, and updating the state estimate according to the accepted configuration data and the accepted measurement data.

Facebook encourages, directs, or promotes users to use the Accused Products to repeatedly update a state estimate, including accepting measurement information from the sensor subsystem, and updating the state estimate according to the accepted configuration data and the accepted measurement data, and Facebook performs such step itself. For example, the Accused Products repeatedly update a state estimate (e.g., the position and orientation of the user's head, the user's hand(s), and/or the Oculus controller(s)), including accepting measurement information from the sensor subsystem (e.g., the headset in the Accused Products receiving data from the cameras and/or IMUs in the headset and/or the IMUs in the Oculus controllers) and updating the state estimate (e.g., the position and orientation of the user's hand(s) and/or the Oculus controller(s)) according to the accepted configuration data (e.g., the configuration of the Oculus controller(s) and/or the available sensing elements) and the accepted measurement data (e.g., the sensor data received from the cameras and/or IMUs within the headset and/or the IMUs within the Oculus controller(s)). The Accused Products update the positional and orientation tracking parameters using the sensor data received. The Accused Products are especially adapted to carry out this method, which is a material part of the claimed invention, and have no substantial noninfringing uses. Further, Facebook conditions a user's use of the Accused Products, and therefore the user's receipt of the benefits of the Accused Products, upon this method and establishes the manner or timing of that use.

See, e.g., Oculus Quest.



The screenshot displays the Oculus Quest product page. On the left, there is a high-quality image of the Oculus Quest VR headset and its two Touch controllers. On the right, the product title "All-In-One VR" is prominently displayed, followed by the tagline "No PC. No wires. No limits." Below this, two pricing options are shown: a 64 GB model for \$399 USD and a 128 GB model for \$499 USD. Each price is accompanied by a "Notify Me" or "Buy Now" button. Three key features are highlighted with icons and text: "Easy Setup" (Set up effortlessly whether you're at home or someplace new**), "Oculus Insight Tracking" (Built-in sensors translate your movements into VR and provide room-scale tracking), and "Oculus Touch Controllers" (Your hands and gestures appear in VR with intuitive, realistic precision).

See also Oculus Quest Features.



See, e.g., Hand Tracking.

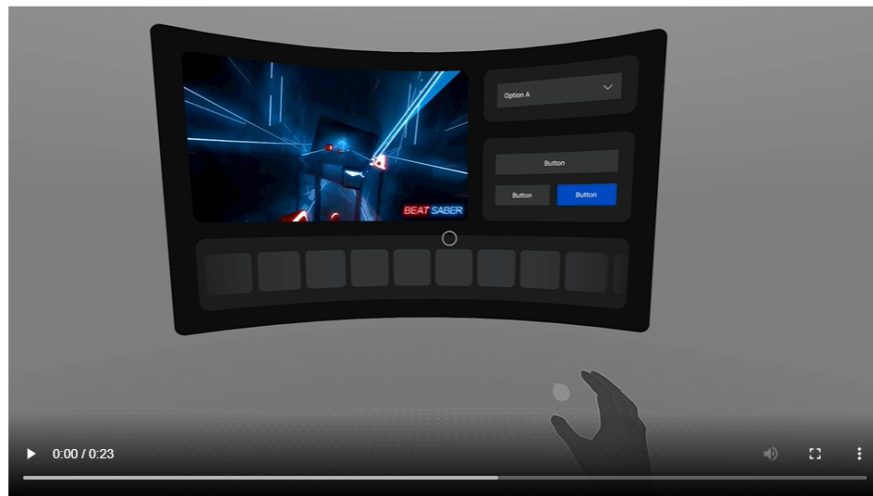
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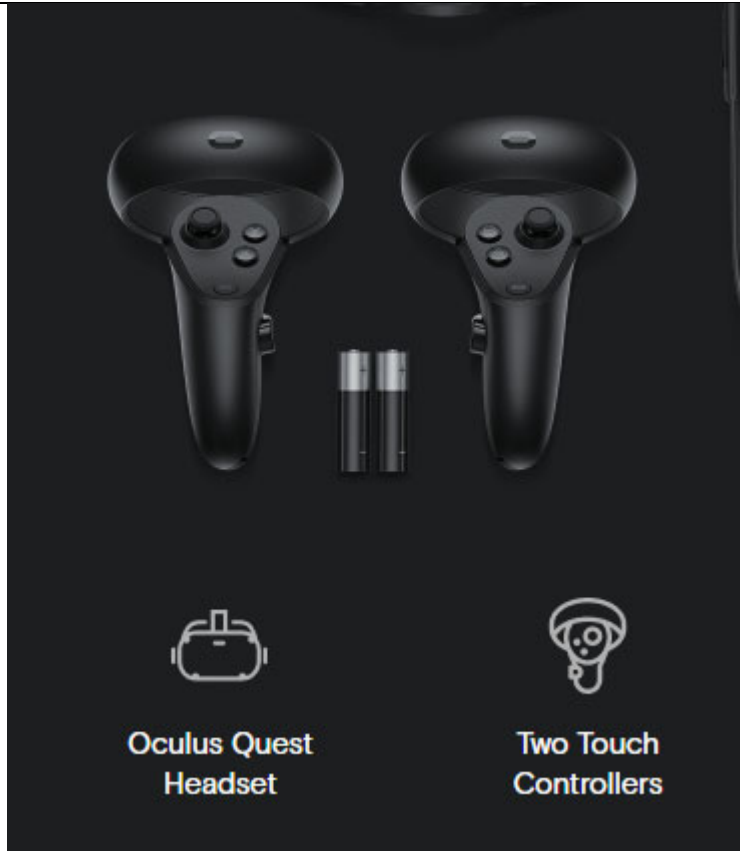
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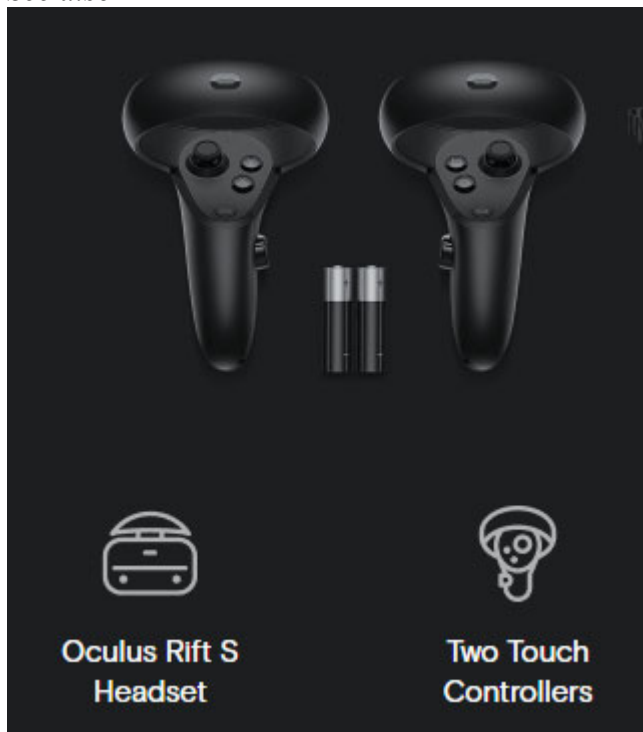
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To build a new, more advanced version of SLAM, the engineering team drew from Facebook's years of AI research and engineering work, building systems to understand the objects and actions that appear in videos and creating highly efficient computer vision algorithms that work well on mobile devices.

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visually anchored to real objects in the world. Oculus Insight is the second generation of this library, and it incorporates significantly more information from a combination of multiple IMUs and ultra-wide-angle cameras, as well as infrared LEDs to jointly track the 6DoF position of a VR headset and controllers.

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headset and controllers with respect to a 3D map that is generated and constantly updated by Insight. The data used for this process comes from three types of sensors built into the Quest and Rift S hardware:

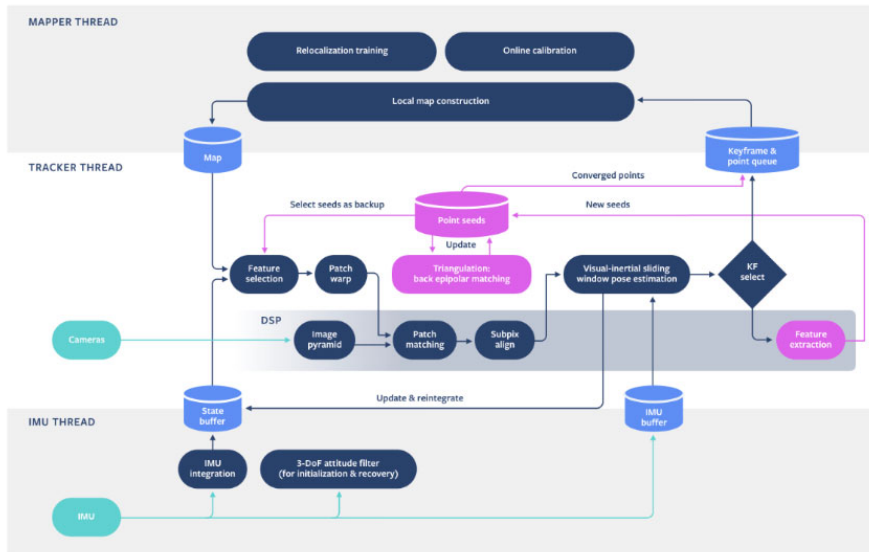
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Another major factor to avoid in delivering immersive experiences is latency — any lag between physical movements and their VR equivalents can disorient the user and degrade the sense of realism. By using low-latency IMU data and a kinematic model that predicts a user's motion into the future, Insight is able to effectively eliminate the apparent latency. We'll go into more detail in the next section about the sensor fusion process that incorporates SLAM data, but reducing both jitter and latency is central to Insight's ability to deliver a new level of realism within VR.

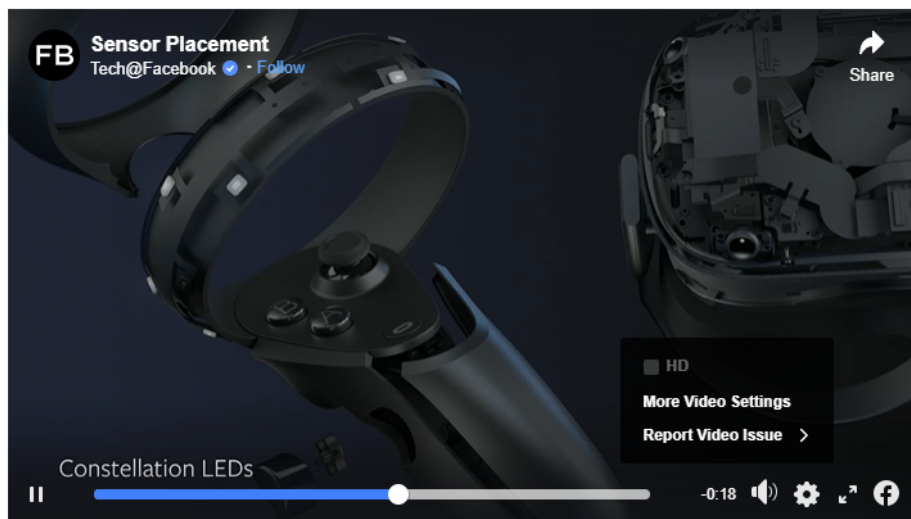
See also *id.*

Headset tracking compute architecture



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The driver also reveals the series model number of the controller's inertial measurement unit (IMU)- the chip within all VR controllers which contains the accelerometer.

Teardowns and the [FCC filings](#) for the current Touch showed it uses TDK's ICM-20601 IMU from late 2015.



The IMU in the current Touch controllers for Rift S and Quest

See also ICM-20601 Specification.

Claim 2

(2) The method of claim 1 wherein coupling the sensor subsystem to the estimation subsystem includes coupling software modules each associated with one or more of the sensing elements.

See supra claim 1. Facebook encourages, directs, or promotes users to use the Accused Products to perform the method of claim 1 in which coupling the sensor subsystem to the estimation subsystem includes coupling software modules each associated with one or more of the sensing elements (e.g., software modules within the Oculus Insight tracking system operating on the Accused Products that receive data from the cameras and/or IMUs within the headset and/or the IMUs within the Oculus controller(s)), and Facebook performs such step itself. The Accused Products are especially adapted to carry out this method, which is a material part of the claimed invention, and have no substantial noninfringing uses. Further, Facebook conditions a user's use of the Accused Products, and therefore the user's receipt of the benefits of the Accused Products, upon this method and establishes the manner or timing of that use.

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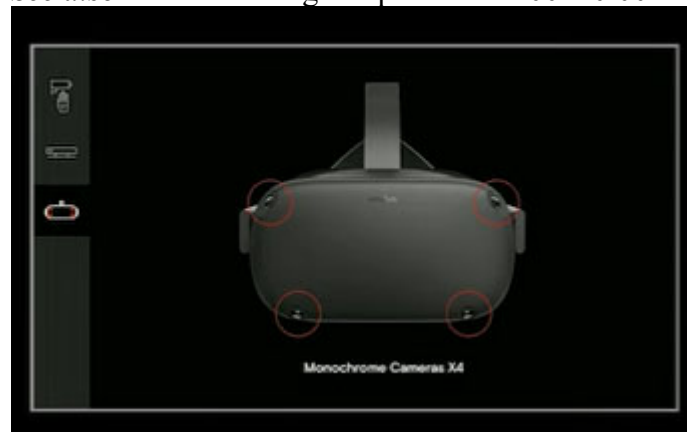
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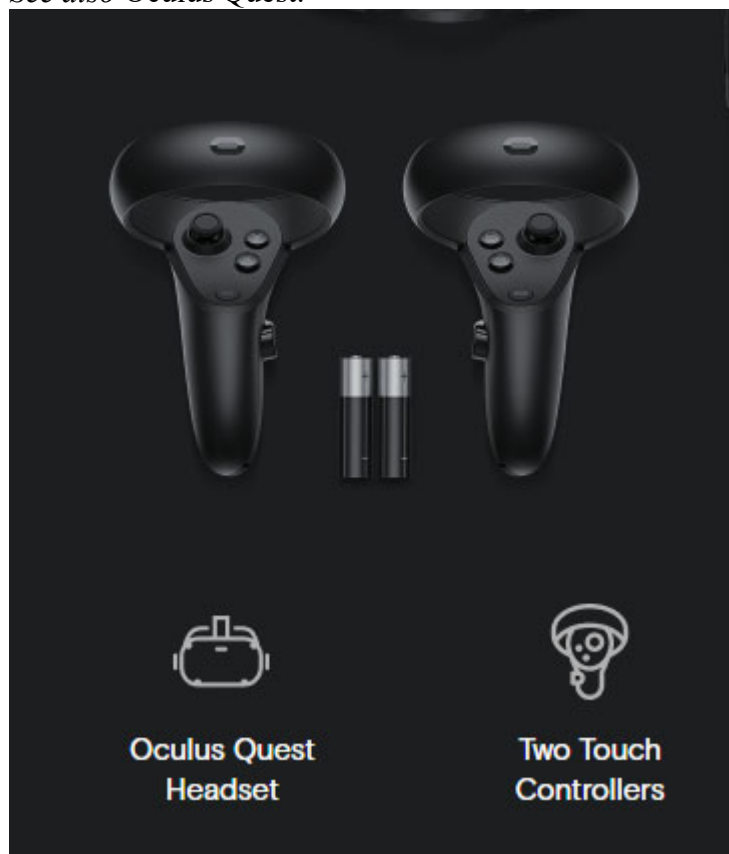
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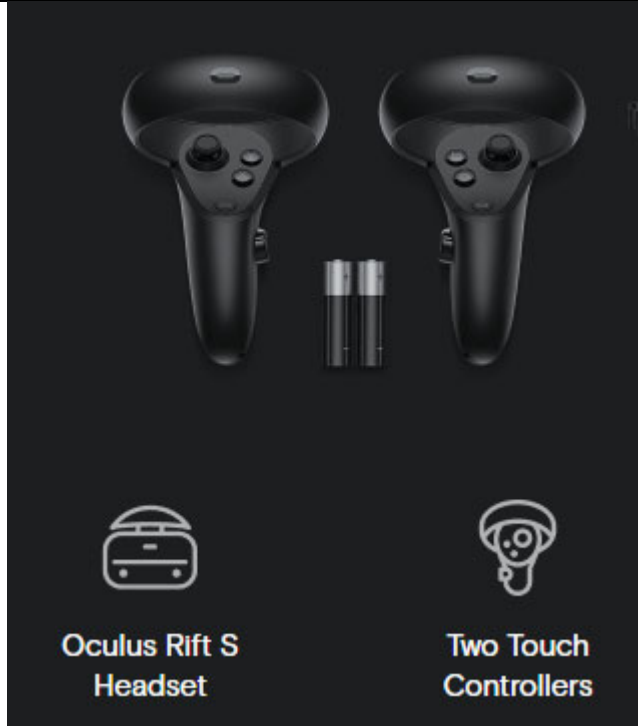
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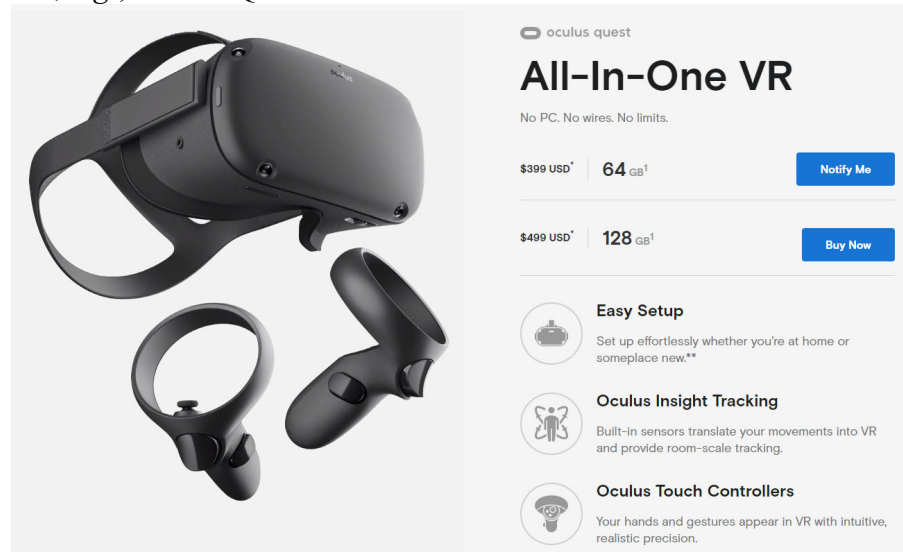


Claim 3

(3) The method of claim 2 wherein each of the software modules provides a software interface for receiving information related to an expected sensor measurement and providing measurement information that depends on said received information.

See supra claims 1, 2. Facebook encourages, directs, or promotes users to use the Accused Products to perform the method of claim 2 in which each of the software modules (e.g., software modules within the Oculus Insight tracking system operating on the Accused Products that receive data from the cameras and/or IMUs within the headset and/or the IMUs within the Oculus controller(s)) provides a software interface for receiving information related to an expected sensor measurement (e.g., the predicted position of the user's hand(s) and/or the Oculus controller(s)) and providing measurement information that depends on said received information (e.g., estimating the position and orientation of the user's hand(s) and/or the Oculus controller(s)), and Facebook performs such step itself. The Accused Products are especially adapted to carry out this method, which is a material part of the claimed invention, and have no substantial noninfringing uses. Further, Facebook conditions a user's use of the Accused Products, and therefore the user's receipt of the benefits of the Accused Products, upon this method and establishes the manner or timing of that use.

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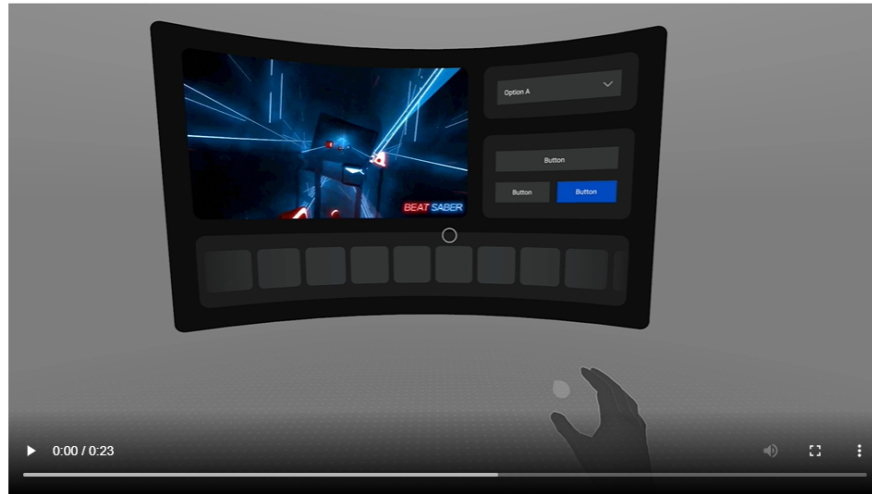
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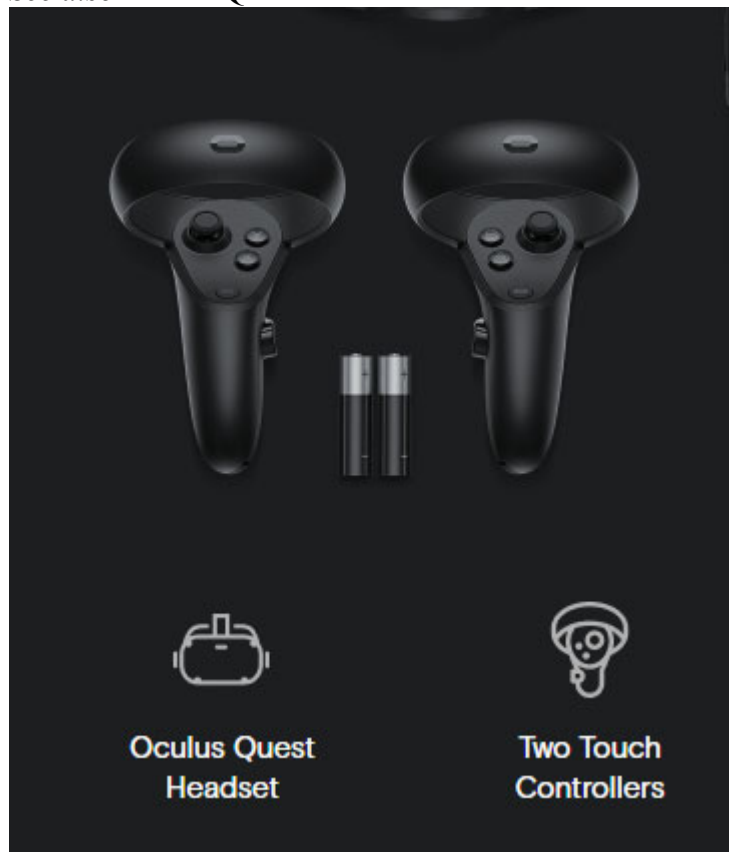
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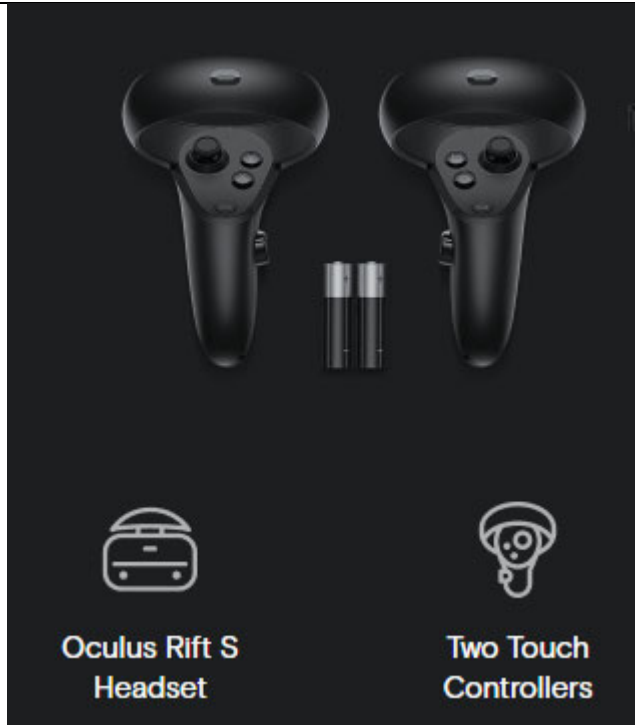
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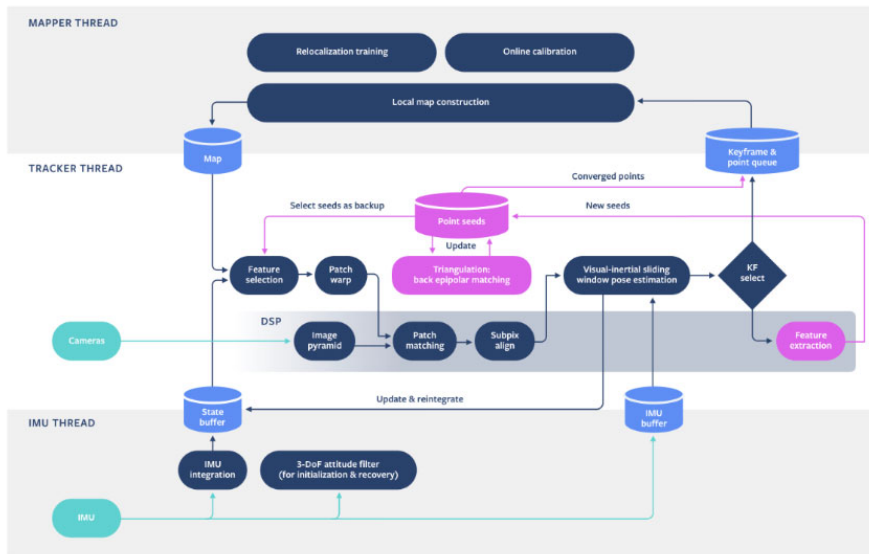
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The IMU in the current Touch controllers for Rift S and Quest


See also ICM-20601 Specification.

Claim 4

(4) The method of claim 3 wherein each of the software modules implements calculations that are independent of a representation of the state in the estimation subsystem.

See supra claims 1, 2, 3. Facebook encourages, directs, or promotes users to use the Accused Products to perform the method of claim 3 in which each of the software modules (e.g., software modules within the Oculus Insight tracking system operating on the Accused Products that receive data from the cameras and/or IMUs within the headset and/or the IMUs within the Oculus controller(s)) implements calculations that are independent of a representation of the state in the estimation subsystem (e.g., processing the data received from the cameras and/or IMUs within the headset and/or the IMUs within the Oculus controller(s), independent of the representation in the Oculus Insight tracking system of the position and orientation of the user's hand(s) and/or the Oculus controller(s)) and Facebook performs such step itself. The Accused Products are especially adapted to carry out this method, which is a material part of the claimed invention, and have no substantial noninfringing uses. Further, Facebook conditions a user's use of the Accused Products, and therefore the user's receipt of the benefits of the Accused Products, upon this method and establishes the manner or timing of that use.

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- Easy Setup**
Set up effortlessly whether you're at home or someplace new.**
- Oculus Insight Tracking**
Built-in sensors translate your movements into VR and provide room-scale tracking.
- Oculus Touch Controllers**
Your hands and gestures appear in VR with intuitive, realistic precision.

See also Oculus Quest Features.



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See, e.g., Hand Tracking.

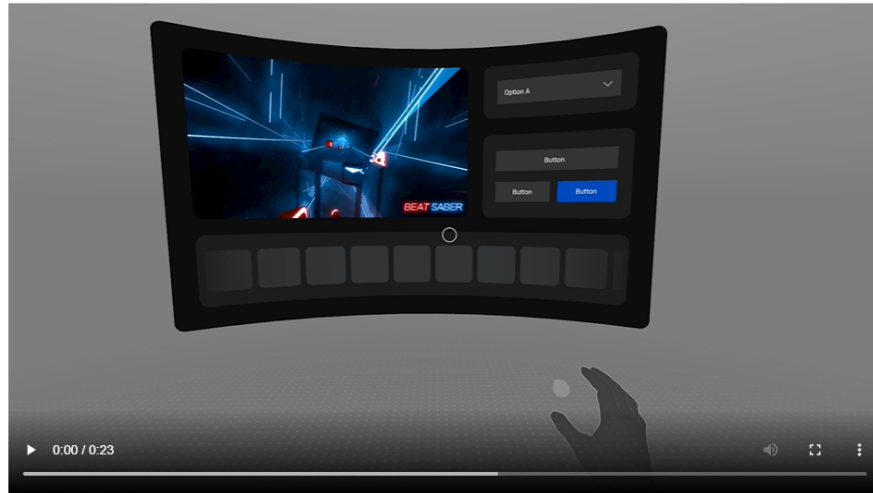
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Designing for Hands



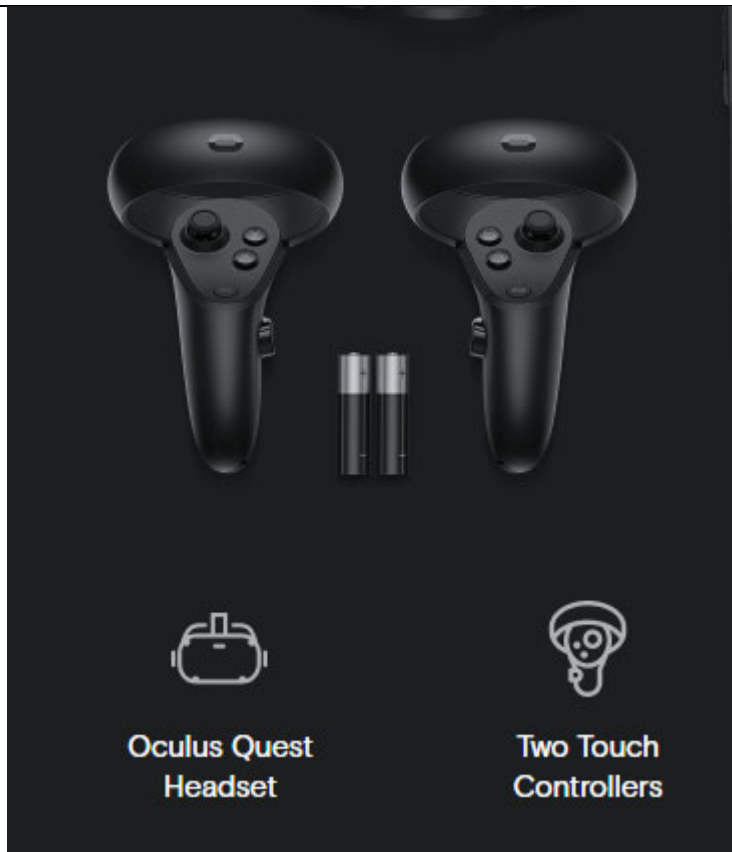
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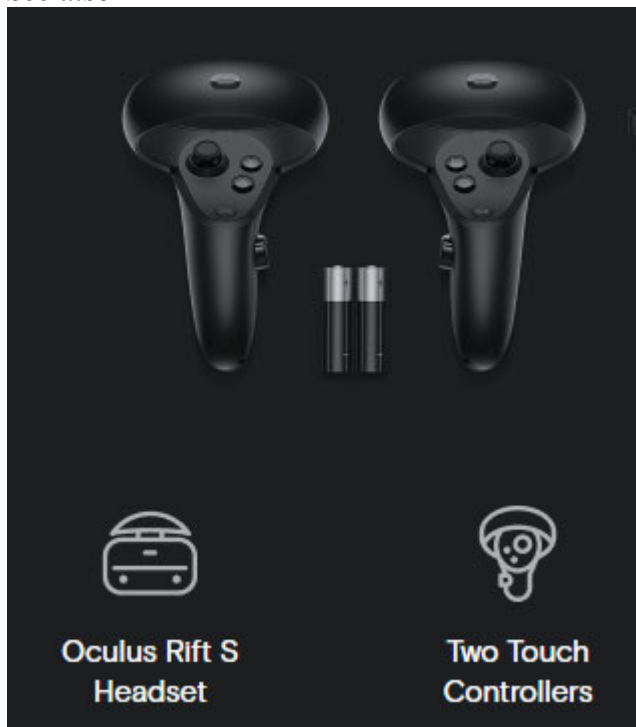
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There are other complications, too. The infrared LEDs in the two hand controllers drastically change appearance when they move closer or farther away from the headset as you swing a virtual sword or maneuver a virtual spaceship. Oculus Insight also uses other sensors, drawing acceleration and velocity data from the inertial measurement units (IMUs) located in the headset and controllers. The system must process all of these data points in real time and, in the case of Quest, on a mobile chipset.

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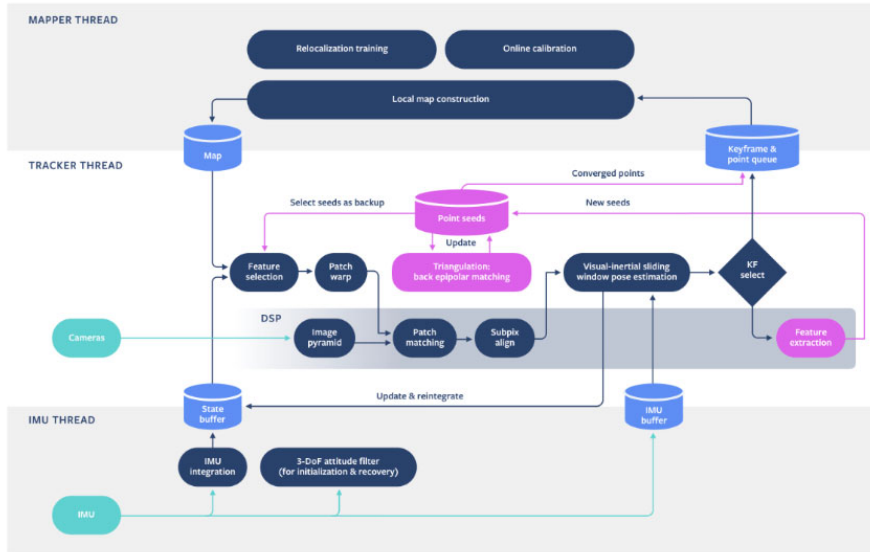
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3. Infrared LEDs in the controllers are detected by the headset cameras, letting the system bound the controller position drift caused by integrating multiple IMUs.

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Another major factor to avoid in delivering immersive experiences is latency — any lag between physical movements and their VR equivalents can disorient the user and degrade the sense of realism. By using low-latency IMU data and a kinematic model that predicts a user's motion into the future, Insight is able to effectively eliminate the apparent latency. We'll go into more detail in the next section about the sensor fusion process that incorporates SLAM data, but reducing both jitter and latency is central to Insight's ability to deliver a new level of realism within VR.

See also id.

Headset tracking compute architecture

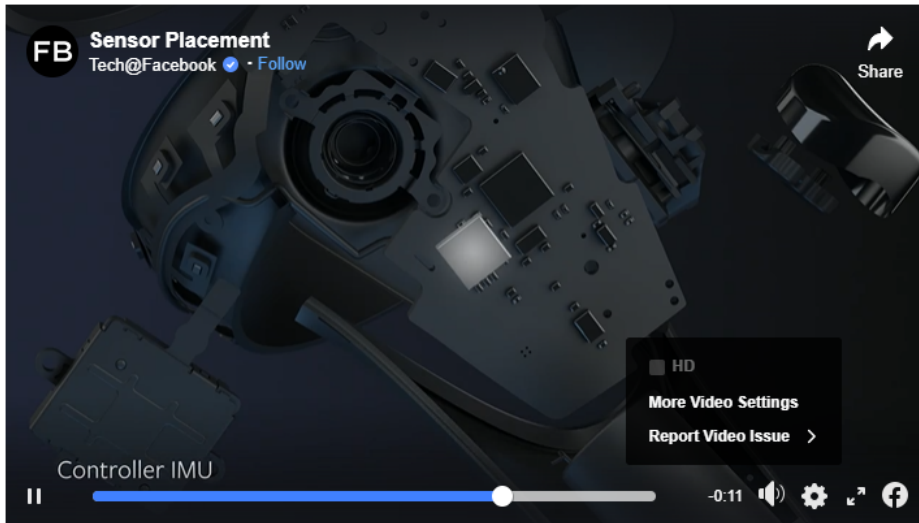


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The IMU in the current Touch controllers for Rift S and Quest


See also ICM-20601 Specification.

Claim 5

(5) The method of claim 1 wherein the state estimate characterizes an estimate of a location of the object.

See supra claim 1. Facebook encourages, directs, or promotes users to use the Accused Products to perform the method of claim 1 in which the state estimate characterizes an estimate of a location of the object (e.g., the position of the user's hand(s) and/or the Oculus controller(s)), and Facebook performs such step itself. The Accused Products are especially adapted to carry out this method, which is a material part of the claimed invention, and have no substantial noninfringing uses. Further, Facebook conditions a user's use of the Accused Products, and therefore the user's receipt of the benefits of the Accused Products, upon this method and establishes the manner or timing of that use.

See, e.g., Oculus Quest.






oculus quest

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- 
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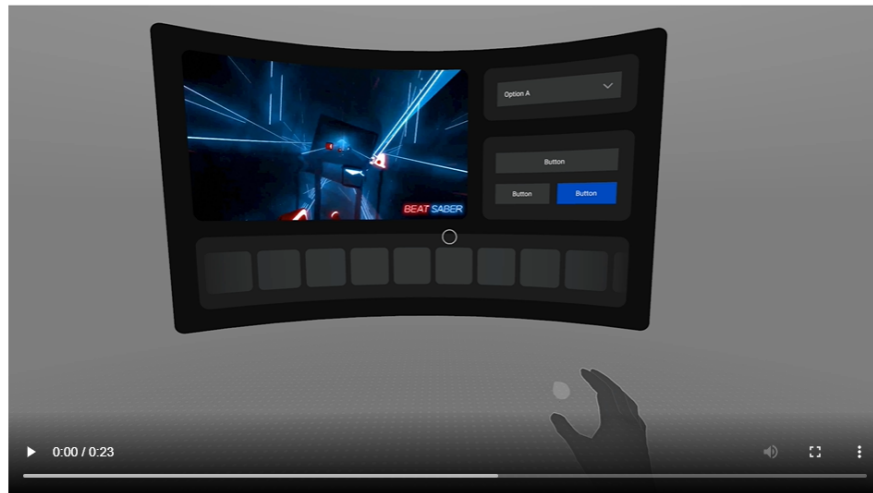
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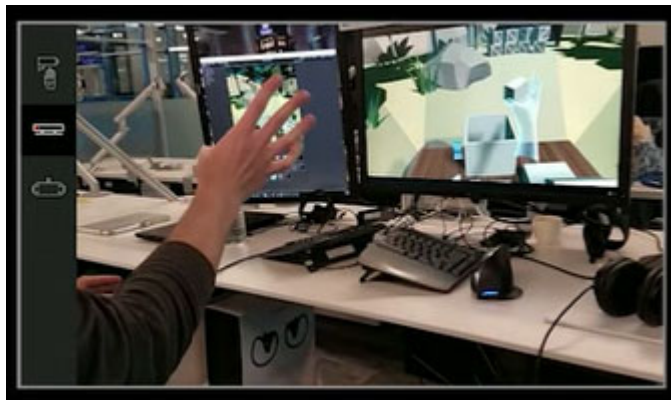
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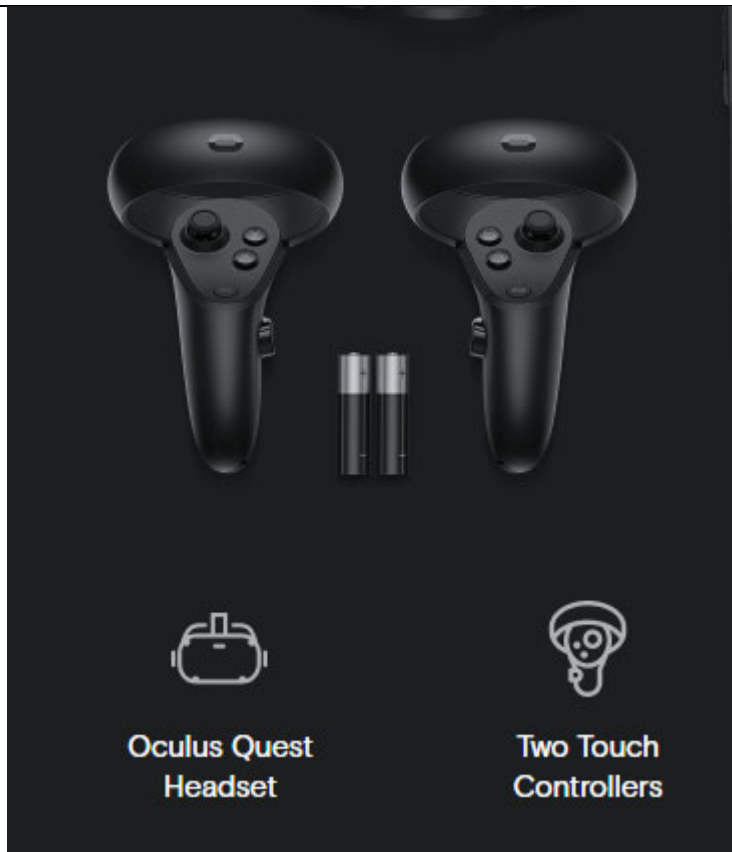
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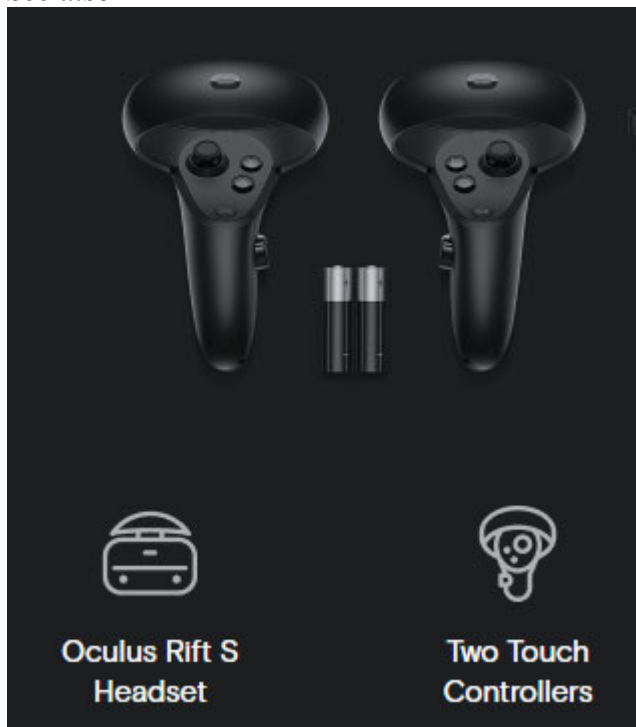
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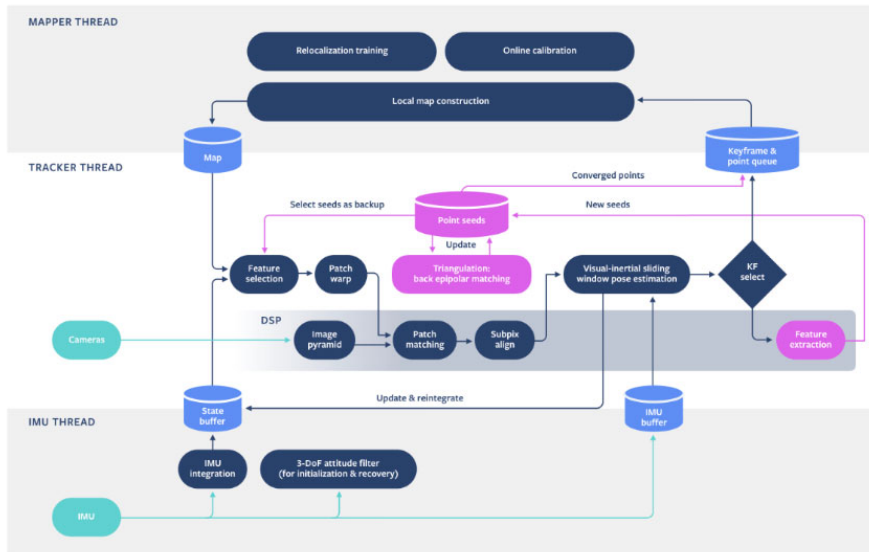
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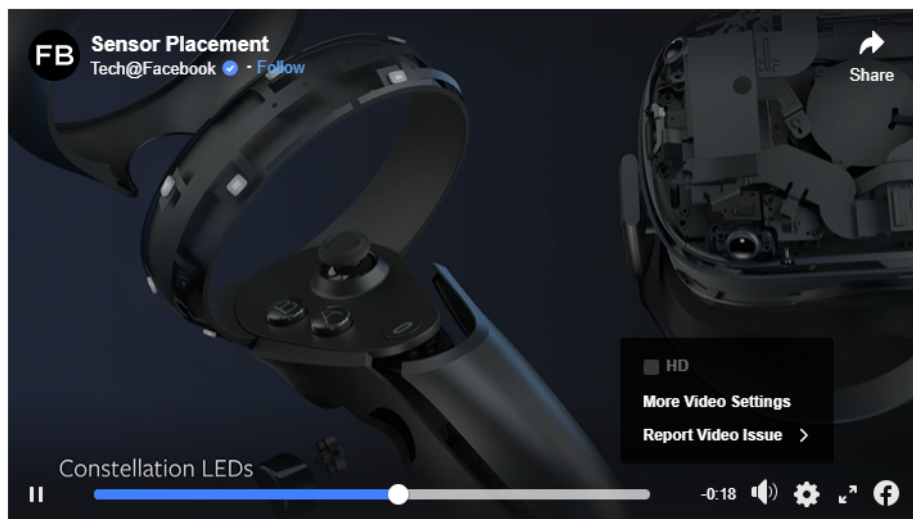
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The IMU in the current Touch controllers for Rift S and Quest

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Claim 6

(6) The method of claim 1 wherein the state estimate characterizes configuration information for one or more sensing elements fixed to the object.

See supra claim 1. Facebook encourages, directs, or promotes users to use the Accused Products to perform the method of claim 1 in which the state estimate characterizes configuration information for one or more sensing elements fixed to the object (e.g., the configuration of the Oculus controller(s) and/or sensing elements), and Facebook performs such step itself. The Accused Products are especially adapted to carry out this method, which is a material part of the claimed invention, and have no substantial noninfringing uses. Further, Facebook conditions a user's use of the Accused Products, and therefore the user's receipt of the benefits of the Accused Products, upon this method and establishes the manner or timing of that use.

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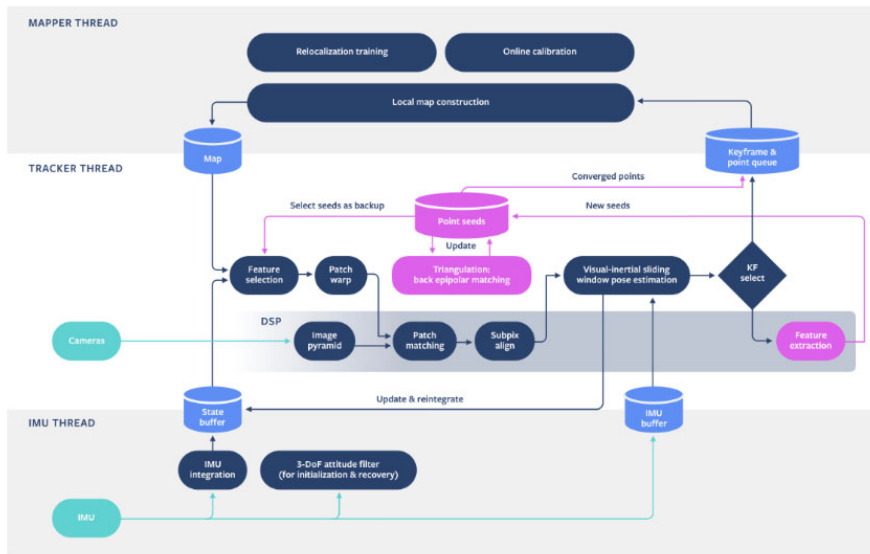
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The IMU in the current Touch controllers for Rift S and Quest

Claim 7

(7) The method of claim 6 wherein the configuration information for the one or more sensing elements fixed to the object includes information related to position or orientation of said sensing elements relative to the object.

See supra claims 1, 6. Facebook encourages, directs, or promotes users to use the Accused Products to perform the method of claim 6 in which the configuration information for the one or more sensing elements fixed to the object (e.g., the Oculus controller(s) and/or sensing elements) includes information related to position or orientation of said sensing elements relative to the object (e.g., the position and orientation of the IMUs and LEDs fixed to the Oculus controllers relative to the controller(s), and Facebook performs such step itself. The Accused Products are especially adapted to carry out this method, which is a material part of the claimed invention, and have no substantial noninfringing uses. Further, Facebook conditions a user's use of the Accused Products, and therefore the user's receipt of the benefits of the Accused Products, upon this method and establishes the manner or timing of that use.

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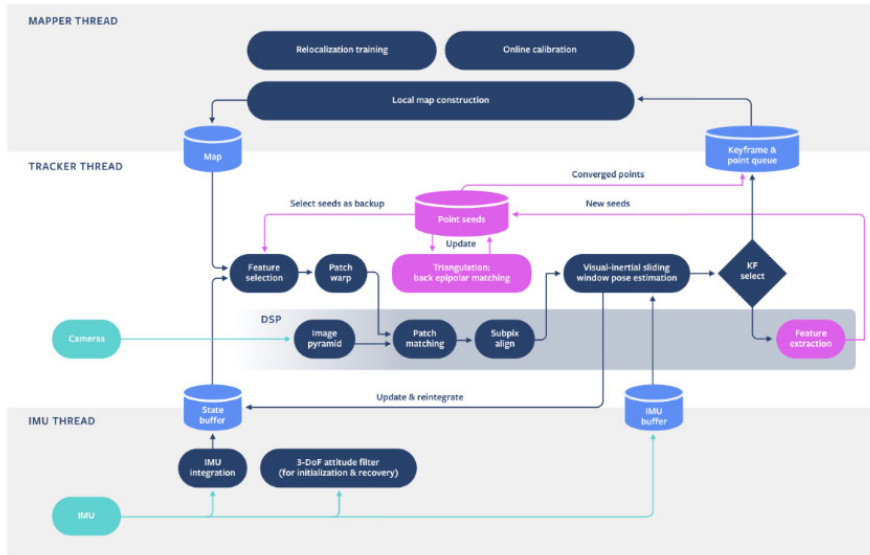
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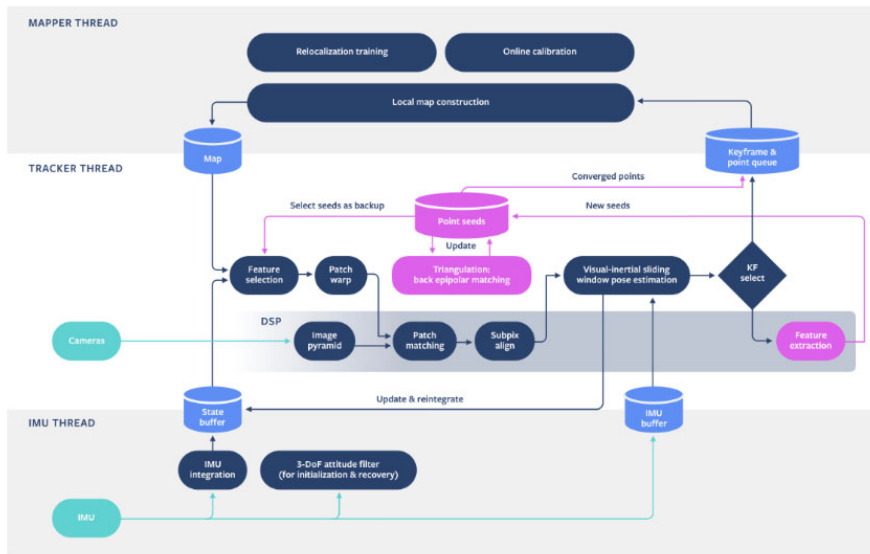
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See also Reddit Single Controller Discussion.

Does the Quest have a single controller mode for any games?

<https://imgur.com/a/1dLoatG>

My stepdad sent his old Oculus Go, it is a lot better than I expected! My good friend who is in the picture absolutely loves the Go. I make sure I bring it every time we hang out since I got it recently. He is able to play some of the games because there is only one controller. He would not be able to operate a controller with his other hand. We are looking at getting him one so we can play together, or both of us upgrading to the Quest. I was wondering if you guys have seen many games you can play with only one controller on the quest, or if we should stick to the Go. My friend would be doing a lot of video but I know he did like the ability to play some of the games. This has been the only video game system he has every really been able to play. I hope the quest will work out for us. Let me know what you guys think, thanks for the help.

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SORT BY BEST

maltakan0 6 points · 1 year ago

Virtual virtual reality can be played with one controller

MRHBK 5 points · 1 year ago

Quest is a bit heavier too if that is a factor

↑ stigzcousin 1 point · 1 year ago

↓ This is something I did not think about. Good to know. Thank you

jebwillnotdivideus 5 points · 1 year ago

Beatsaber and sportsscramble can be played with 1 controller. Other games im not sure.

See also Expert Mode at 2:36.



Claim 11

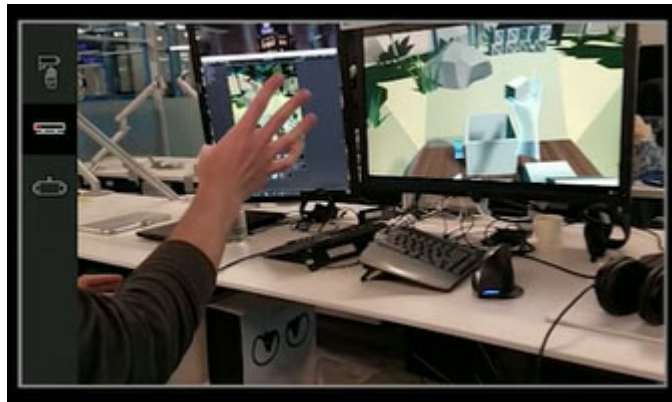
(11a) The method of claim 1 wherein repeatedly updating the state further includes: providing to the sensor subsystems information related to an expected sensor measurement; and

See supra claim 1. Facebook encourages, directs, or promotes users to use the Accused Products to perform the method of claim 1 in which repeatedly updating the state further includes providing to the sensor subsystems information related to an expected sensor measurement (e.g., the predicted position of the user’s hand(s) and/or the Oculus controllers), and Facebook performs such step itself. The Accused Products are especially adapted to carry out this method, which is a material part of the claimed invention, and have no substantial noninfringing uses. Further, Facebook conditions a user’s use of the Accused Products, and therefore the user’s receipt of the benefits of the Accused Products, upon this method and establishes the manner or timing of that use.

See also Hand Tracking Deep Dive at 4:00–10:00.



See also id. at 4:00–10:00.



See also From the Lab.

Taking SLAM technology ...

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See also Powered by AI.

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1. Linear acceleration and rotational velocity data from IMUs in the headset and controllers are integrated to track the orientation and position of each with low latency.
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3. Infrared LEDs in the controllers are detected by the headset cameras, letting the system bound the controller position drift caused by integrating multiple IMUs.

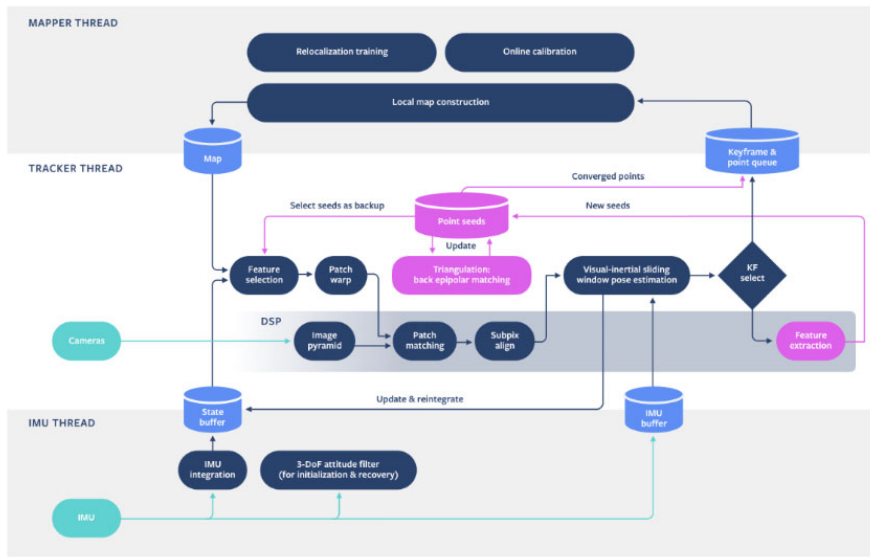
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SLAM addresses these challenges by automatically recognizing features in the environment, letting Oculus Insight incorporate the player's current position into a VR display. Insight also uses an extrapolation function with dynamic damping to help predict where the user's head and hands will move in the milliseconds ahead. This provides a number of benefits, including reducing the visual stuttering effect known as jitter, which is the key metric that tracking systems are measured against. To help enable a comfortable VR experience, tracking should be in the submillimeter range, meaning that the system can track with precision greater than a single millimeter. Insight exceeds this target in most environments.

Another major factor to avoid in delivering immersive experiences is latency — any lag between physical movements and their VR equivalents can disorient the user and degrade the sense of realism. By using low-latency IMU data and a kinematic model that predicts a user's motion into the future, Insight is able to effectively eliminate the apparent latency. We'll go into more detail in the next section about the sensor fusion process that incorporates SLAM data, but reducing both jitter and latency is central to Insight's ability to deliver a new level of realism within VR.

See also id.

Headset tracking compute architecture




Oculus Insight processes multiple threads of data at once, in real-time — the mapper thread modifies the map, sending updated copies to the tracker thread, which uses camera frames to estimate poses in the mapper-provided frames, while the IMU thread uses measurements from the IMUs to update the latest SLAM state.

(11b) wherein accepting the measurement information from the sensor subsystem includes accepting information related to an actual sensor measurement.

See supra claim 1. Facebook encourages, directs, or promotes users to use the Accused Products to perform the method of claim 1 in which accepting the measurement information from the sensor subsystem includes accepting information related to an actual sensor measurement (e.g., the headset in the Accused Products receiving data from the cameras and IMUs in the headset and/or the IMUs in the Oculus controllers), and Facebook performs such step itself. The Accused Products are especially adapted to carry out this method, which is a material part of the claimed invention, and have no substantial noninfringing uses. Further, Facebook conditions a user’s use of the Accused Products, and therefore the user’s receipt of the benefits of the Accused Products, upon this method and establishes the manner or timing of that use.

See, e.g., Oculus Quest.






oculus quest

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- 
Easy Setup
 Set up effortlessly whether you're at home or someplace new.**
- 
Oculus Insight Tracking
 Built-in sensors translate your movements into VR and provide room-scale tracking.
- 
Oculus Touch Controllers
 Your hands and gestures appear in VR with intuitive, realistic precision.

See also Oculus Quest Features.



OCULUS INSIGHT TRACKING

Make your move.

Oculus Insight translates your movements into VR no matter which way you're facing and provides room-scale tracking without external sensors. Look around, duck for cover and turn the tide of the battle from anywhere in your playspace.

See, e.g., Hand Tracking.

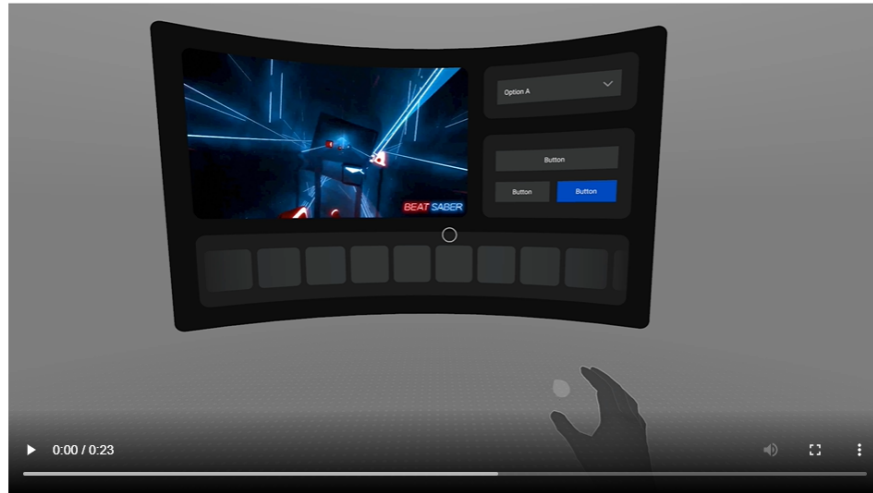
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See also Powered by AI.

visually anchored to real objects in the world. Oculus Insight is the second generation of this library, and it incorporates significantly more information from a combination of multiple IMUs and ultra-wide-angle cameras, as well as infrared LEDs to jointly track the 6DoF position of a VR headset and controllers.

See also Powered by AI.

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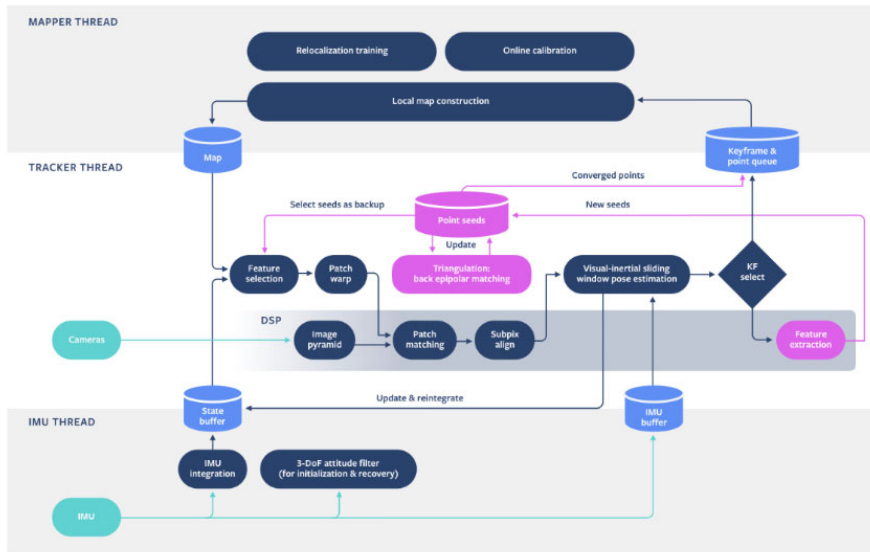
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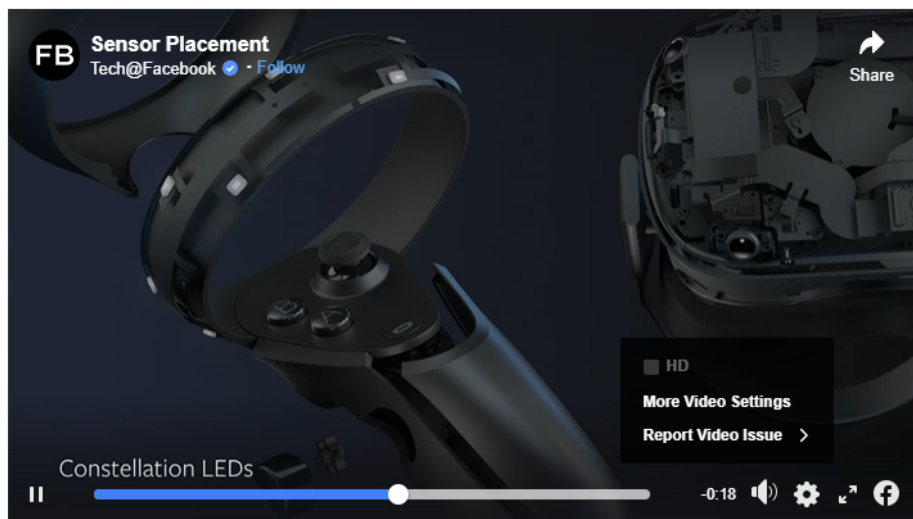
See also *id.*

Headset tracking compute architecture



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See also *From the Lab*, Sensor Placement at 0:23.



See also *From the Lab*, Sensor Placement at 0:30.



See also Heaney.

More Precise Tracking

A function for infrared LED calibration exists, suggesting this controller is optically tracked in the same way as the current Touch— cameras on the headset follow the movement of the LED constellation, and this is fused with the accelerometer readings to achieve sub-mm precision.



Facebook's VR controllers are tracked via infrared LEDs under the plastic

See also id.

The driver also reveals the series model number of the controller's inertial measurement unit (IMU)- the chip within all VR controllers which contains the accelerometer.

Teardowns and the [FCC filings](#) for the current Touch showed it uses TDK's ICM-20601 IMU from late 2015.



The IMU in the current Touch controllers for Rift S and Quest

See also ICM-20601 Specification.

Claim 12

(12) The method of claim 11 wherein providing the information related to an expected sensor measurement includes providing information related to a relative geometric configuration of two of the sensing elements.

See supra claims 1, 11. On information and belief and subject to discovery which has not yet occurred, Facebook encourages, directs, or promotes users to use the Accused Products to perform the method of claim 11 in which providing the information related to an expected sensor measurement includes providing information related to a relative geometric configuration of two of the sensing elements (e.g., the predicted positions of the user's hand(s) and/or the Oculus controller(s) relative to the headset), and Facebook performs such step itself. The Accused Products are especially adapted to carry out this method, which is a material part of the claimed invention, and have no substantial noninfringing uses. Further, Facebook conditions a user's use of the Accused Products, and therefore the user's receipt of the benefits of the Accused Products, upon this method and establishes the manner or timing of that use.

To the extent this limitation is not met literally, the Accused Products also satisfy this limitation under the doctrine of equivalents. Any difference between the Accused Products and the claim element is insubstantial.

See also From the Lab.

There are other complications, too. The infrared LEDs in the two hand controllers drastically change appearance when they move closer or farther away from the headset as you swing a virtual sword or maneuver a virtual spaceship. Oculus Insight also uses other sensors, drawing acceleration and velocity data from the inertial measurement units (IMUs) located in the headset and controllers. The system must process all of these data points in real time and, in the case of Quest, on a mobile chipset.

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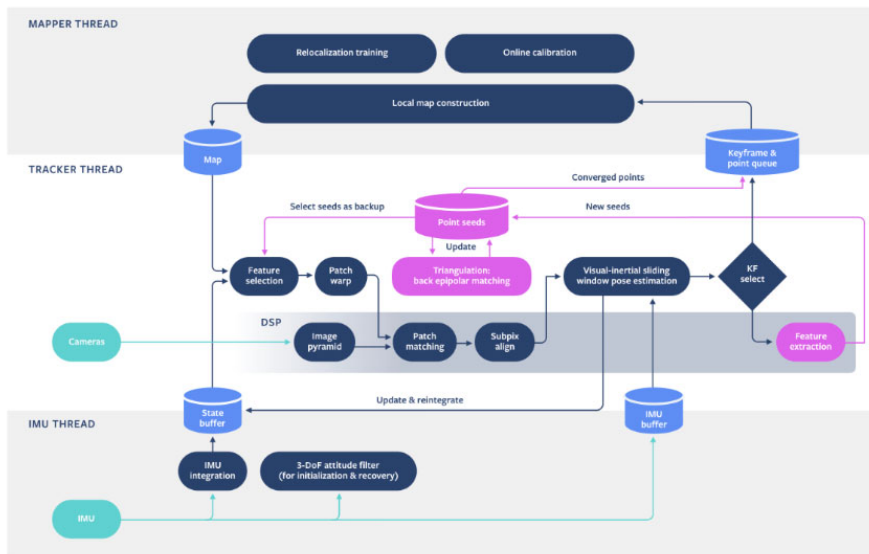
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See also id.

Headset tracking compute architecture



Oculus Insight processes multiple threads of data at once, in real-time — the mapper thread modifies the map, sending updated copies to the tracker thread, which uses camera frames to estimate poses in the mapper-provided frames, while the IMU thread uses measurements from the IMUs to update the latest SLAM state.

Claim 13

(13) The method of claim 12 wherein providing information related to a relative geometric configuration of the two of the sensing elements includes providing information characterizing a

See supra claims 1, 11, 12. On information and belief and subject to discovery which has not yet occurred, Facebook encourages, directs, or promotes users to use the Accused Products to perform the method of claim 12 in which providing information related to a relative geometric configuration of the two of the sensing elements includes providing information characterizing a relative location of said sensing elements (e.g., the predicted positions of the user's hand(s) and/or the Oculus controller(s) relative to the headset), and Facebook performs such step itself. The Accused Products are especially adapted to carry out this method, which is a material part of the claimed invention, and have no substantial noninfringing uses. Further, Facebook conditions a user's use of the Accused Products, and therefore the user's receipt of the benefits of the Accused Products, upon this method and establishes the manner or timing of that use.

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See, e.g., Hand Tracking.

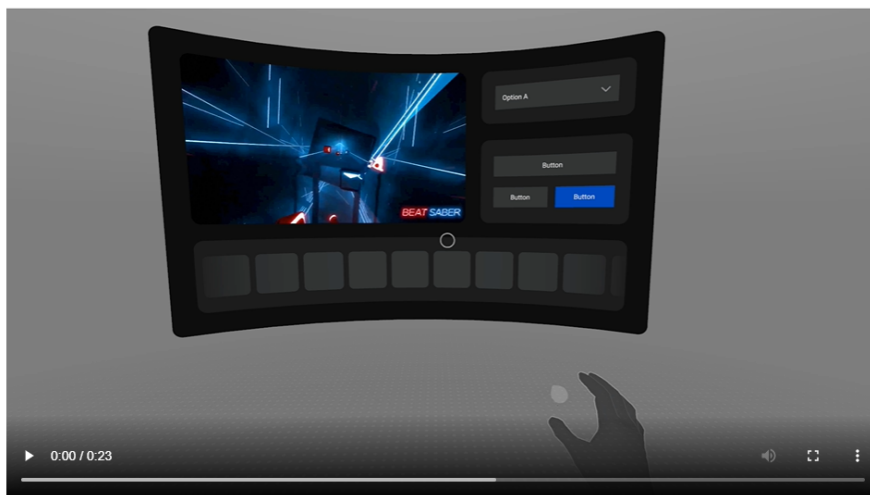
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See also Designing for Hands.

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See also Hand Tracking Deep Dive at 4:00–10:00.



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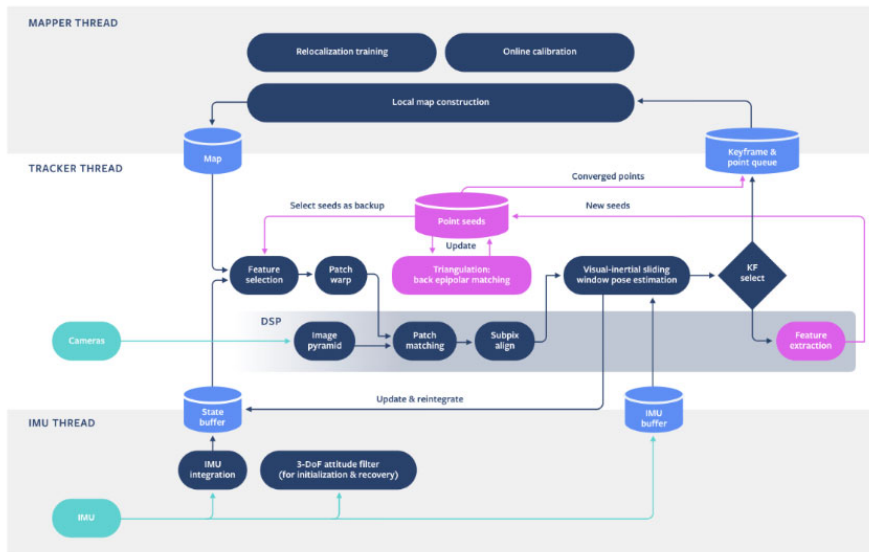
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Claim 14

(14) The method of claim 11 wherein accepting the information related to an actual sensor measurement includes accepting information enabling the estimation subsystem to calculate a difference between the actual measurement and the expected measurement.

See supra claims 1, 11. Facebook encourages, directs, or promotes users to use the Accused Products to perform the method of claim 11 in which accepting the information related to an actual sensor measurement includes accepting information enabling the estimation subsystem to calculate a difference between the actual measurement and the expected measurement, and Facebook performs such step itself. For example, on information and belief and subject to discovery which has not yet occurred, the headset in the Accused Products and/or a computer or other external processor for the Oculus Rift S receives data from the cameras and/or IMUs within the headset and/or the IMUs within the Oculus controller(s), which enables the Oculus Insight tracking system to calculate a difference between the data received and the predicted movement of the user's hand(s) and/or the Oculus controller(s). The Accused Products are especially adapted to carry out this method, which is a material part of the claimed invention, and have no substantial noninfringing uses. Further, Facebook conditions a user's use of the Accused Products, and therefore the user's receipt of the benefits of the Accused Products, upon this method and establishes the manner or timing of that use.

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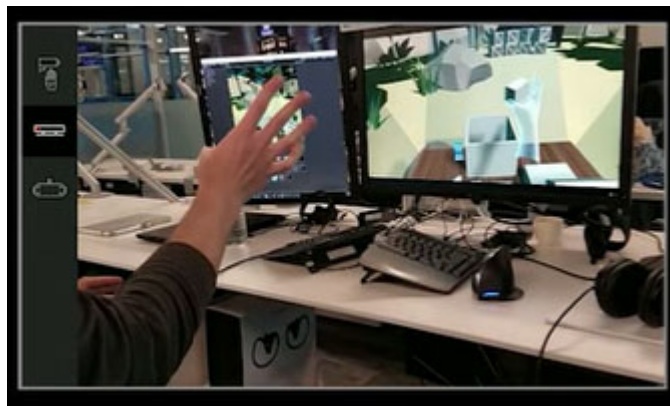
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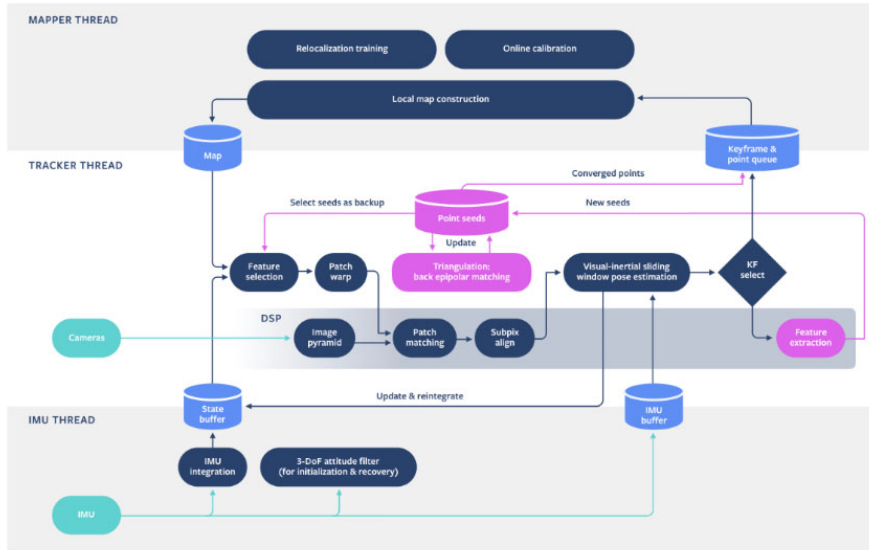
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See also *id.*

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Claim 15

(15) The method of claim 11 wherein accepting the information related to an actual sensor measurement includes accepting information for correlating measurements and geometric relationships between sensing elements.

See *supra* claims 1, 11. Facebook encourages, directs, or promotes users to use the Accused Products to perform the method of claim 11 in which accepting the information related to an actual sensor measurement includes accepting information for correlating measurements and geometric relationships between sensing elements, and Facebook performs such step itself. For example, on information and belief and subject to discovery which has not yet occurred, the headset in the Accused Products and/or a computer or other external processor for the Oculus Rift S receives data from the cameras and/or IMUs within the headset and/or the IMUs within the Oculus controller(s), where the data includes information for correlating measurements and geometric relationships between these sensing elements. The Accused Products are especially adapted to carry out this method, which is a material part of the claimed invention, and have no substantial noninfringing uses. Further, Facebook conditions a user's use of the Accused Products, and therefore the user's receipt of the benefits of the Accused Products, upon this method and establishes the manner or timing of that use.

See, e.g., Hand Tracking.

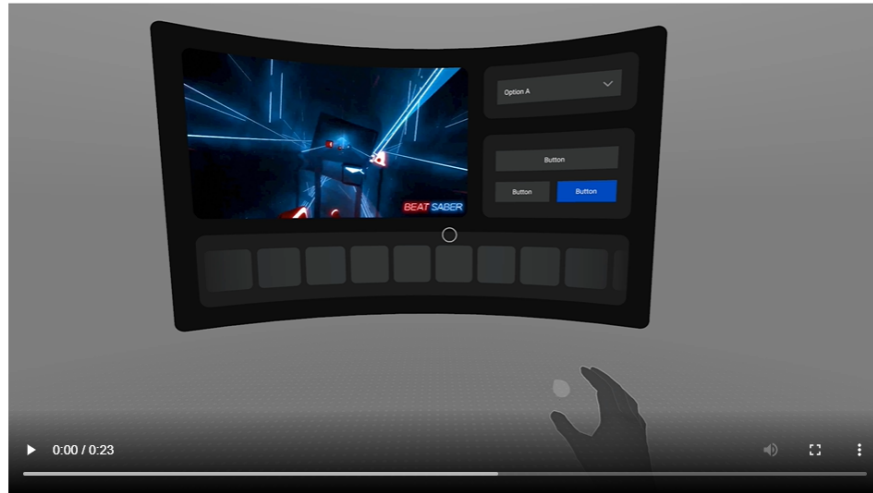
The hand tracking feature enables the use of hands as an input method for the Oculus Quest device. It delivers a new sense of presence, enhances social engagement, and delivers more natural interactions with fully tracked hands and articulated fingers. Integrated hands can perform object interactions by using simple hand gestures such as pinch, unpinch, and pinch and hold.

The hand tracking feature lets you operate with hands and controllers interchangeably. When you opt to use hands, the hand's pose drives a laser cursor-pointer that behaves like the standard controller cursor. You can use the cursor-pointer to highlight, select, click, or write your own app-level event logic.

Hand tracking complements the Touch controllers and is not intended to replace controllers in all scenarios, especially with games or creative tools that require a high degree of precision. By opting-in to hand support, your app also needs to satisfy additional technical requirements specific to hand tracking in order to be accepted on Oculus Store. To submit an app to Oculus Store, the app must support controllers along with hand tracking.

See also Designing for Hands.

Designing for Hands



See also Hand Tracking Deep Dive at 4:00–10:00.



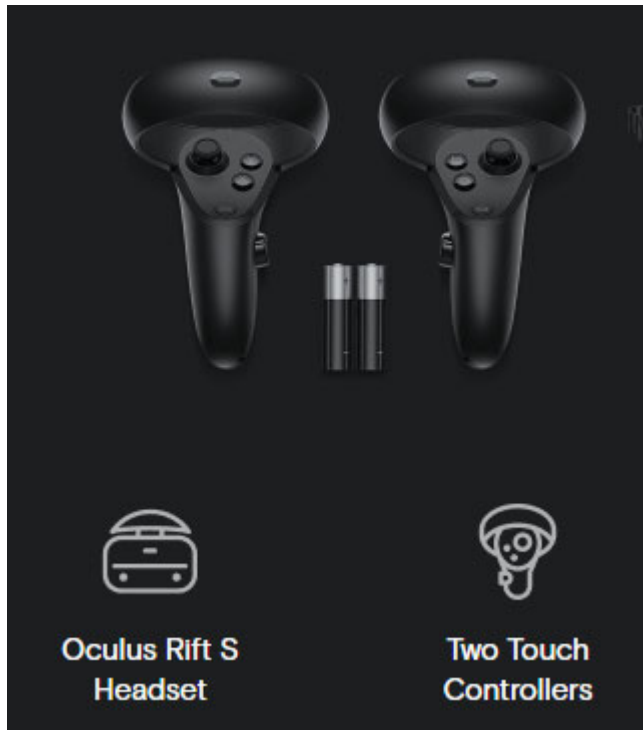
See also id. at 4:00–10:00.



See also Oculus Quest.



See also Oculus Rift S.



See also From the Lab.

There are other complications, too. The infrared LEDs in the two hand controllers drastically change appearance when they move closer or farther away from the headset as you swing a virtual sword or maneuver a virtual spaceship. Oculus Insight also uses other sensors, drawing acceleration and velocity data from the inertial measurement units (IMUs) located in the headset and controllers. The system must process all of these data points in real time and, in the case of Quest, on a mobile chipset.

See also From the Lab.

Taking SLAM technology ...

The foundation of Oculus Insight's inside-out tracking is [simultaneous localization and mapping, or SLAM](#), which uses computer vision CV algorithms to essentially fuse incoming data from multiple sensors in order to fix the position of an object within a constantly updated digital map. SLAM has been used in robotics and in [AR camera effects](#) on smartphones and was demoed in the Oculus [Santa Cruz VR headset prototype](#) in 2016. But Oculus Insight required an unprecedented level of precision and efficiency, and that meant adapting the latest research on tracking and computer vision.

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To build a new, more advanced version of SLAM, the engineering team drew from Facebook's years of AI research and engineering work, building systems to understand the objects and actions that appear in videos and creating highly efficient computer vision algorithms that work well on mobile devices.

See also Powered by AI.

headset and controllers with respect to a 3D map that is generated and constantly updated by Insight. The data used for this process comes from three types of sensors built into the Quest and Rift S hardware:

1. Linear acceleration and rotational velocity data from IMUs in the headset and controllers are integrated to track the orientation and position of each with low latency.
2. Image data from cameras in the headset helps generate a 3D map of the room, pinpointing landmarks like the corners of furniture or the patterns on your floor. These landmarks are observed repeatedly, which enables Insight to compensate for drift (a common challenge with IMUs, where even tiny measurement discrepancies build up over time, resulting in inaccurate location tracking).
3. Infrared LEDs in the controllers are detected by the headset cameras, letting the system bound the controller position drift caused by integrating multiple IMUs.

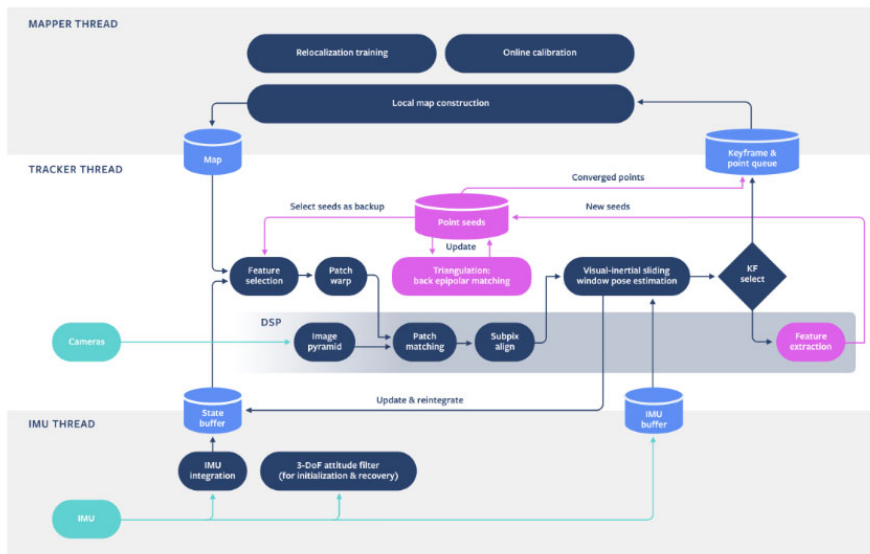
See also Powered by AI.

SLAM addresses these challenges by automatically recognizing features in the environment, letting Oculus Insight incorporate the player's current position into a VR display. Insight also uses an extrapolation function with dynamic damping to help predict where the user's head and hands will move in the milliseconds ahead. This provides a number of benefits, including reducing the visual stuttering effect known as jitter, which is the key metric that tracking systems are measured against. To help enable a comfortable VR experience, tracking should be in the submillimeter range, meaning that the system can track with precision greater than a single millimeter. Insight exceeds this target in most environments.

Another major factor to avoid in delivering immersive experiences is latency — any lag between physical movements and their VR equivalents can disorient the user and degrade the sense of realism. By using low-latency IMU data and a kinematic model that predicts a user's motion into the future, Insight is able to effectively eliminate the apparent latency. We'll go into more detail in the next section about the sensor fusion process that incorporates SLAM data, but reducing both jitter and latency is central to Insight's ability to deliver a new level of realism within VR.

See also id.

Headset tracking compute architecture



Oculus Insight processes multiple threads of data at once, in real-time — the mapper thread modifies the map, sending updated copies to the tracker thread, which uses camera frames to estimate poses in the mapper-provided frames, while the IMU thread uses measurements from the IMUs to update the latest SLAM state.

Claim 16

(16) The method of claim 15 wherein the information for correlating measurements and geometric relationships between sensing elements includes a mapping between a relative pose of the sensing

See supra claims 1, 11, 15. Facebook encourages, directs, or promotes users to use the Accused Products to perform the method of claim 15 in which the information for correlating measurements and geometric relationships between sensing elements includes a mapping between a relative pose of the sensing elements and a sensor measurement, and Facebook performs such step itself. For example, on information and belief and subject to discovery which has not yet occurred, the data that the headset in the Accused Products and/or a computer or other external processor for the Oculus Rift S receives from the cameras and/or IMUs within the headset and/or the IMUs within the Oculus controller(s) includes information for correlating measurements and geometric relationships between the Oculus controllers and the IMUs within them, including a mapping between a relative position of the controllers and the data received. The

elements and a sensor measurement.

Accused Products are especially adapted to carry out this method, which is a material part of the claimed invention, and have no substantial noninfringing uses. Further, Facebook conditions a user's use of the Accused Products, and therefore the user's receipt of the benefits of the Accused Products, upon this method and establishes the manner or timing of that use.

See, e.g., Hand Tracking.

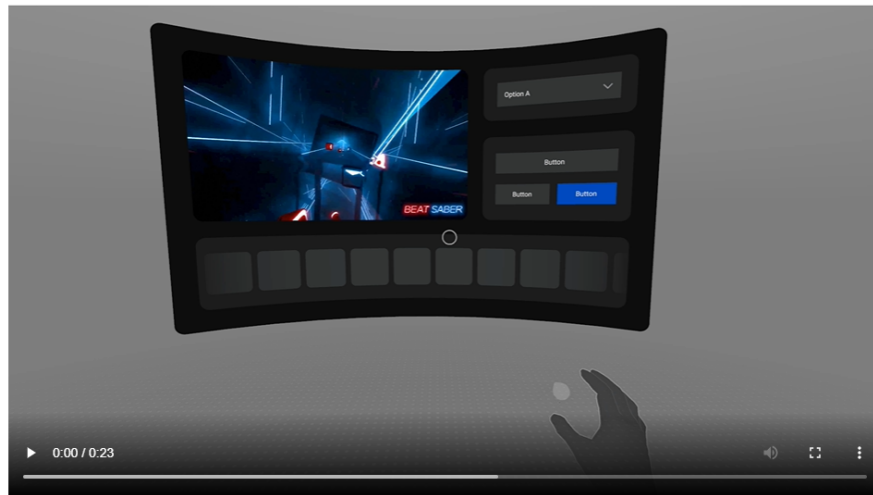
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See also Designing for Hands.

Designing for Hands



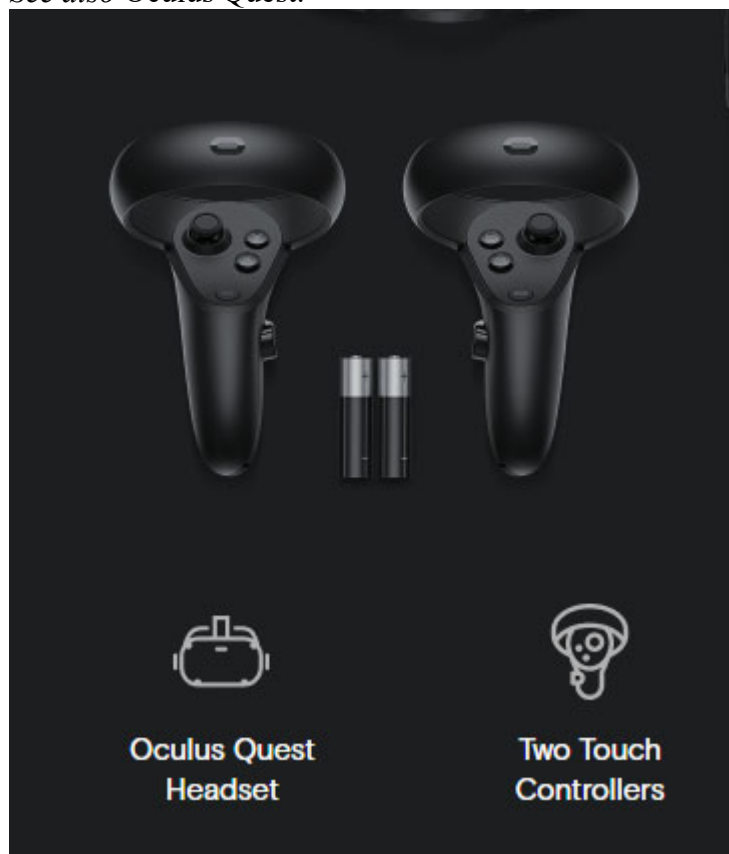
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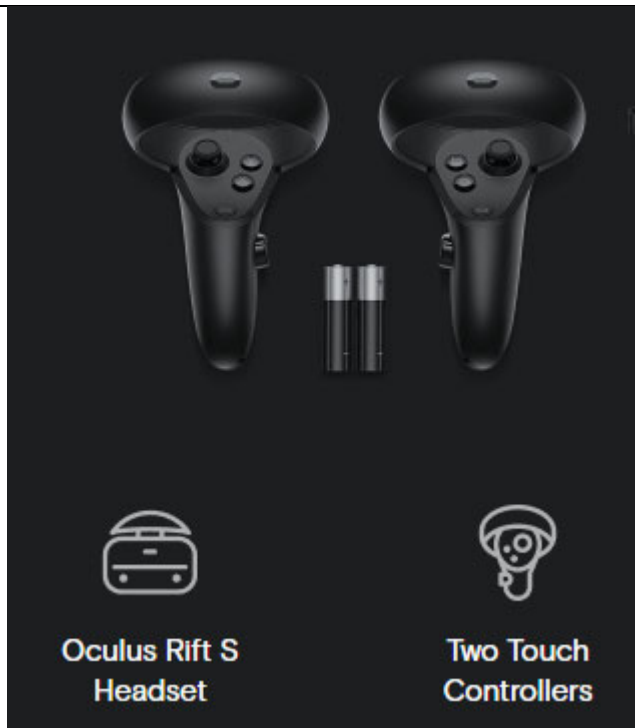
See also id. at 4:00–10:00.



See also Oculus Quest.



See also Oculus Rift S.



Oculus Rift S
Headset

Two Touch
Controllers

See also From the Lab.

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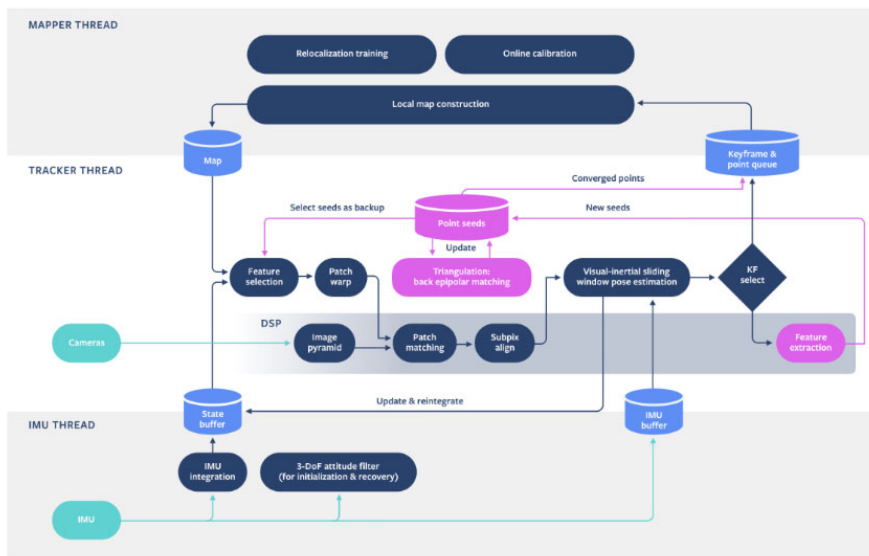
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See also id.

Headset tracking compute architecture



Oculus Insight processes multiple threads of data at once, in real-time — the mapper thread modifies the map, sending updated copies to the tracker thread, which uses camera frames to estimate poses in the mapper-provided frames, while the IMU thread uses measurements from the IMUs to update the latest SLAM state.

Claim 17

(17) The method of claim 16 wherein the mapping between the relative pose of the sensing elements and the sensor measurement characterizes a linear mapping.

See supra claims 1, 11, 15, 16. Facebook encourages, directs, or promotes users to use the Accused Products to perform the method of claim 16 in which the mapping between the relative pose of the sensing elements and the sensor measurement characterizes a linear mapping. For example, on information and belief and subject to discovery which has not yet occurred, the data that the headset in the Accused Products and/or a computer or other external processor for the Oculus Rift S receives from the IMUs in the Oculus controllers includes information for correlating measurements and geometric relationships between these sensing elements, including a linear mapping between a relative position of these sensing elements and the data received. The Accused Products are especially adapted to carry out this method, which is a material part of the claimed invention, and have no substantial noninfringing uses. Further, Facebook conditions a user's use of the Accused Products, and therefore the user's receipt of the benefits of the Accused Products, upon this method and establishes the manner or timing of that use.

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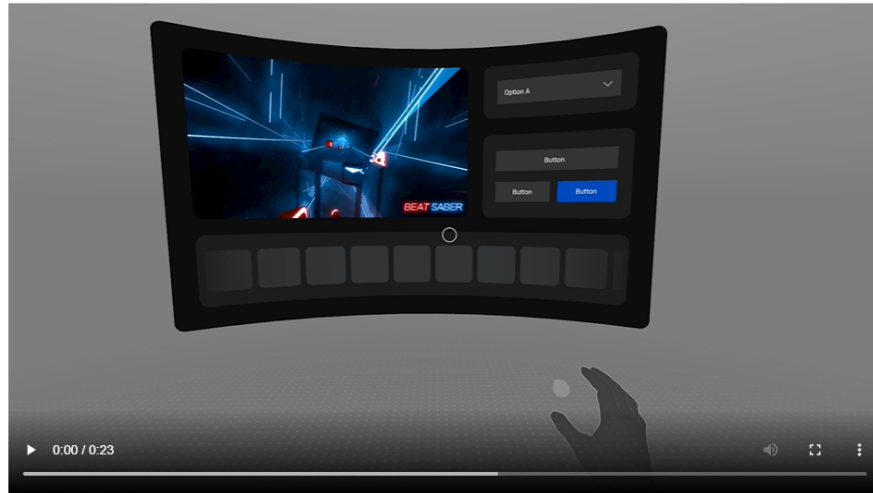
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See also Designing for Hands.

Designing for Hands



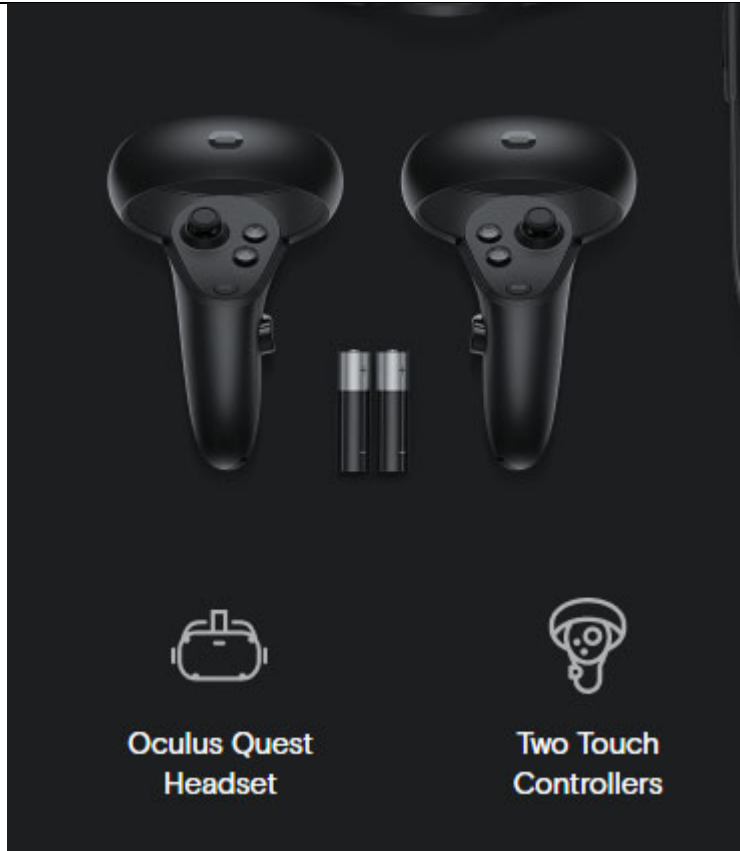
See also Hand Tracking Deep Dive at 4:00–10:00.



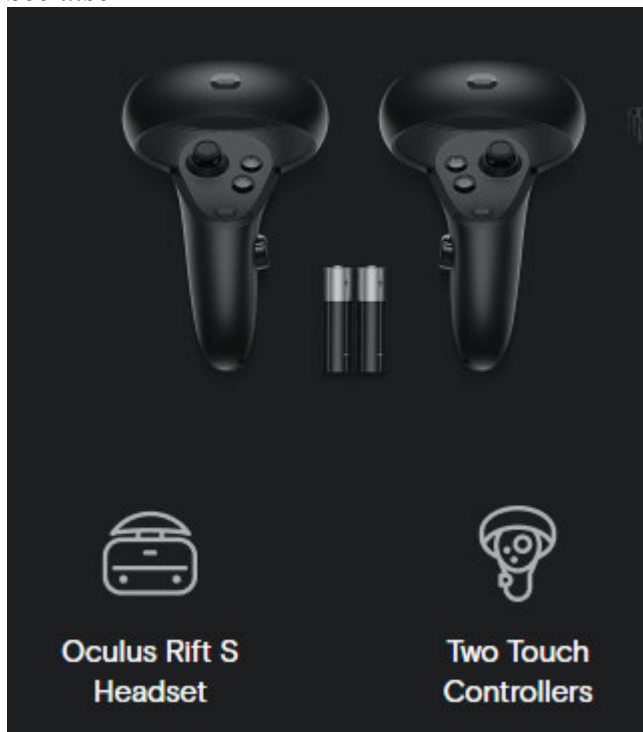
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See also Oculus Quest.



See also Oculus Rift S.



See also From the Lab.

There are other complications, too. The infrared LEDs in the two hand controllers drastically change appearance when they move closer or farther away from the headset as you swing a virtual sword or maneuver a virtual spaceship. Oculus Insight also uses other sensors, drawing acceleration and velocity data from the inertial measurement units (IMUs) located in the headset and controllers. The system must process all of these data points in real time and, in the case of Quest, on a mobile chipset.

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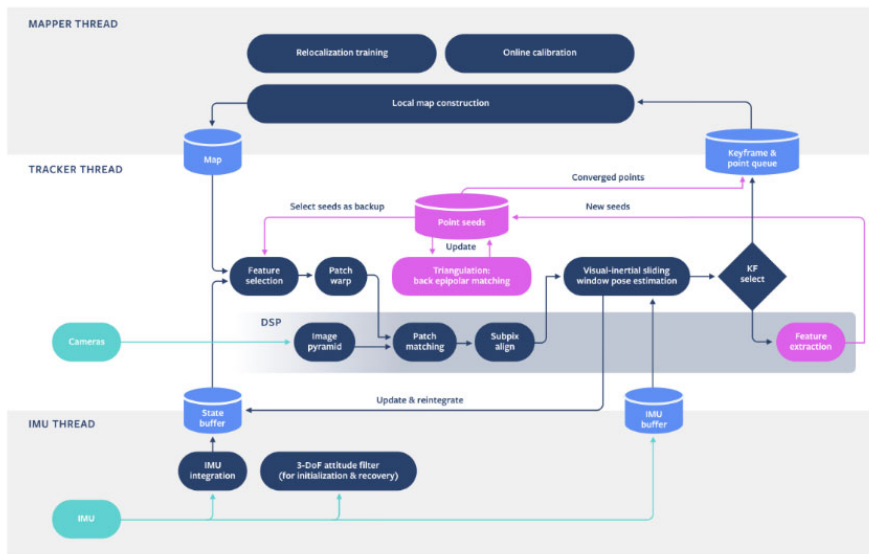
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Headset tracking compute architecture



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Claim 18

(18) The method of claim 11 wherein accepting the information related to an actual sensor measurement includes accepting information characterizing an uncertainty in the actual measurement.

See supra claims 1, 11. Facebook encourages, directs, or promotes users to use the Accused Products to perform the method of claim 11 in which accepting the information related to an actual sensor measurement includes accepting information characterizing an uncertainty in the actual measurement. For example, on information and belief and subject to discovery which has not yet occurred, the headset in the Accused Products and/or a computer or other external processor for the Oculus Rift S receives data from the cameras and/or IMUs within the headset and/or the IMUs within the Oculus controller(s), including data characterizing the uncertainty in the actual measurement made by these sensing elements. The Accused Products are especially adapted to carry out this method, which is a material part of the claimed invention, and have no substantial noninfringing uses. Further, Facebook conditions a user's use of the Accused

Products, and therefore the user's receipt of the benefits of the Accused Products, upon this method and establishes the manner or timing of that use.

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See, e.g., Hand Tracking.

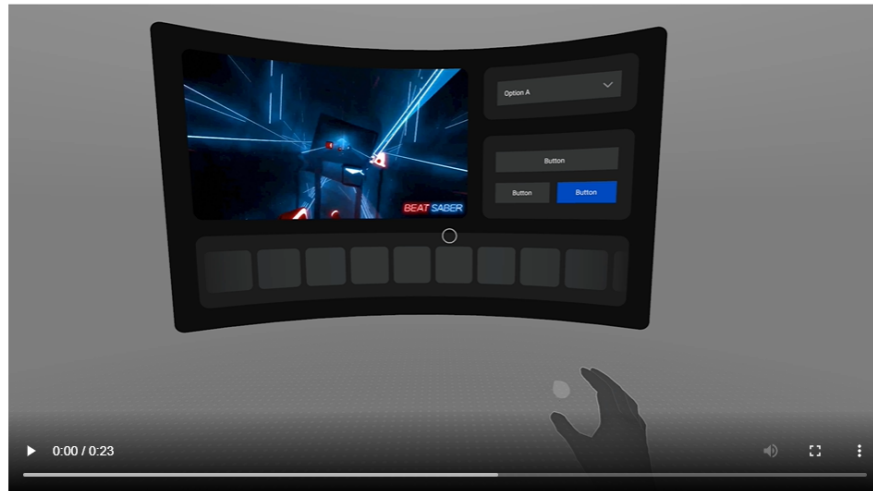
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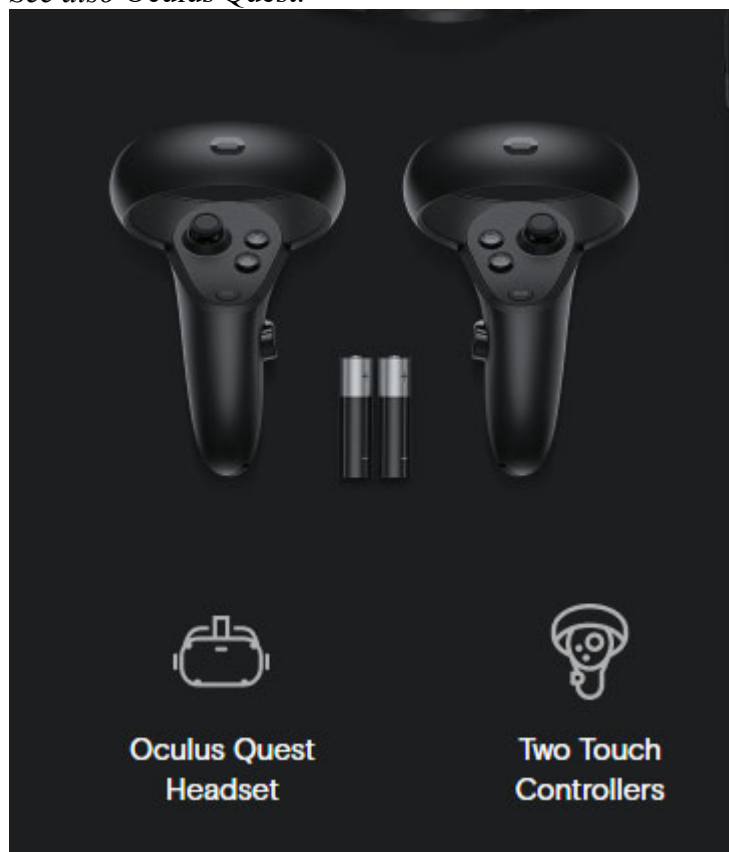
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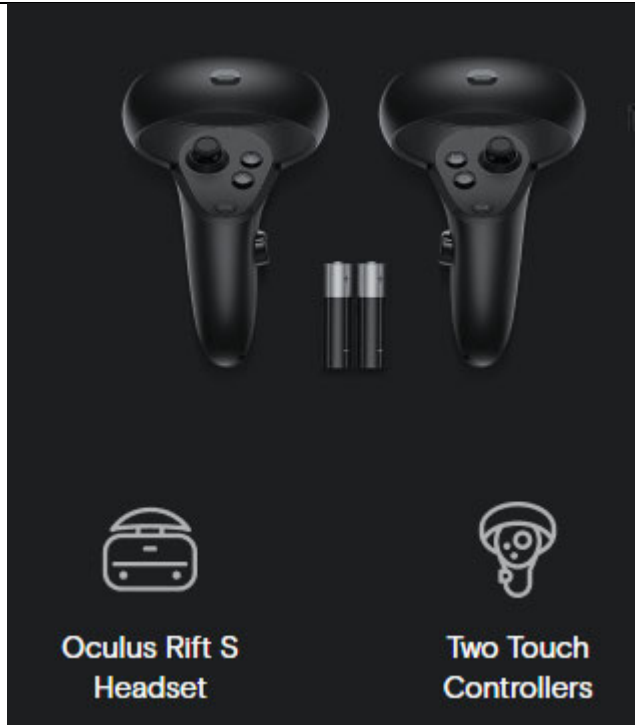
See also id. at 4:00–10:00.



See also Oculus Quest.



See also Oculus Rift S.



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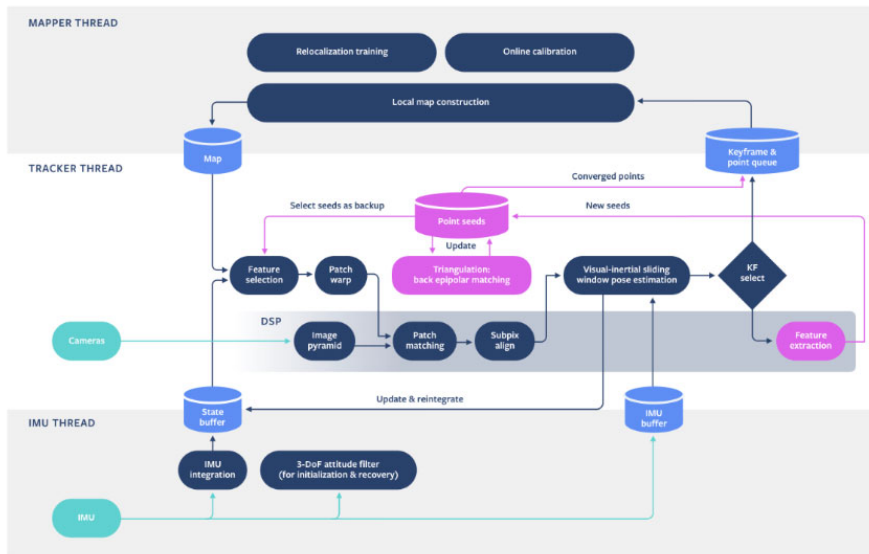
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Claim 19

(19) The method of claim 18 wherein the information characterizing the uncertainty in the actual measurement includes parameters of a statistical distribution of an error of the actual measurement.

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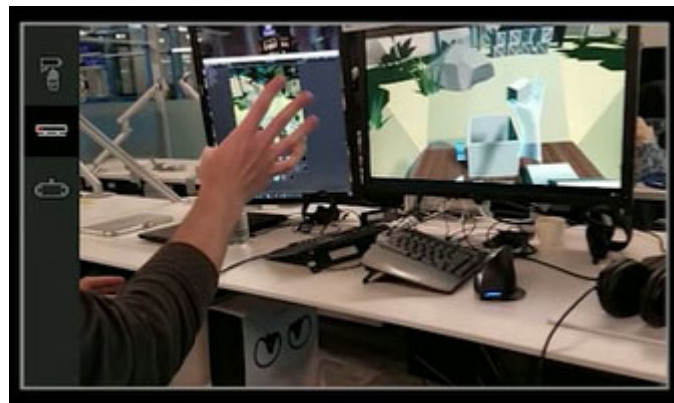
See also Designing for Hands.
Designing for Hands



See also Hand Tracking Deep Dive at 4:00–10:00.



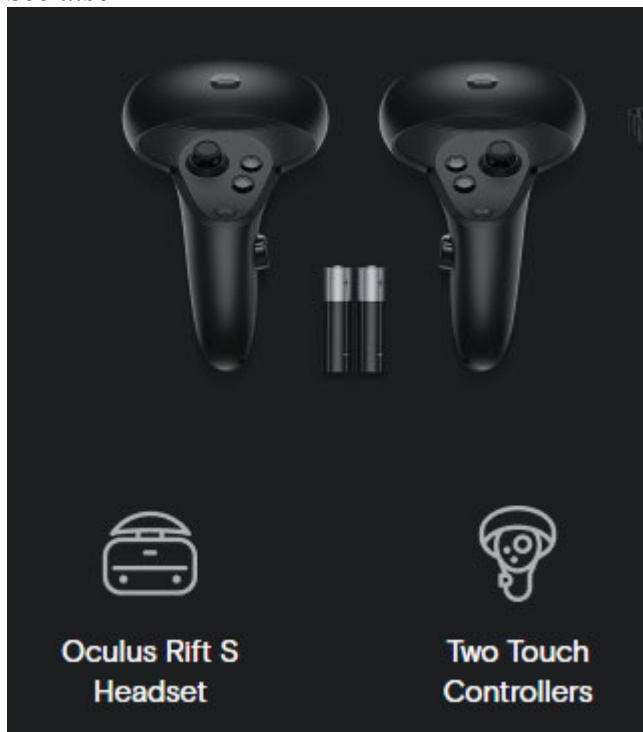
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See also From the Lab.

Taking SLAM technology ...

The foundation of Oculus Insight's inside-out tracking is [simultaneous localization and mapping, or SLAM](#), which uses computer vision CV algorithms to essentially fuse incoming data from multiple sensors in order to fix the position of an object within a constantly updated digital map. SLAM has been used in robotics and in [AR camera effects](#) on smartphones and was demoed in the Oculus [Santa Cruz VR headset prototype](#) in 2016. But Oculus Insight required an unprecedented level of precision and efficiency, and that meant adapting the latest research on tracking and computer vision.

"A lot of these technologies really start in academia — inside the lab," Kozminski notes. It's no coincidence, then, that she's part of Facebook's Zurich-based team of engineers, many of whom came from [Zurich Eye](#) — a joint program from the prestigious [ETH University](#) and [University of Zurich](#) that researched self-navigating systems.

To build a new, more advanced version of SLAM, the engineering team drew from Facebook's years of AI research and engineering work, building systems to understand the objects and actions that appear in videos and creating highly efficient computer vision algorithms that work well on mobile devices.

See also Powered by AI.

headset and controllers with respect to a 3D map that is generated and constantly updated by Insight. The data used for this process comes from three types of sensors built into the Quest and Rift S hardware:

1. Linear acceleration and rotational velocity data from IMUs in the headset and controllers are integrated to track the orientation and position of each with low latency.
2. Image data from cameras in the headset helps generate a 3D map of the room, pinpointing landmarks like the corners of furniture or the patterns on your floor. These landmarks are observed repeatedly, which enables Insight to compensate for drift (a common challenge with IMUs, where even tiny measurement discrepancies build up over time, resulting in inaccurate location tracking).
3. Infrared LEDs in the controllers are detected by the headset cameras, letting the system bound the controller position drift caused by integrating multiple IMUs.

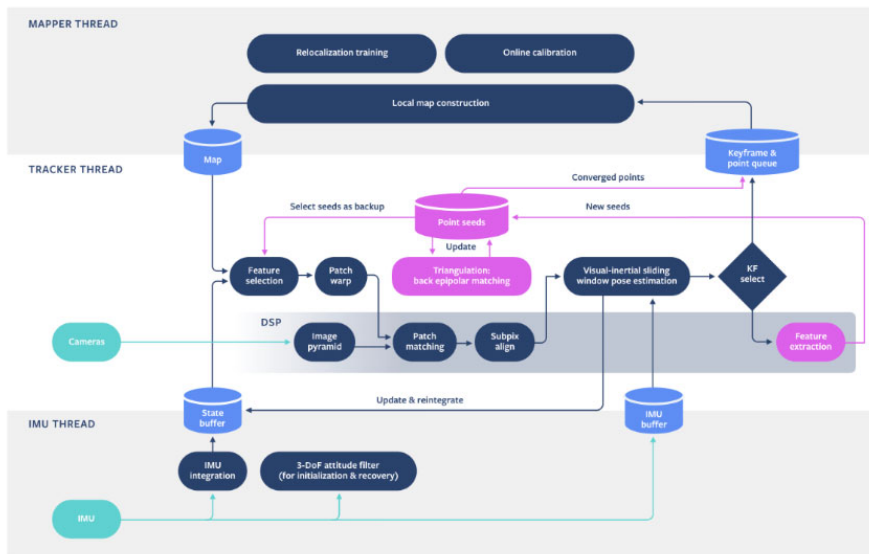
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SLAM addresses these challenges by automatically recognizing features in the environment, letting Oculus Insight incorporate the player's current position into a VR display. Insight also uses an extrapolation function with dynamic damping to help predict where the user's head and hands will move in the milliseconds ahead. This provides a number of benefits, including reducing the visual stuttering effect known as jitter, which is the key metric that tracking systems are measured against. To help enable a comfortable VR experience, tracking should be in the submillimeter range, meaning that the system can track with precision greater than a single millimeter. Insight exceeds this target in most environments.

Another major factor to avoid in delivering immersive experiences is latency — any lag between physical movements and their VR equivalents can disorient the user and degrade the sense of realism. By using low-latency IMU data and a kinematic model that predicts a user's motion into the future, Insight is able to effectively eliminate the apparent latency. We'll go into more detail in the next section about the sensor fusion process that incorporates SLAM data, but reducing both jitter and latency is central to Insight's ability to deliver a new level of realism within VR.

See also id.

Headset tracking compute architecture



Oculus Insight processes multiple threads of data at once, in real-time — the mapper thread modifies the map, sending updated copies to the tracker thread, which uses camera frames to estimate poses in the mapper-provided frames, while the IMU thread uses measurements from the IMUs to update the latest SLAM state.

Claim 20

(20a) The method of claim 1 wherein repeatedly updating the state further includes: selecting a pair of sensing elements for measurement; and

See supra claim 1. Facebook encourages, directs, or promotes users to use the Accused Products to perform the method of claim 1 in which repeatedly updating the state further includes selecting a pair of sensing elements for measurement, and Facebook performs such step itself. For example, the Accused Products select a pair of sensing elements (e.g., a camera within the headset and an infrared LED, IMUs, and/or other sensors on an Oculus controller, or a camera within the headset and a marker on the user's hand) for measurement. The Accused Products are especially adapted to carry out this method, which is a material part of the claimed invention, and have no substantial noninfringing uses. Further, Facebook conditions a user's use of the Accused Products, and therefore the user's receipt of the benefits of the Accused Products, upon this method and establishes the manner or timing of that use.

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There are other complications, too. The infrared LEDs in the two hand controllers drastically change appearance when they move closer or farther away from the headset as you swing a virtual sword or maneuver a virtual spaceship. Oculus Insight also uses other sensors, drawing acceleration and velocity data from the inertial measurement units (IMUs) located in the headset and controllers. The system must process all of these data points in real time and, in the case of Quest, on a mobile chipset.

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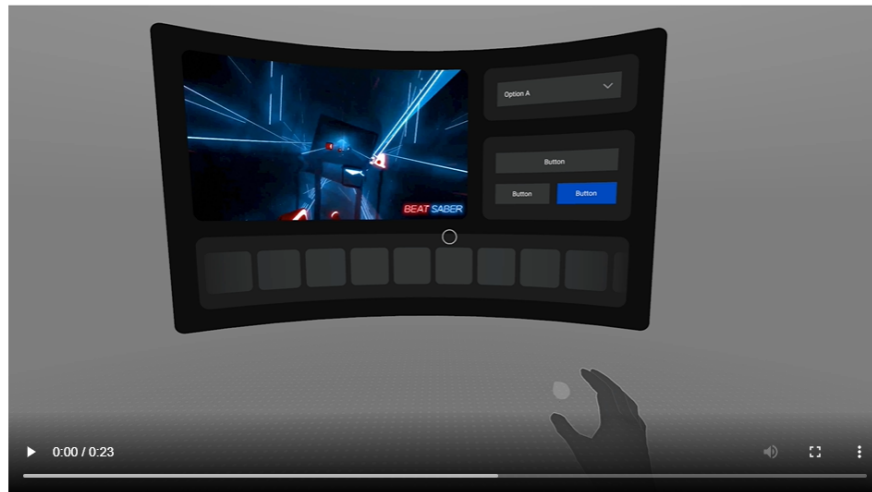
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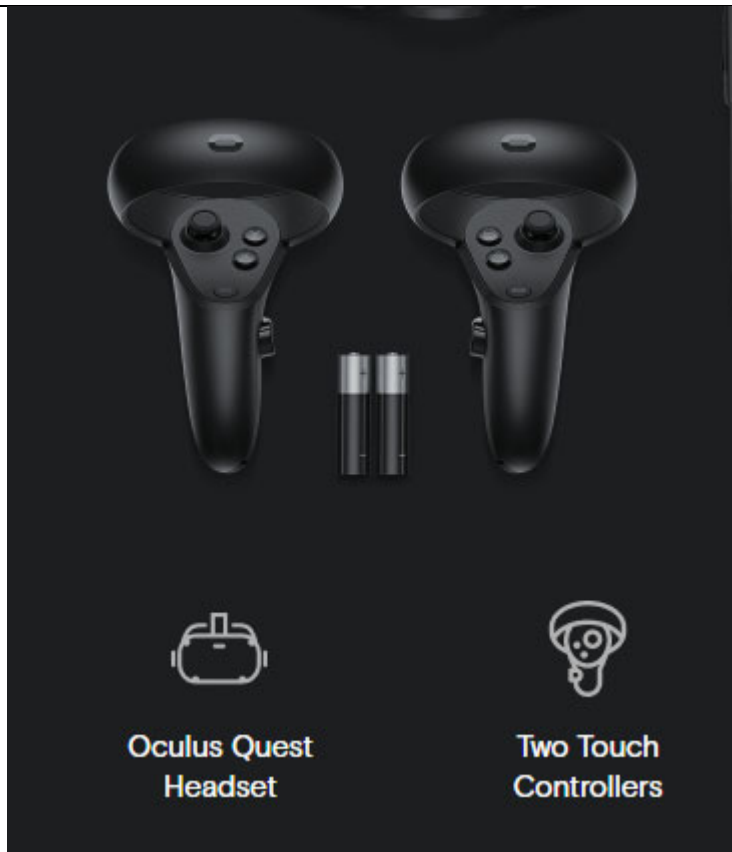
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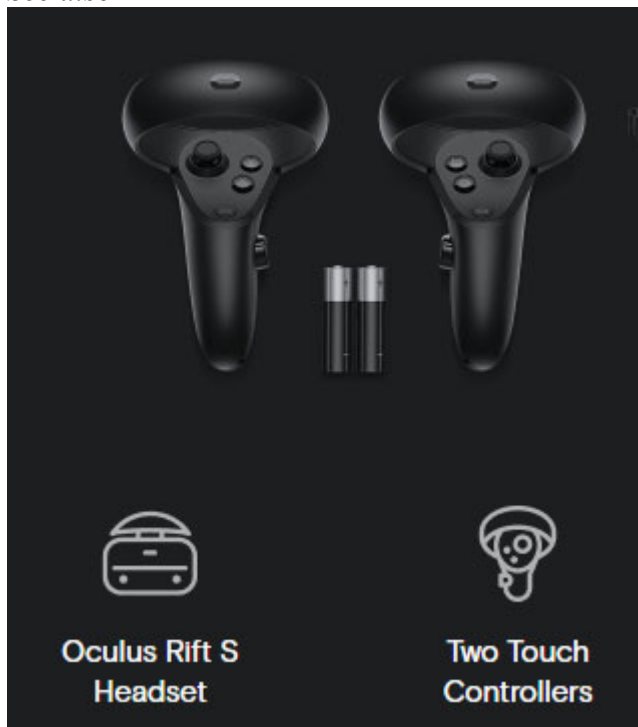
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The Oculus Insight system uses a custom hardware architecture and advanced computer vision algorithms — including visual-inertial mapping, place recognition, and geometry reconstruction — to establish the location of objects in relation to other objects within a given space. This novel algorithm stack enables a VR device to pinpoint its location, identify aspects of room geometry (such as floor location), and track the positions of the headset and controllers with respect to a 3D map that is generated and constantly updated by Insight. The data used for this process comes from three types of sensors built into the Quest and Rift S hardware:

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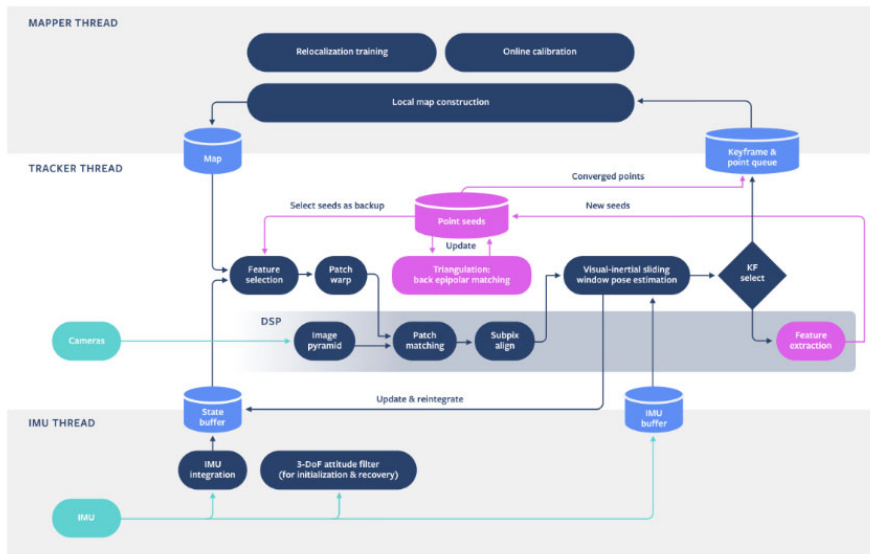
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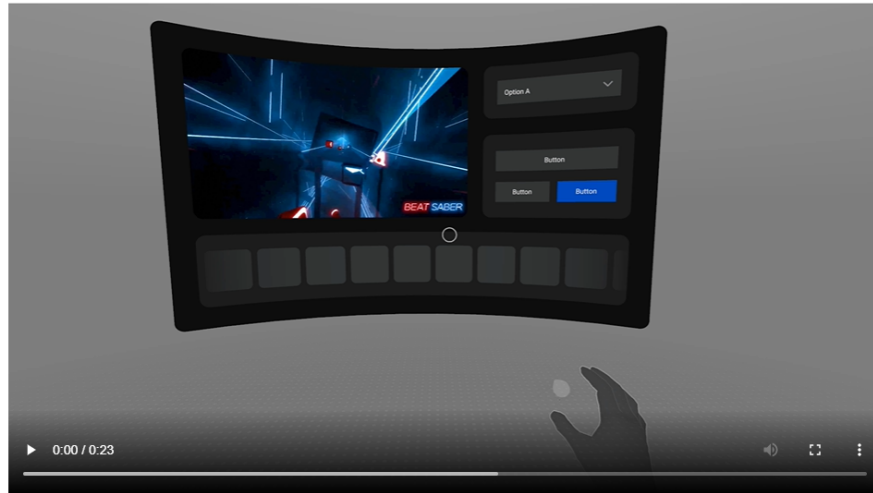
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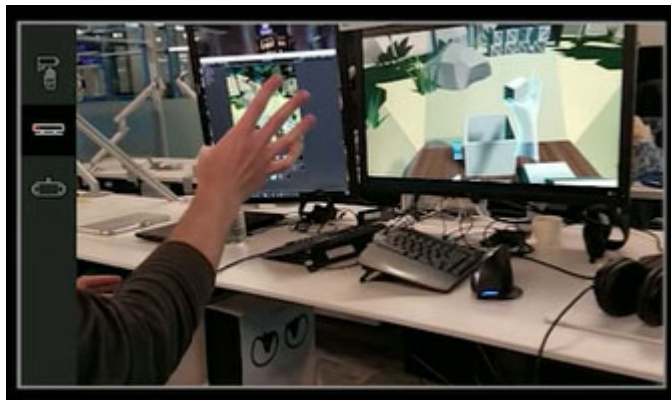
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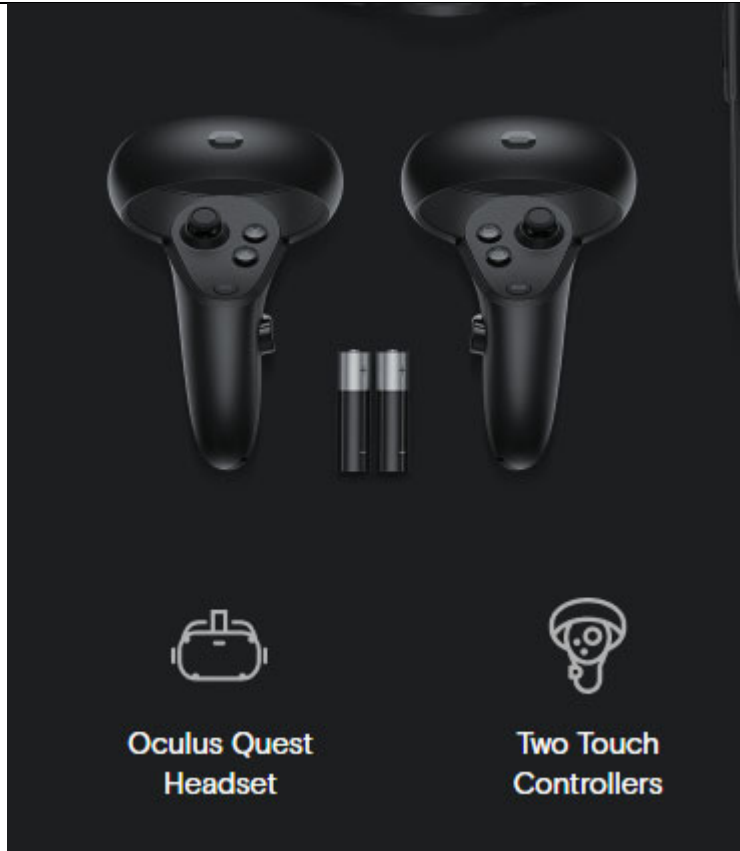
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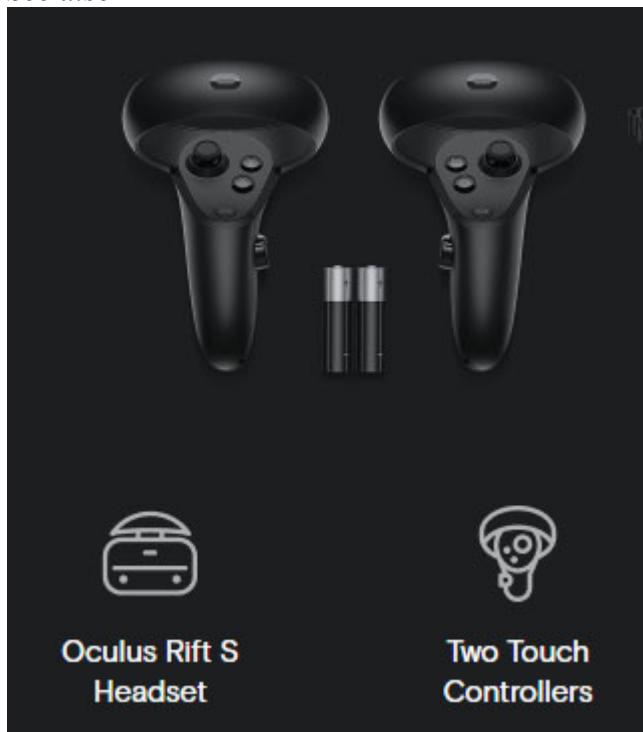
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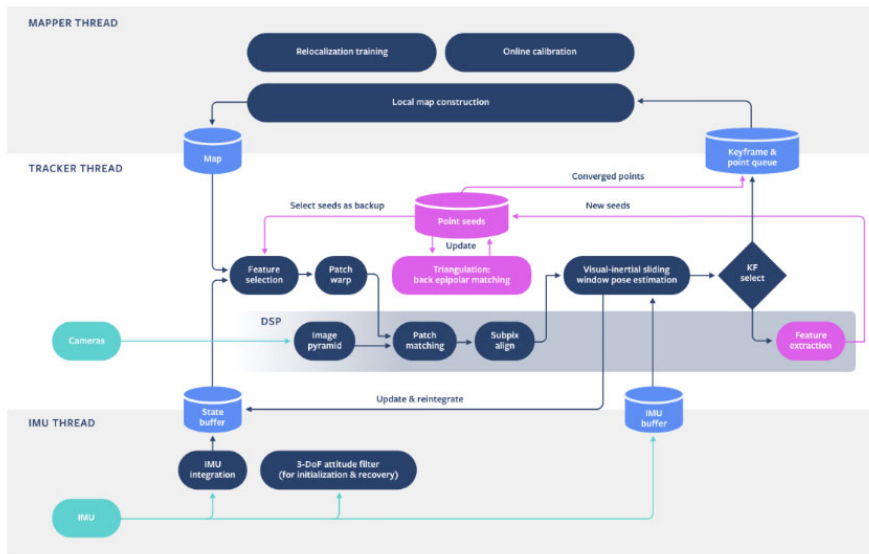
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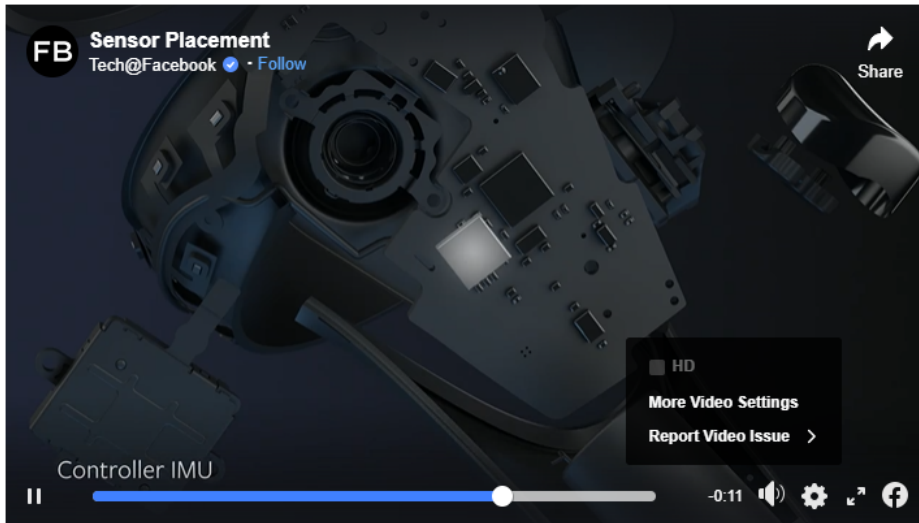


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To the extent this limitation is not met literally, the Accused Products also satisfy this limitation under the doctrine of equivalents. Any difference between the Accused Products and the claim element is insubstantial.

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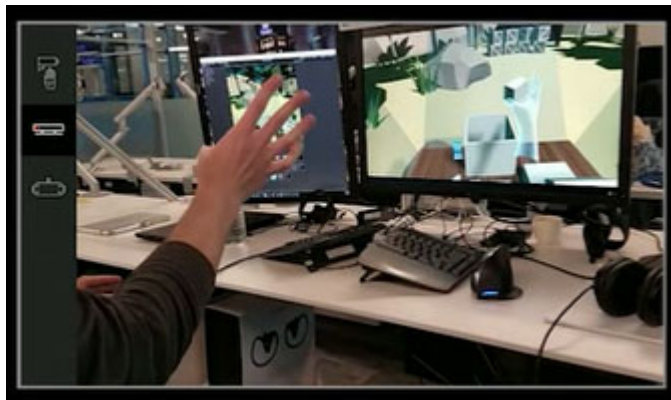
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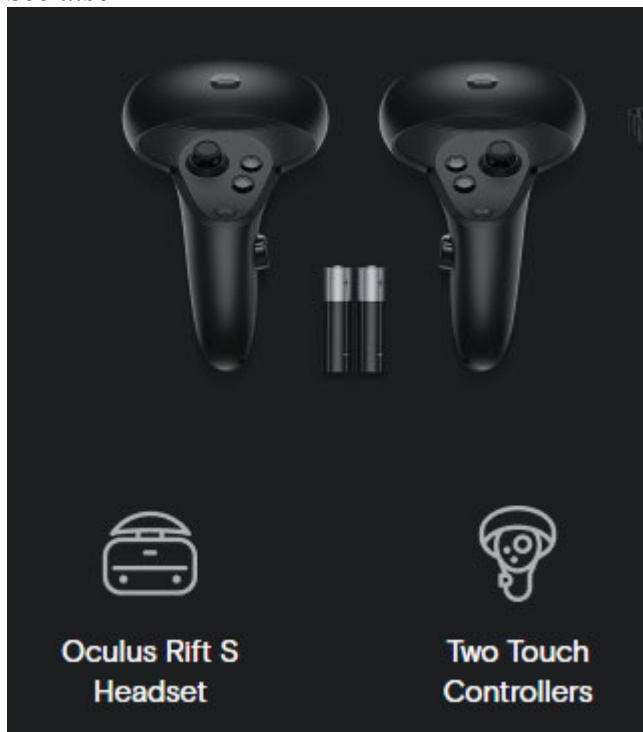
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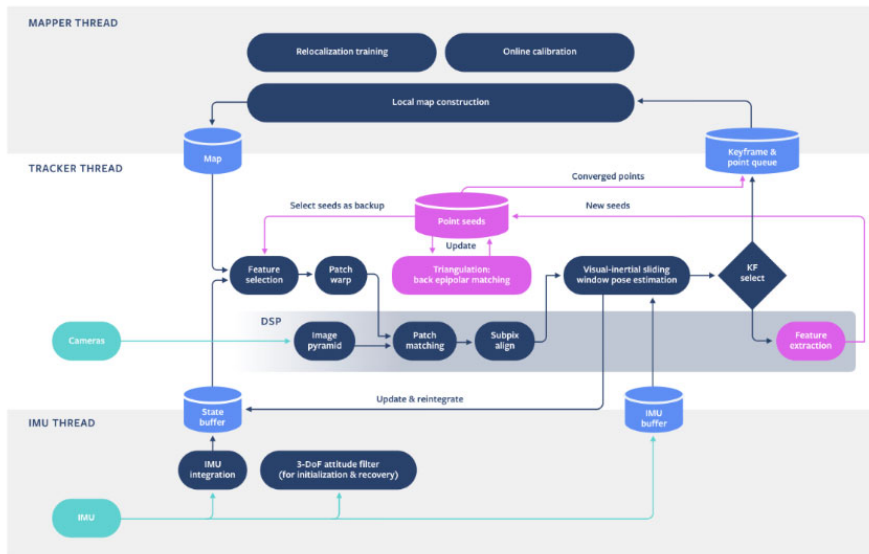
See also Powered by AI.

headset and controllers with respect to a 3D map that is generated and constantly updated by Insight. The data used for this process comes from three types of sensors built into the Quest and Rift S hardware:

1. Linear acceleration and rotational velocity data from IMUs in the headset and controllers are integrated to track the orientation and position of each with low latency.
2. Image data from cameras in the headset helps generate a 3D map of the room, pinpointing landmarks like the corners of furniture or the patterns on your floor. These landmarks are observed repeatedly, which enables Insight to compensate for drift (a common challenge with IMUs, where even tiny measurement discrepancies build up over time, resulting in inaccurate location tracking).
3. Infrared LEDs in the controllers are detected by the headset cameras, letting the system bound the controller position drift caused by integrating multiple IMUs.

See also id.

Headset tracking compute architecture



Oculus Insight processes multiple threads of data at once, in real-time — the mapper thread modifies the map, sending updated copies to the tracker thread, which uses camera frames to estimate poses in the mapper-provided frames, while the IMU thread uses measurements from the IMUs to update the latest SLAM state.

See also *From the Lab*, Sensor Placement at 0:23.



See also *From the Lab*, Sensor Placement at 0:30.



See also Heaney.

More Precise Tracking

A function for infrared LED calibration exists, suggesting this controller is optically tracked in the same way as the current Touch— cameras on the headset follow the movement of the LED constellation, and this is fused with the accelerometer readings to achieve sub-mm precision.



Facebook's VR controllers are tracked via infrared LEDs under the plastic

See also id.

The driver also reveals the series model number of the controller's inertial measurement unit (IMU)- the chip within all VR controllers which contains the accelerometer.

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The IMU in the current Touch controllers for Rift S and Quest

See also ICM-20601 Specification.

FEATURES

- 3-Axis Gyroscope with Programmable FSR of $\pm 500\text{dps}$, $\pm 100\text{dps}$, $\pm 2000\text{dps}$ and $\pm 4000\text{dps}$
- 3-Axis Accelerometer with Programmable FSR of $\pm 4g$, $\pm 8g$, $\pm 16g$, and $\pm 32g$
- User-programmable interrupts
- Wake-on-motion interrupt for low power operation of applications processor
- 512 byte FIFO buffer enables the applications processor to read the data in bursts
- On-Chip 16-bit ADCs and Programmable Filters
- Host interface: 8 MHz SPI or 400k Hz Fast Mode I²C
- Digital-output temperature sensor
- VDD operating range of 1.71 to 3.45V
- MEMS structure hermetically sealed and bonded at wafer level
- RoHS and Green compliant

See also Reddit Single Controller Discussion.

Does the Quest have a single controller mode for any games?

<https://imgur.com/a/1dLoatG>

My stepdad sent his old Oculus Go, it is a lot better than I expected! My good friend who is in the picture absolutely loves the Go. I make sure I bring it every time we hang out since I got it recently. He is able to play some of the games because there is only one controller. He would not be able to operate a controller with his other hand. We are looking at getting him one so we can play together, or both of us upgrading to the Quest. I was wondering if you guys have seen many games you can play with only one controller on the quest, or if we should stick to the Go. My friend would be doing a lot of video but I know he did like the ability to play some of the games. This has been the only video game system he has every really been able to play. I hope the quest will work out for us. Let me know what you guys think, thanks for the help.

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SORT BY BEST

maltakan0 6 points · 1 year ago

Virtual virtual reality can be played with one controller

MRHBK 5 points · 1 year ago

Quest is a bit heavier too if that is a factor

↑ stigzcousin 1 point · 1 year ago

↓ This is something I did not think about. Good to know. Thank you

jebwillnotdivideus 5 points · 1 year ago

Beatsaber and sportsscramble can be played with 1 controller. Other games im not sure.

See also Expert Mode at 2:36.

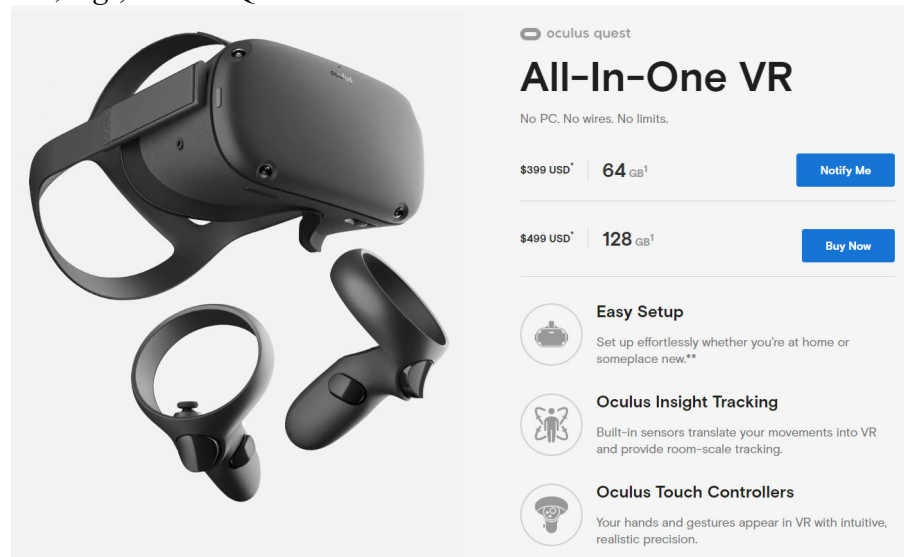


Claim 22

(22) The method of claim 11 wherein repeatedly updating the state further includes: updating the state according to the accepted information related to an actual sensor measurement.

See supra claims 1, 11. Facebook encourages, directs, or promotes users to use the Accused Products to perform the method of claim 11 in which repeatedly updating the state further includes updating the state according to the accepted information related to an actual sensor measurement. For example, the headset in the Accused Products and/or a computer or other external processor for the Oculus Rift S receives and accepts data from the cameras and/or IMUs within the headset and/or the IMUs within the Oculus controller(s), which enables the Oculus Insight tracking system to update the estimated position and orientation of the user’s head, hand(s), and/or the Oculus controller(s) according to the accepted data. The Accused Products are especially adapted to carry out this method, which is a material part of the claimed invention, and have no substantial noninfringing uses. Further, Facebook conditions a user’s use of the Accused Products, and therefore the user’s receipt of the benefits of the Accused Products, upon this method and establishes the manner or timing of that use.

See, e.g., Oculus Quest.



See also Oculus Quest Features.



See, e.g., Hand Tracking.

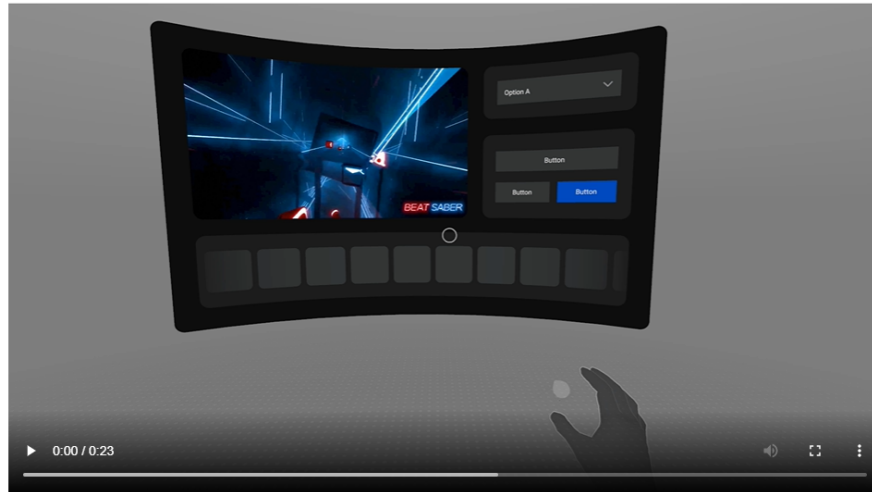
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See also Designing for Hands.

Designing for Hands



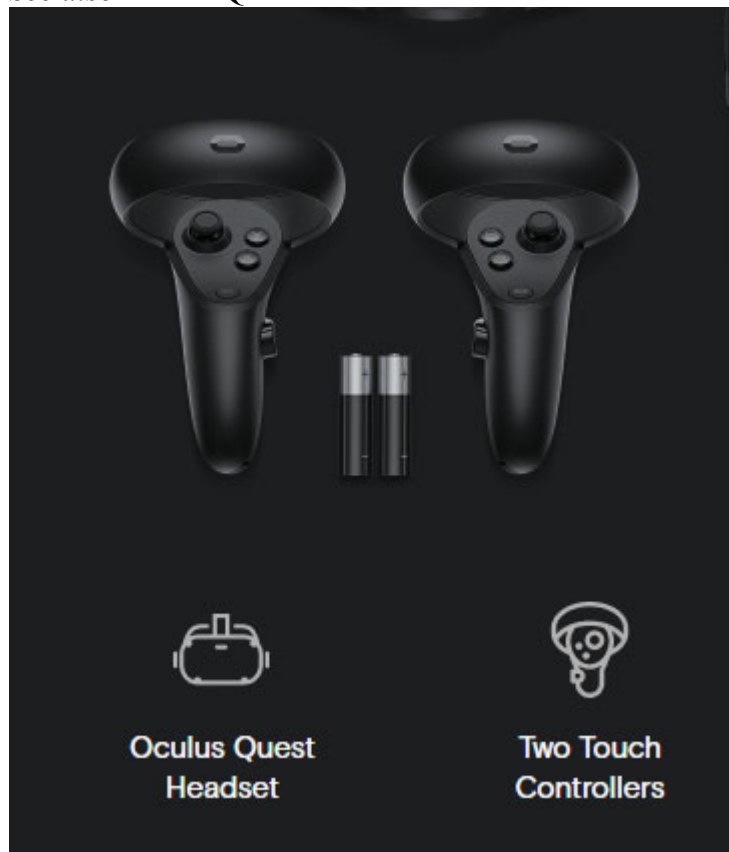
See also Hand Tracking Deep Dive at 4:00–10:00.



See also *id.* at 4:00–10:00.



See also Oculus Quest.



See also Oculus Rift S.



See also From the Lab.

There are other complications, too. The infrared LEDs in the two hand controllers drastically change appearance when they move closer or farther away from the headset as you swing a virtual sword or maneuver a virtual spaceship. Oculus Insight also uses other sensors, drawing acceleration and velocity data from the inertial measurement units (IMUs) located in the headset and controllers. The system must process all of these data points in real time and, in the case of Quest, on a mobile chipset.

See also From the Lab.

Taking SLAM technology ...

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visually anchored to real objects in the world. Oculus Insight is the second generation of this library, and it incorporates significantly more information from a combination of multiple IMUs and ultra-wide-angle cameras, as well as infrared LEDs to jointly track the 6DoF position of a VR headset and controllers.

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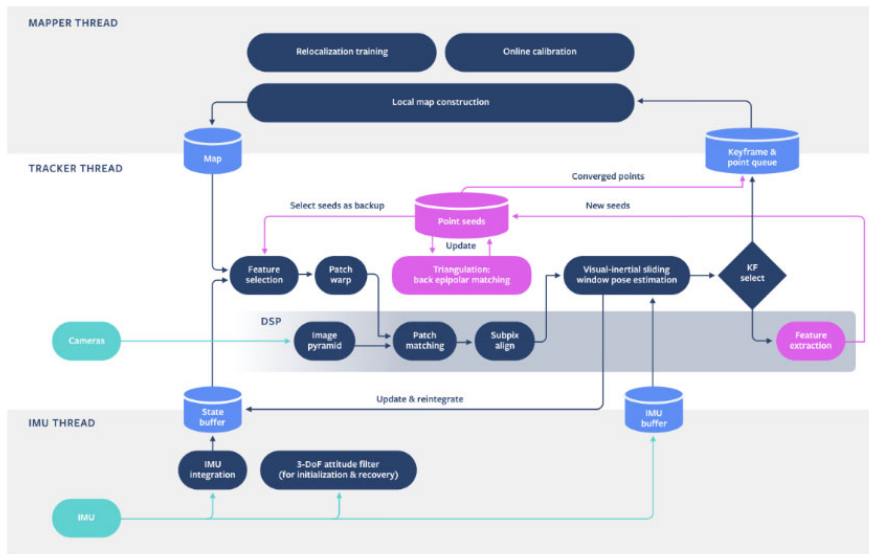
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Headset tracking compute architecture



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The IMU in the current Touch controllers for Rift S and Quest


See also ICM-20601 Specification.

Claim 23

(23) The method of claim 20 wherein repeatedly updating the state further includes: updating the state according to accepted measurements from inertial sensors.

See supra claims 1, 20. Facebook encourages, directs, or promotes users to use the Accused Products to perform the method of claim 20 in which repeatedly updating the state further includes updating the state according to accepted measurements from inertial sensors. For example, the headset in the Accused Products receives and accepts measurement data from the IMUs within the headset and/or the IMUs within the Oculus controller(s), which are inertial sensors, and updates the estimated position and orientation of the user's head, hand(s), and/or the Oculus controller(s) according to the accepted measurements. The Accused Products are especially adapted to carry out this method, which is a material part of the claimed invention, and have no substantial noninfringing uses. Further, Facebook conditions a user's use of the Accused Products, and therefore the user's receipt of the benefits of the Accused Products, upon this method and establishes the manner or timing of that use.

See, e.g., Oculus Quest.






oculus quest

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- 
Easy Setup
 Set up effortlessly whether you're at home or someplace new.**
- 
Oculus Insight Tracking
 Built-in sensors translate your movements into VR and provide room-scale tracking.
- 
Oculus Touch Controllers
 Your hands and gestures appear in VR with intuitive, realistic precision.

See also Oculus Quest Features.



OCULUS INSIGHT TRACKING

Make your move.

Oculus Insight translates your movements into VR no matter which way you're facing and provides room-scale tracking without external sensors. Look around, duck for cover and turn the tide of the battle from anywhere in your playspace.

See, e.g., Hand Tracking.

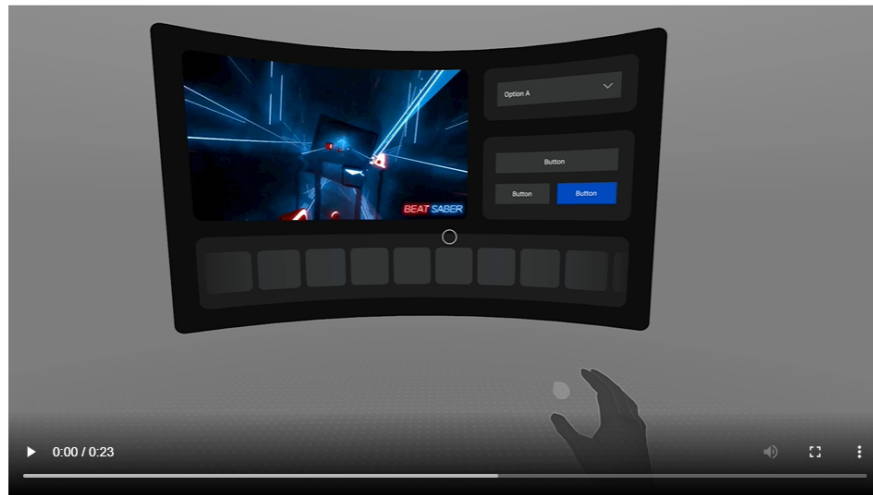
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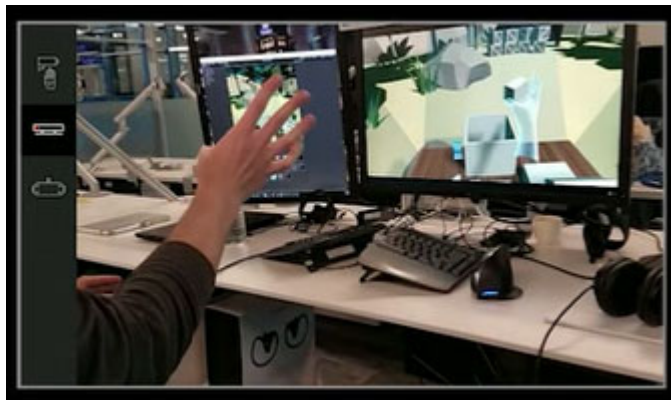
Designing for Hands



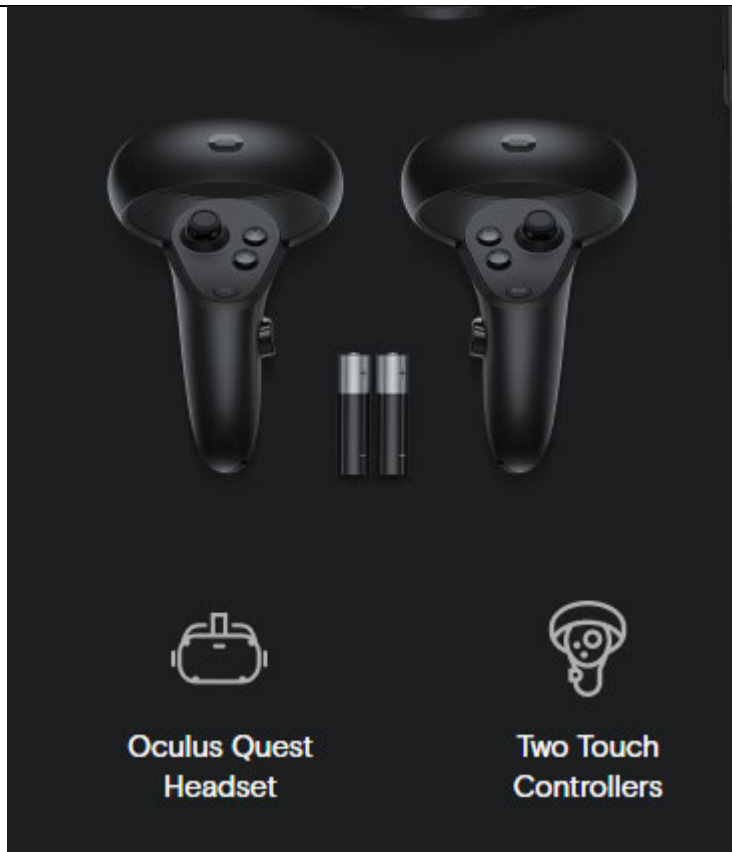
See also Hand Tracking Deep Dive at 4:00–10:00.



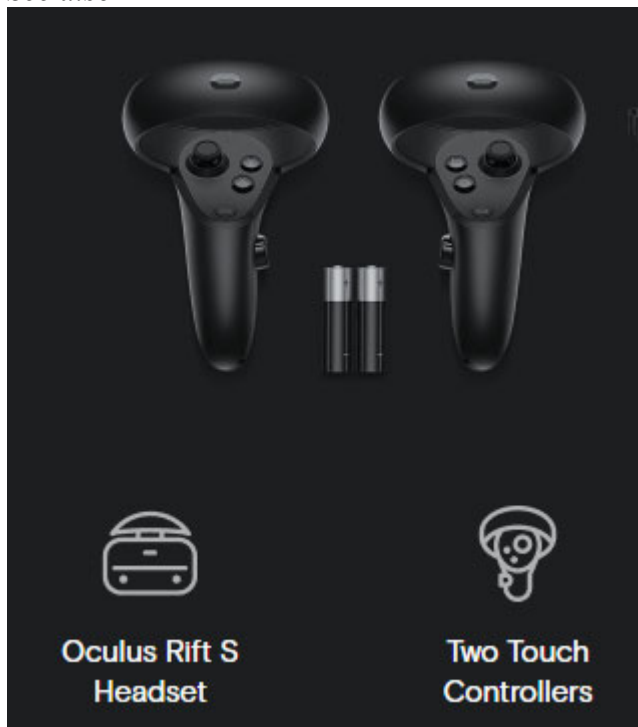
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See also Oculus Quest.



See also Oculus Rift S.



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The foundation of Oculus Insight's inside-out tracking is [simultaneous localization and mapping, or SLAM](#), which uses computer vision CV algorithms to essentially fuse incoming data from multiple sensors in order to fix the position of an object within a constantly updated digital map. SLAM has been used in robotics and in [AR camera effects](#) on smartphones and was demoed in the Oculus [Santa Cruz VR headset prototype](#) in 2016. But Oculus Insight required an unprecedented level of precision and efficiency, and that meant adapting the latest research on tracking and computer vision.

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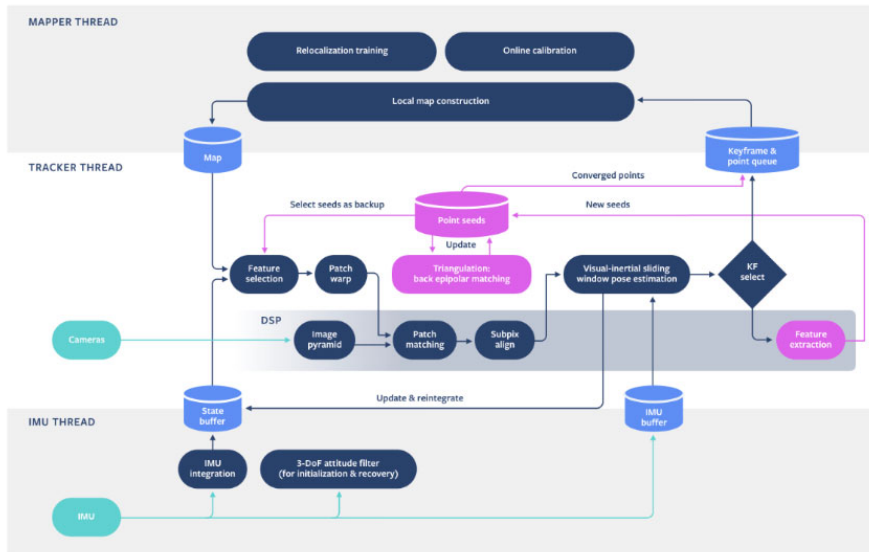
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Another major factor to avoid in delivering immersive experiences is latency — any lag between physical movements and their VR equivalents can disorient the user and degrade the sense of realism. By using low-latency IMU data and a kinematic model that predicts a user's motion into the future, Insight is able to effectively eliminate the apparent latency. We'll go into more detail in the next section about the sensor fusion process that incorporates SLAM data, but reducing both jitter and latency is central to Insight's ability to deliver a new level of realism within VR.

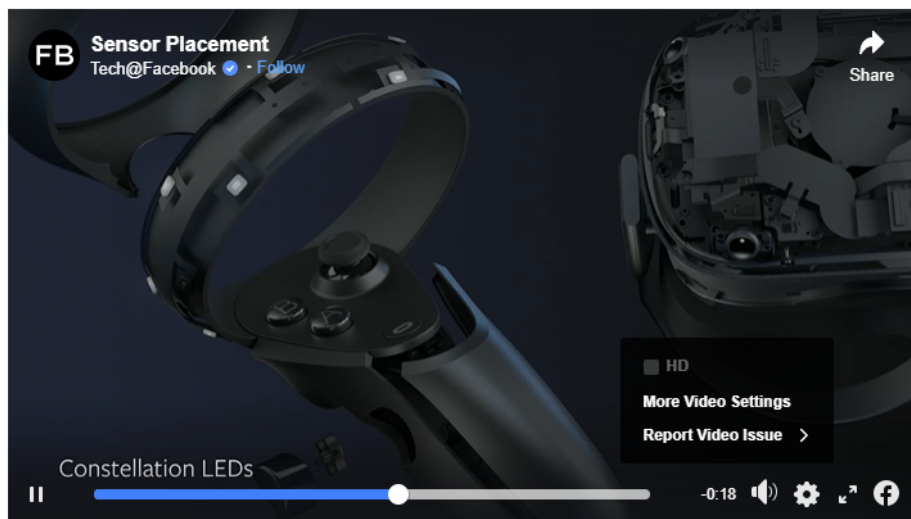
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More Precise Tracking

A function for infrared LED calibration exists, suggesting this controller is optically tracked in the same way as the current Touch— cameras on the headset follow the movement of the LED constellation, and this is fused with the accelerometer readings to achieve sub-mm precision.



Facebook's VR controllers are tracked via infrared LEDs under the plastic

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The IMU in the current Touch controllers for Rift S and Quest

See also ICM-20601 Specification.

Claim 24

(24) The method of claim 1 wherein updating the state estimate includes applying a Kalman Filter approach.

See supra claim 1. Facebook encourages, directs, or promotes users to use the Accused Products to perform the method of claim 1 in which updating the state estimate includes applying a Kalman Filter approach, and Facebook performs such step itself. For example, on information and belief and subject to discovery which has not yet occurred, the Oculus Insight tracking system in the Accused Products uses a Kalman filter approach to update the estimated positions and orientations of objects (e.g., the user's head, the user's hand(s), and/or the Oculus controller(s)). The Accused Products are especially adapted to carry out this method, which is a material part of the claimed invention, and have no substantial noninfringing uses. Further, Facebook conditions a user's use of the Accused Products, and therefore the user's receipt of the benefits of the Accused Products, upon this method and establishes the manner or timing of that use.

To the extent this limitation is not met literally, the Accused Products also satisfy this limitation under the doctrine of equivalents. Any difference between the Accused Products and the claim element is insubstantial.

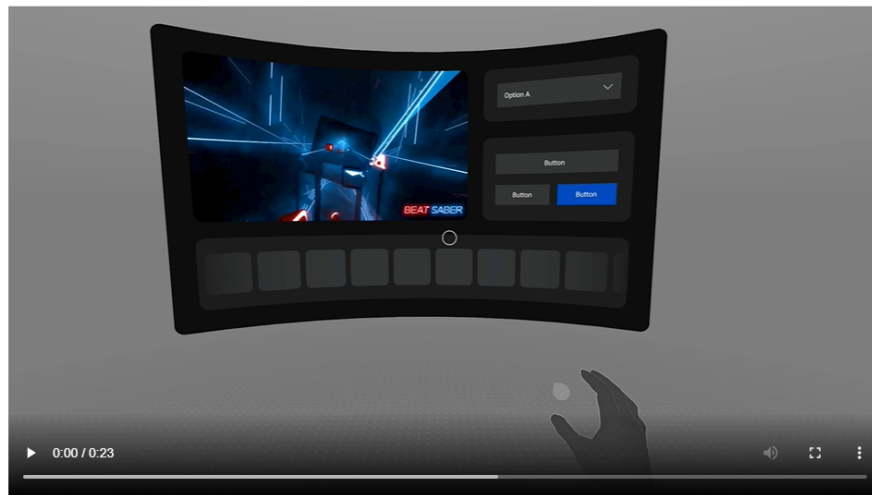
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See also Designing for Hands.
Designing for Hands



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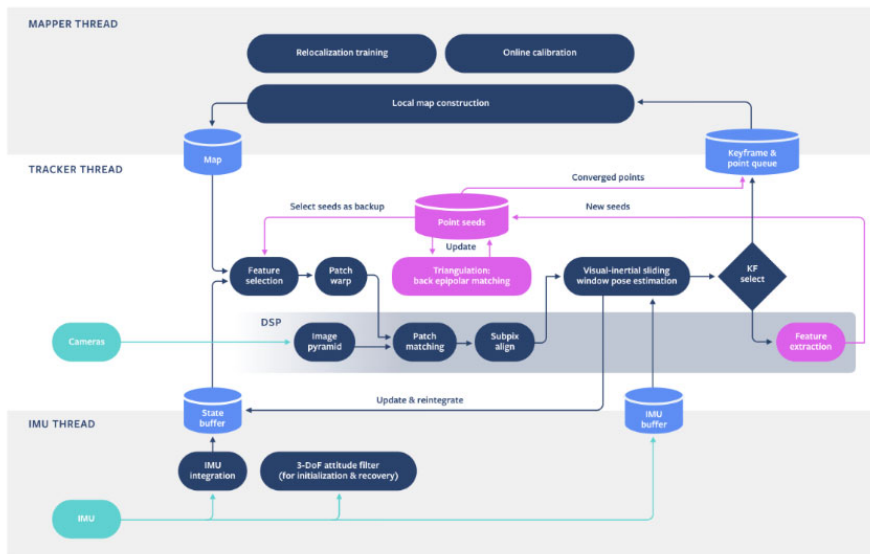
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Facebook's VR controllers are tracked via infrared LEDs under the plastic

Claim 25

(25) The method of claim 1 wherein each of said sensing elements comprises at least one of a sensor and a target.

See supra claim 1. Facebook encourages, directs, or promotes users to use the Accused Products to perform the method of claim 1 in which each of said sensing elements comprises at least one of a sensor and a target, and Facebook performs such step itself. For example, the set of sensing elements in the Accused Products comprises at least one sensor (e.g., cameras and/or IMUs within the HMD, and/or the IMUs within the Oculus controllers) and at least one target (e.g., the user's head, the user's hand(s), the Oculus controller(s), and/or objects in the environment).

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See also Oculus Rift S.

Is your PC VR Ready?

Your PC is the engine that powers Oculus Rift S. Show off the true potential of high-performance VR gameplay with our recommended level of hardware.

See also Hand Tracking.

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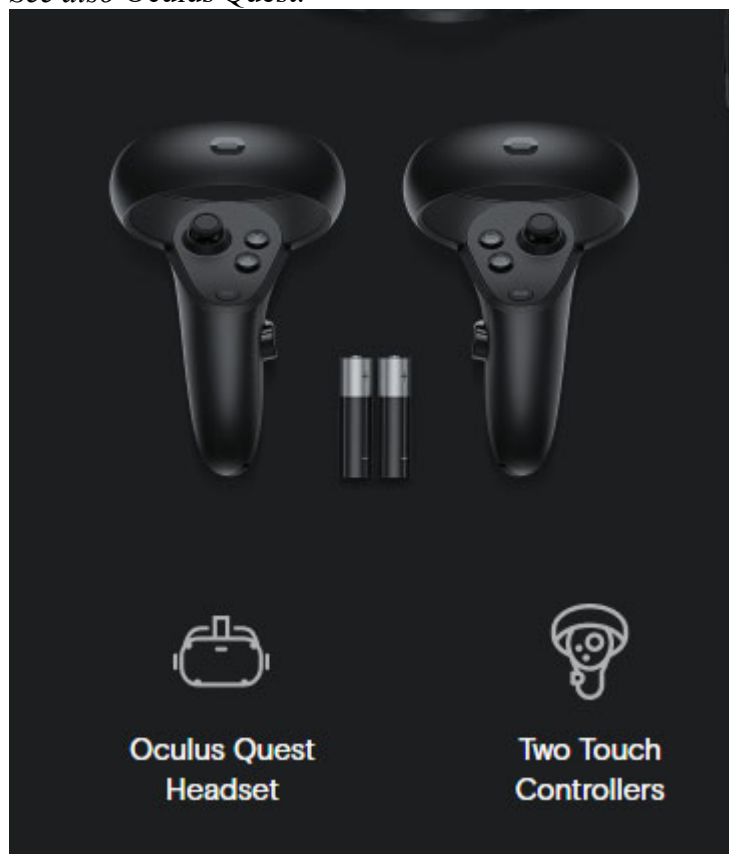
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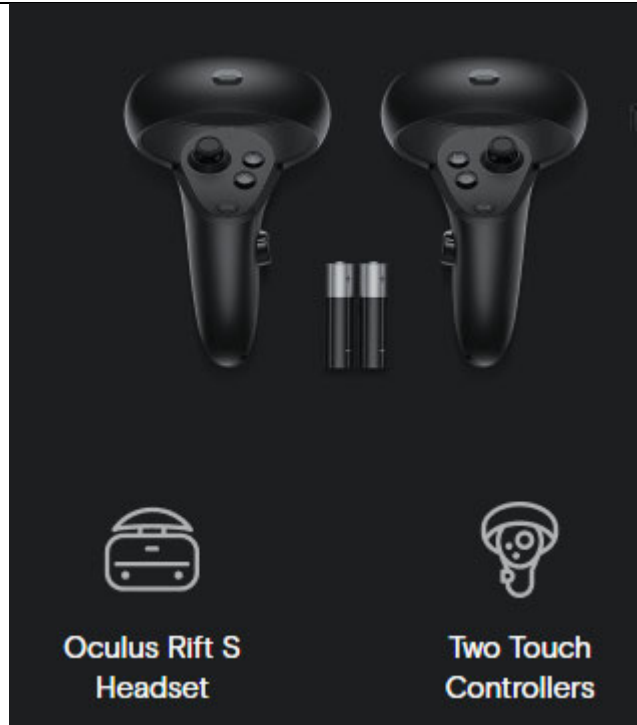
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See also Oculus Rift S.



See also Powered by AI.

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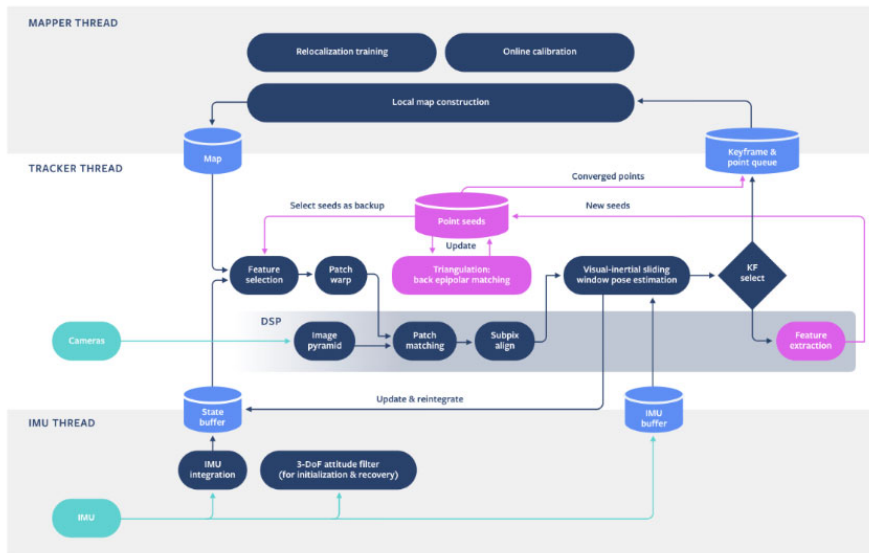
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Claim 26

(26) The method of claim 25 wherein the target comprises an active device that interacts with the sensor.

See supra claims 1, 25. Facebook encourages, directs, or promotes users to use the Accused Products to perform the method of claim 25 in which the target comprises an active device that interacts with the sensor. For example, the set of sensing elements in the Accused Products comprises a target (e.g., the Oculus controller(s)) that comprises an active device that interacts with the sensor (e.g., the cameras and/or IMUs within the headset and/or the IMUs within the Oculus controller(s)). The Accused Products are especially adapted to carry out this method, which is a material part of the claimed invention, and have no substantial noninfringing uses. Further, Facebook conditions a user's use of the Accused Products, and therefore the user's receipt of the benefits of the Accused Products, upon this method and establishes the manner or timing of that use.

See, e.g., From the Lab.

There are other complications, too. The infrared LEDs in the two hand controllers drastically change appearance when they move closer or farther away from the headset as you swing a virtual sword or maneuver a virtual spaceship. Oculus Insight also uses other sensors, drawing acceleration and velocity data from the inertial measurement units (IMUs) located in the headset and controllers. The system must process all of these data points in real time and, in the case of Quest, on a mobile chipset.

See also Oculus Rift S.

Is your PC VR Ready?

Your PC is the engine that powers Oculus Rift S. Show off the true potential of high-performance VR gameplay with our recommended level of hardware.

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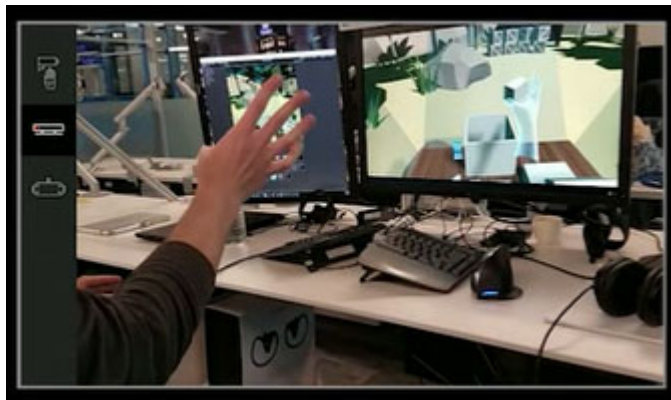
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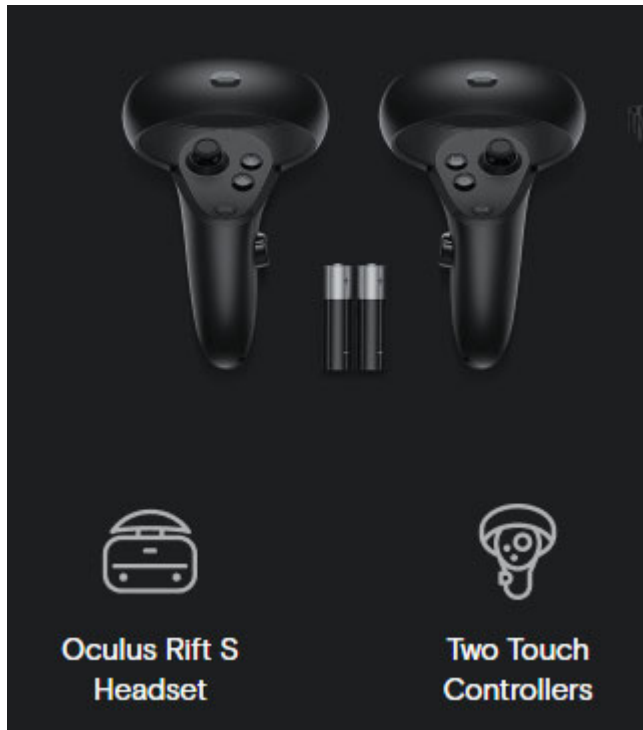
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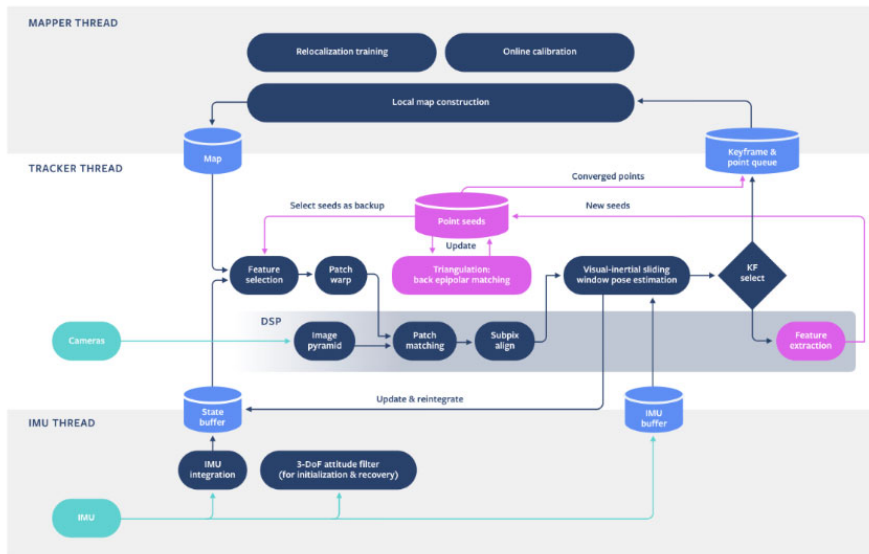
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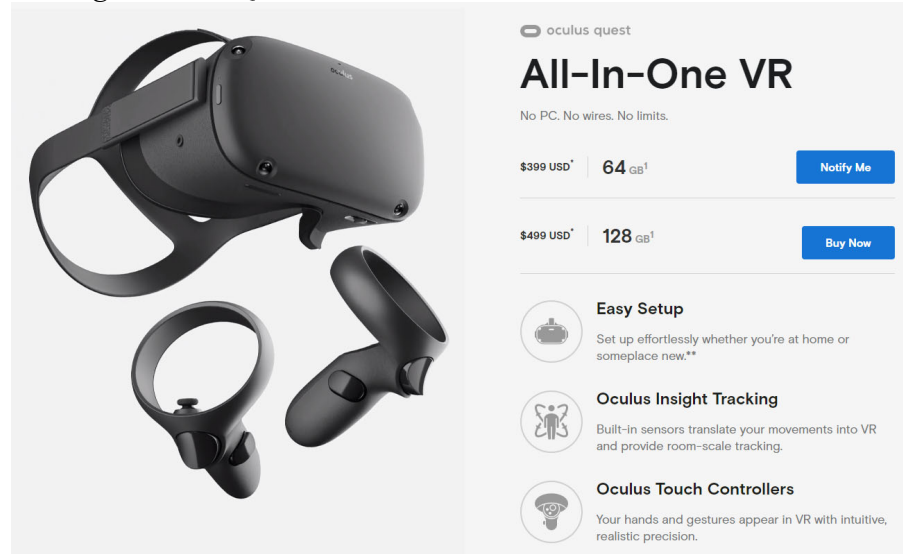


Claim 28

(28) The method of claim 1 wherein the object is selected from a group consisting of a vehicle, a robot, a person, a part of a person, a flying object, a floating object, an underwater moving object, an animal, a camera, a sensing apparatus, a helmet, a tool, a piece of sports equipment, a shoe, a boot, an article of clothing, a personal protective equipment, a rigid object having a dimension between 1 nanometer to 109 meters.

See supra claim 1. Facebook encourages, directs, or promotes users to use the Accused Products to perform the method of claim 1 in which the object is a part of a person (e.g., the user's head and/or hand(s) or part of the hand(s)) or a tool or rigid object (e.g., the Oculus controller(s)), and Facebook performs such step itself. The Accused Products are especially adapted to carry out this method, which is a material part of the claimed invention, and have no substantial noninfringing uses. Further, Facebook conditions a user's use of the Accused Products, and therefore the user's receipt of the benefits of the Accused Products, upon this method and establishes the manner or timing of that use.

See, e.g., Oculus Quest.



The screenshot displays the Oculus Quest product page. On the left, there is a high-quality image of the Oculus Quest VR headset and its two Touch controllers. On the right, the page features the following content: the Oculus Quest logo, the headline "All-In-One VR", the tagline "No PC. No wires. No limits.", two pricing options: "\$399 USD* | 64 GB¹" with a "Notify Me" button, and "\$499 USD* | 128 GB¹" with a "Buy Now" button. Below the pricing, there are three feature highlights: "Easy Setup" (Set up effortlessly whether you're at home or someplace new**), "Oculus Insight Tracking" (Built-in sensors translate your movements into VR and provide room-scale tracking), and "Oculus Touch Controllers" (Your hands and gestures appear in VR with intuitive, realistic precision).

See also Oculus Quest Features.



The screenshot shows the Oculus Insight Tracking feature page. On the left, the text reads: "OCULUS INSIGHT TRACKING", "Make your move.", and "Oculus Insight translates your movements into VR no matter which way you're facing and provides room-scale tracking without external sensors. Look around, duck for cover and turn the tide of the battle from anywhere in your playspace." On the right, there is a large image of the Oculus Quest VR headset with blue and purple light trails around it, illustrating the room-scale tracking feature.

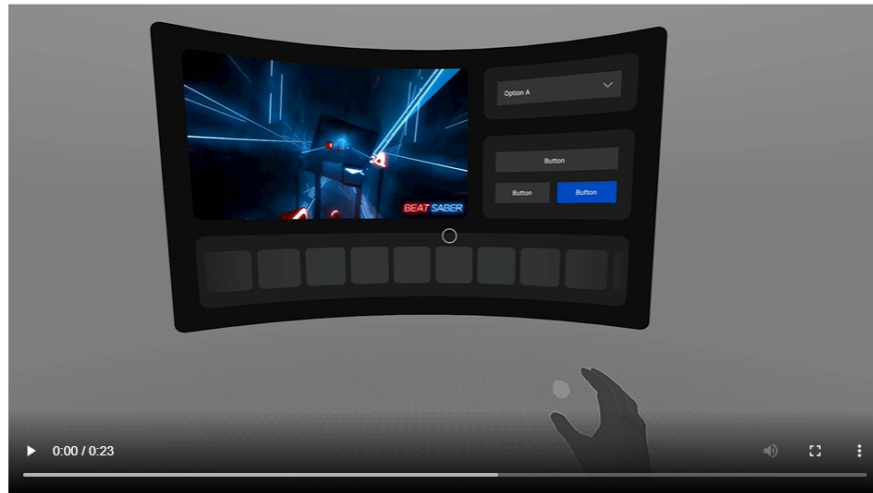
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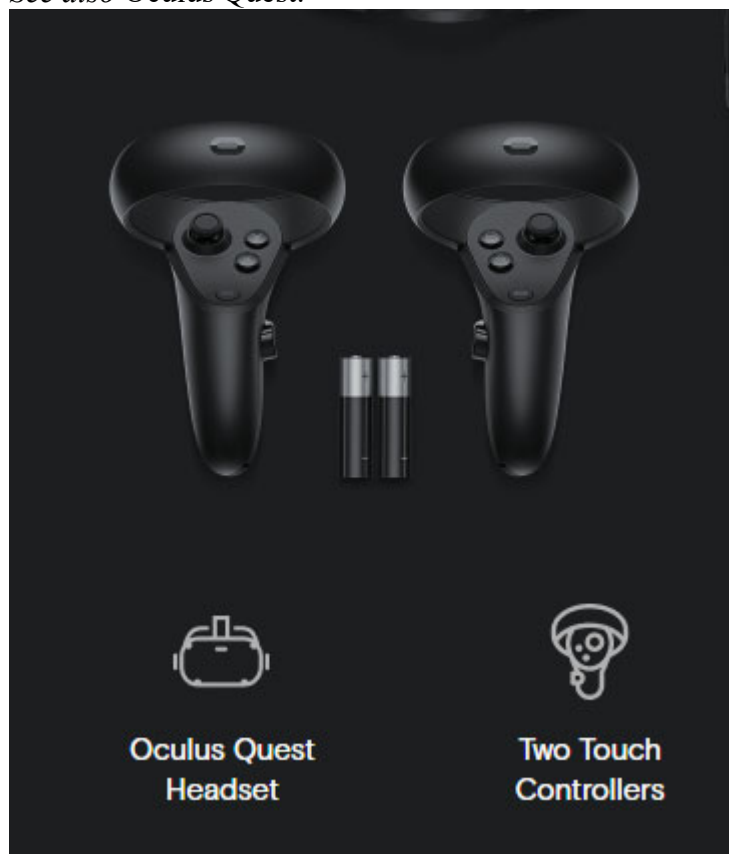
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See also id. at 4:00–10:00.



See also Oculus Quest.



See also Oculus Rift S.



Oculus Rift S
Headset

Two Touch
Controllers

See also From the Lab.

There are other complications, too. The infrared LEDs in the two hand controllers drastically change appearance when they move closer or farther away from the headset as you swing a virtual sword or maneuver a virtual spaceship. Oculus Insight also uses other sensors, drawing acceleration and velocity data from the inertial measurement units (IMUs) located in the headset and controllers. The system must process all of these data points in real time and, in the case of Quest, on a mobile chipset.

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Taking SLAM technology ...

The foundation of Oculus Insight's inside-out tracking is [simultaneous localization and mapping, or SLAM](#), which uses computer vision CV algorithms to essentially fuse incoming data from multiple sensors in order to fix the position of an object within a constantly updated digital map. SLAM has been used in robotics and in [AR camera effects](#) on smartphones and was demoed in the Oculus [Santa Cruz VR headset prototype](#) in 2016. But Oculus Insight required an unprecedented level of precision and efficiency, and that meant adapting the latest research on tracking and computer vision.

"A lot of these technologies really start in academia — inside the lab," Kozminski notes. It's no coincidence, then, that she's part of Facebook's Zurich-based team of engineers, many of whom came from [Zurich Eye](#) — a joint program from the prestigious [ETH University](#) and [University of Zurich](#) that researched self-navigating systems.

To build a new, more advanced version of SLAM, the engineering team drew from Facebook's years of AI research and engineering work, building systems to understand the objects and actions that appear in videos and creating highly efficient computer vision algorithms that work well on mobile devices.

See also Powered by AI.

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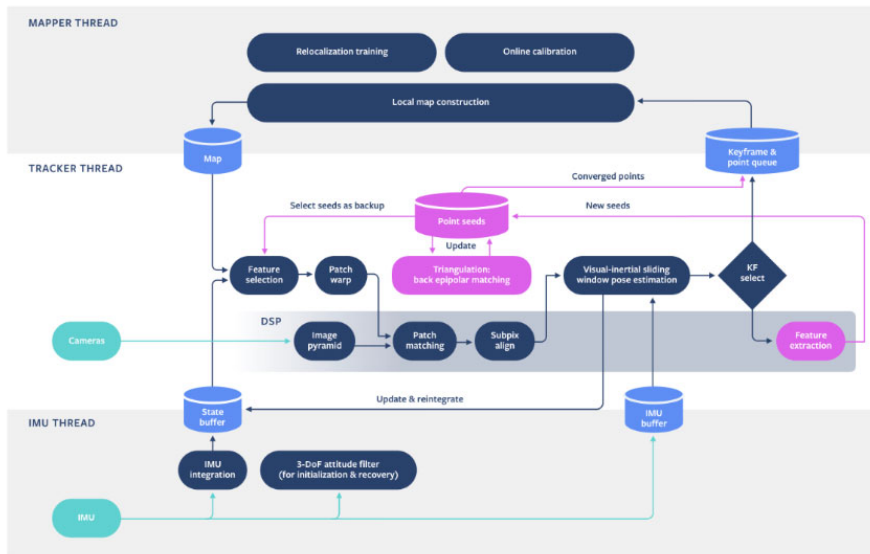
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Another major factor to avoid in delivering immersive experiences is latency — any lag between physical movements and their VR equivalents can disorient the user and degrade the sense of realism. By using low-latency IMU data and a kinematic model that predicts a user's motion into the future, Insight is able to effectively eliminate the apparent latency. We'll go into more detail in the next section about the sensor fusion process that incorporates SLAM data, but reducing both jitter and latency is central to Insight's ability to deliver a new level of realism within VR.

See also id.

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Claim 29

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oculus quest

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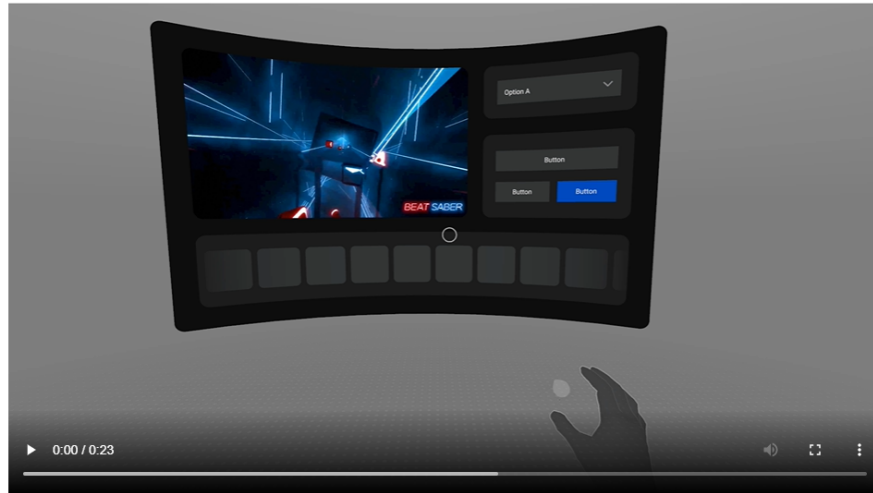
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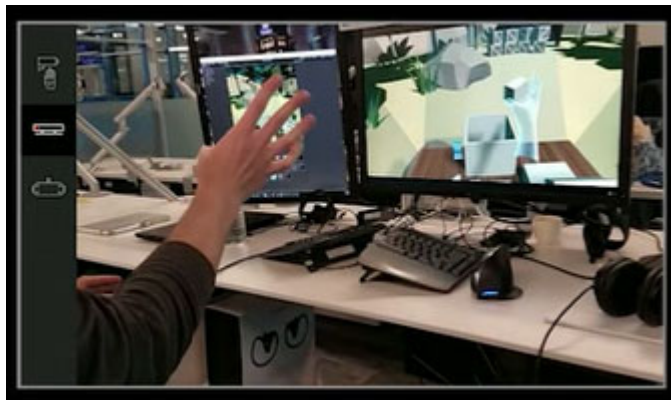
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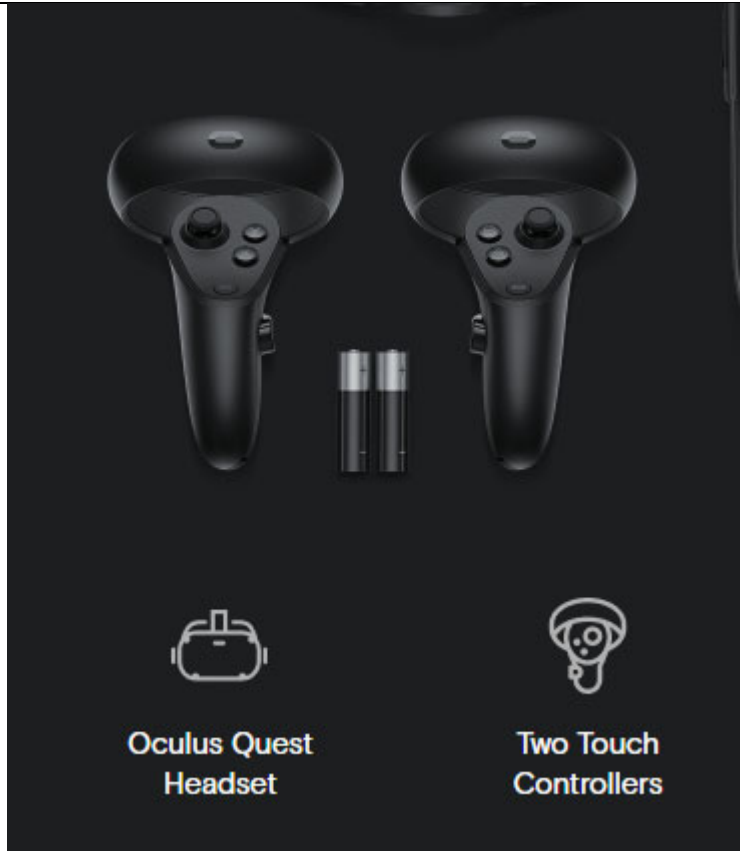
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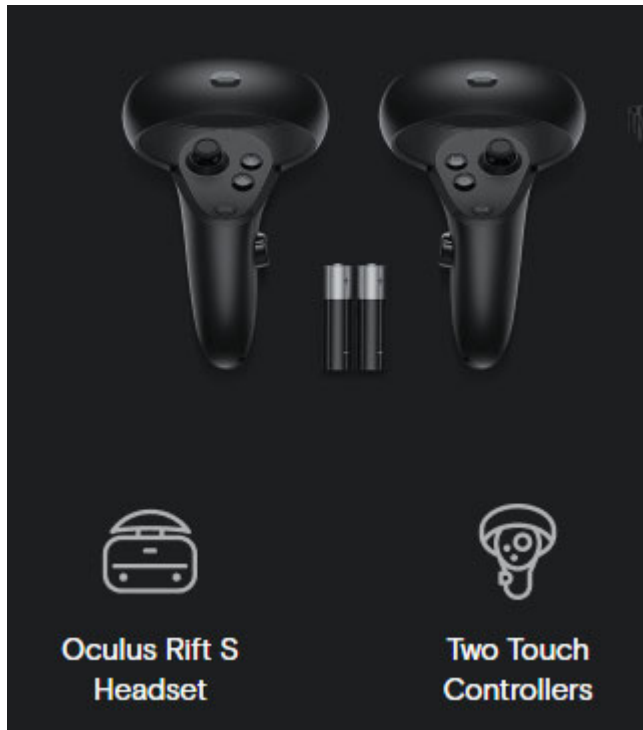
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"A lot of these technologies really start in academia — inside the lab," Kozminski notes. It's no coincidence, then, that she's part of Facebook's Zurich-based team of engineers, many of whom came from [Zurich Eye](#) — a joint program from the prestigious [ETH University](#) and [University of Zurich](#) that researched self-navigating systems.

To build a new, more advanced version of SLAM, the engineering team drew from Facebook's years of AI research and engineering work, building systems to understand the objects and actions that appear in videos and creating highly efficient computer vision algorithms that work well on mobile devices.

See also Powered by AI.

visually anchored to real objects in the world. Oculus Insight is the second generation of this library, and it incorporates significantly more information from a combination of multiple IMUs and ultra-wide-angle cameras, as well as infrared LEDs to jointly track the 6DoF position of a VR headset and controllers.

See also Powered by AI, Video.



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headset and controllers with respect to a 3D map that is generated and constantly updated by Insight. The data used for this process comes from three types of sensors built into the Quest and Rift S hardware:

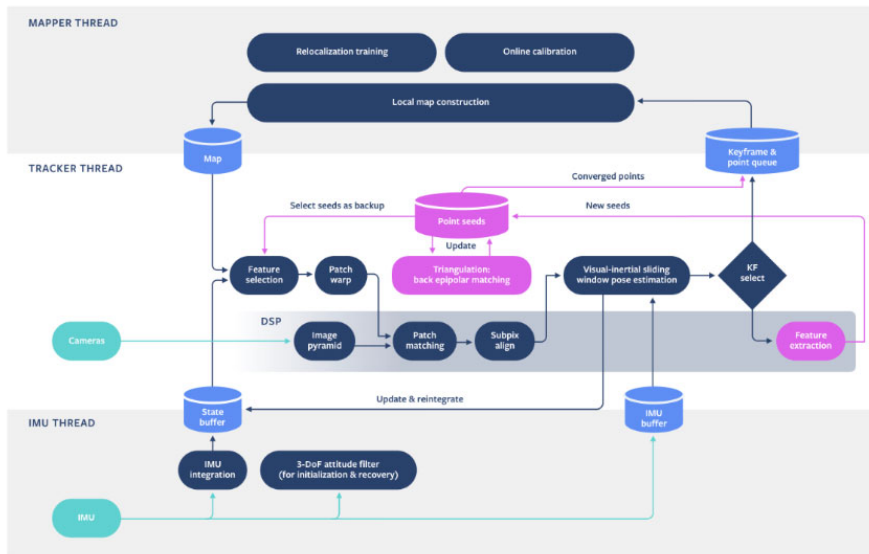
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3. Infrared LEDs in the controllers are detected by the headset cameras, letting the system bound the controller position drift caused by integrating multiple IMUs.

See also Powered by AI.

Another major factor to avoid in delivering immersive experiences is latency — any lag between physical movements and their VR equivalents can disorient the user and degrade the sense of realism. By using low-latency IMU data and a kinematic model that predicts a user's motion into the future, Insight is able to effectively eliminate the apparent latency. We'll go into more detail in the next section about the sensor fusion process that incorporates SLAM data, but reducing both jitter and latency is central to Insight's ability to deliver a new level of realism within VR.

See also id.

Headset tracking compute architecture



Oculus Insight processes multiple threads of data at once, in real-time — the mapper thread modifies the map, sending updated copies to the tracker thread, which uses camera frames to estimate poses in the mapper-provided frames, while the IMU thread uses measurements from the IMUs to update the latest SLAM state.

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Claim 30

(30pre) A sensor module comprising:

Facebook makes, uses, sells, and/or offers for sale in the United States, and/or imports into the United States, the Accused Products, which comprise a sensor module. For example, the Accused Products comprise software and hardware components (e.g., the headset and Oculus controller(s) and their associated software, including the Oculus Insight tracking system, and/or a computer or other external processor for the Oculus Rift S) that interact with a corresponding set of measurement sensors (e.g., cameras and/or IMUs within the headset, and/or the IMUs within the Oculus controllers).

Facebook encourages, directs, or promotes users to use the sensor module within the Accused Products (e.g., through its software and/or user instructions, which have not been provided at this stage of the litigation), and its users use the sensor module within the Accused Products. Facebook further provides or sells the Accused Products to third parties (e.g., distributors and retailers) and directs them to sell and/or offer for sale in the United States, or import the Accused Products into the United States. Facebook also makes, uses, sells, and/or offers for sale in the United States, and/or imports into the United States, components (e.g., Oculus controllers) that are especially made and adapted to be used with the Accused Products, are a material part of the claimed invention, and have no substantial noninfringing uses.

See, e.g., From the Lab.

There are other complications, too. The infrared LEDs in the two hand controllers drastically change appearance when they move closer or farther away from the headset as you swing a virtual sword or maneuver a virtual spaceship. Oculus Insight also uses other sensors, drawing acceleration and velocity data from the inertial measurement units (IMUs) located in the headset and controllers. The system must process all of these data points in real time and, in the case of Quest, on a mobile chipset.

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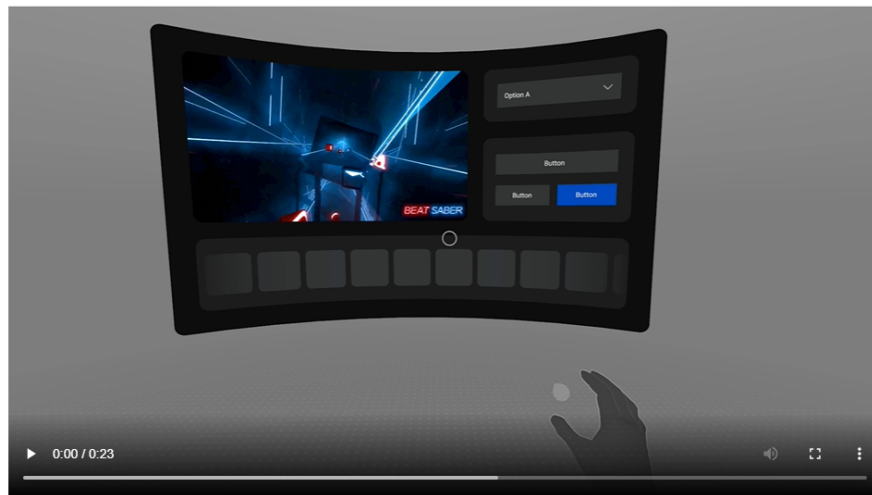
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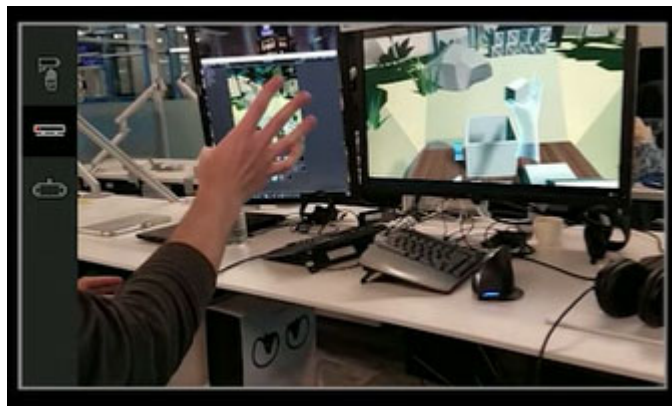
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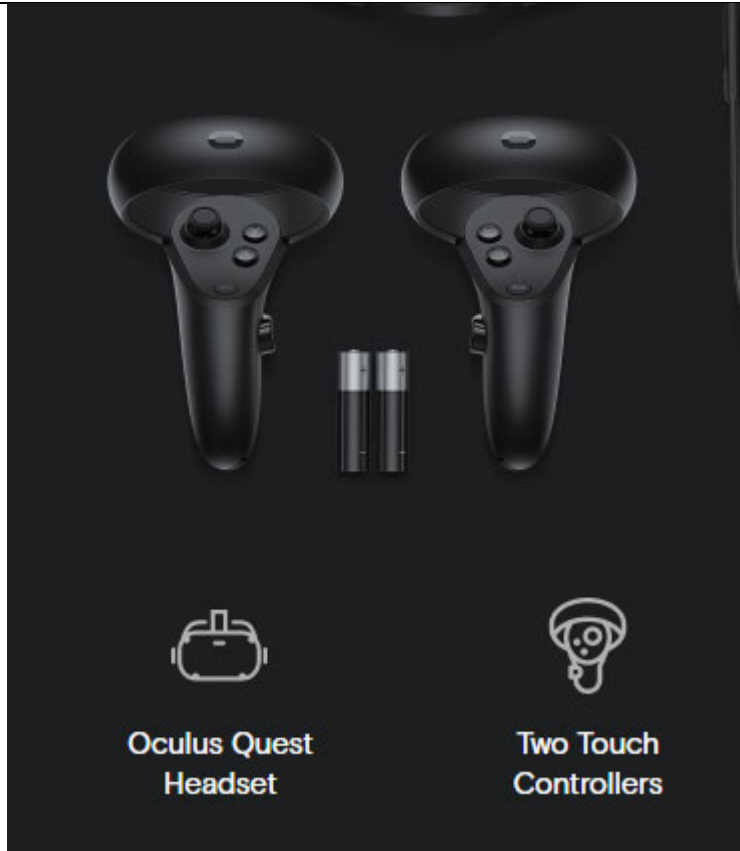
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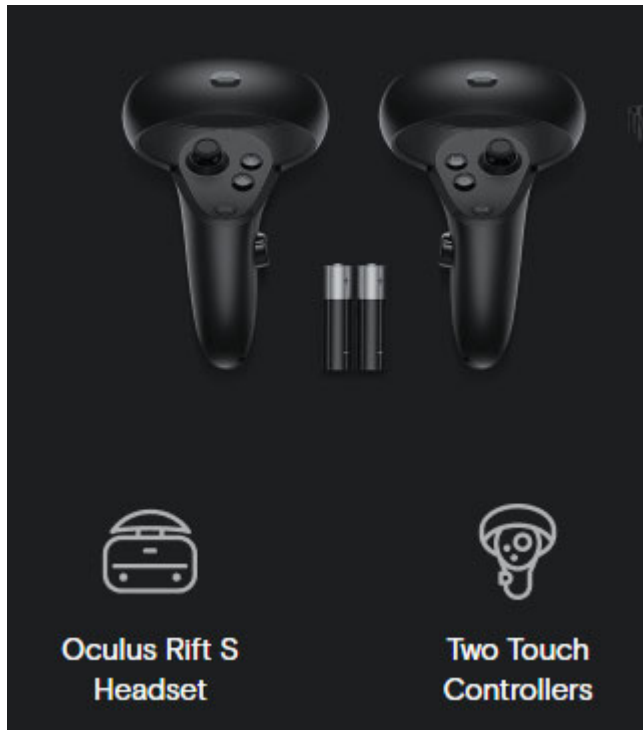
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The Oculus Insight system uses a custom hardware architecture and advanced computer vision algorithms — including visual-inertial mapping, place recognition, and geometry reconstruction — to establish the location of objects in relation to other objects within a given space. This novel algorithm stack enables a VR device to pinpoint its location, identify aspects of room geometry (such as floor location), and track the positions of the headset and controllers with respect to a 3D map that is generated and constantly updated by Insight. The data used for this process comes from three types of sensors built into the Quest and Rift S hardware:

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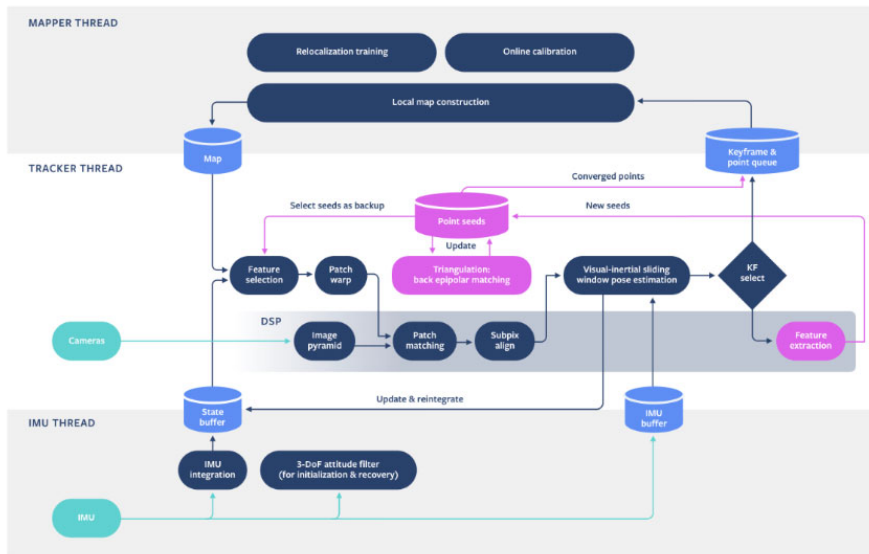
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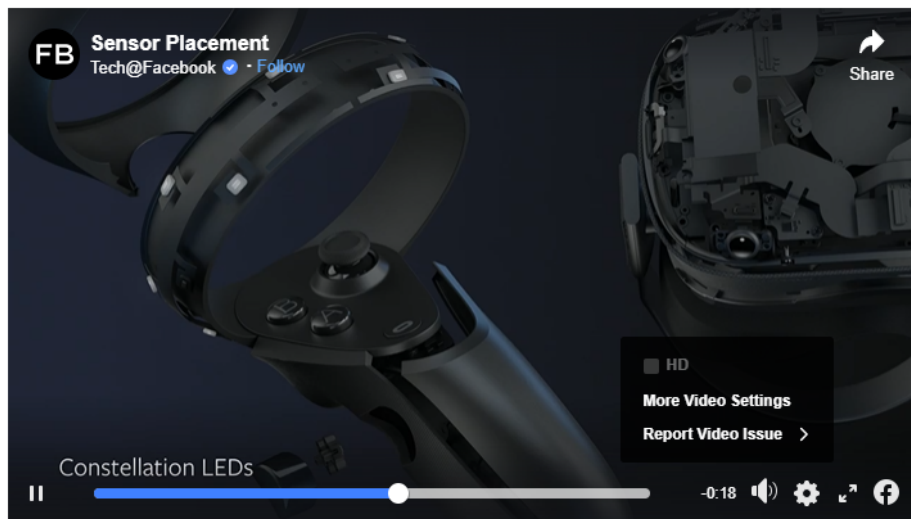
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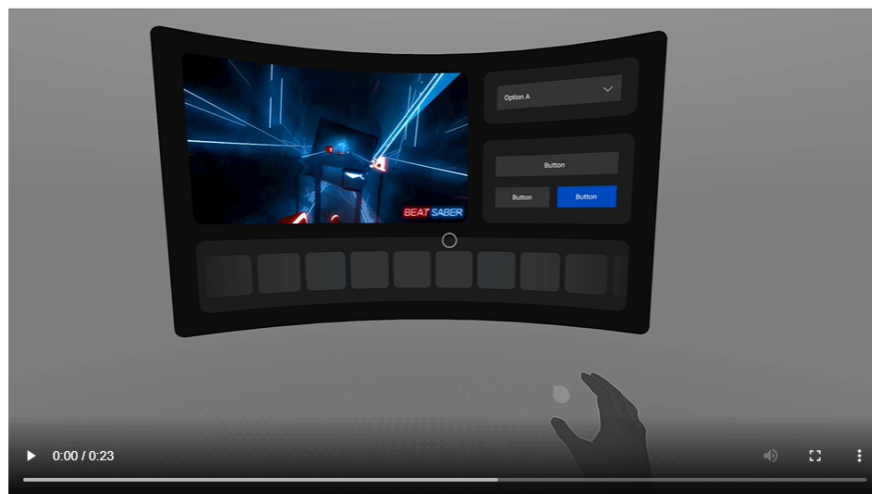
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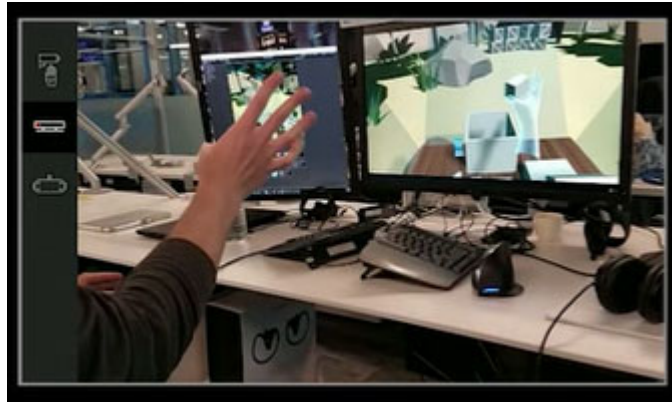
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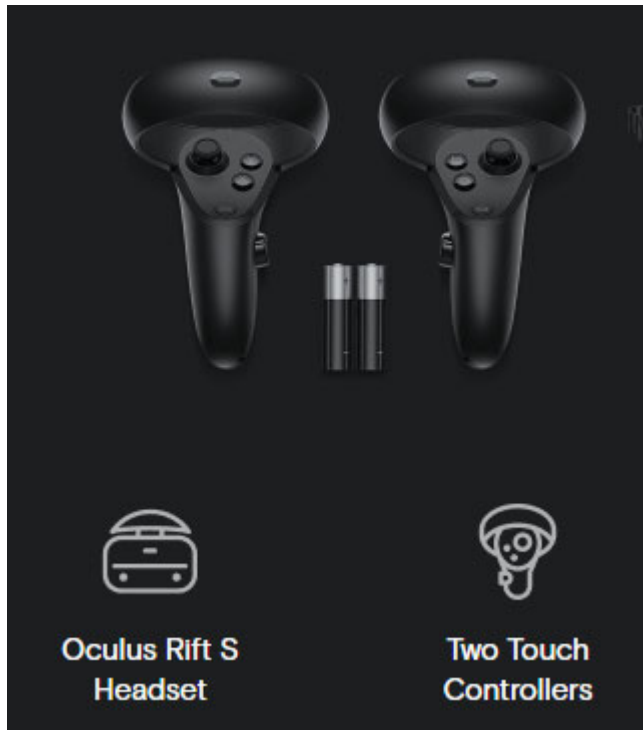
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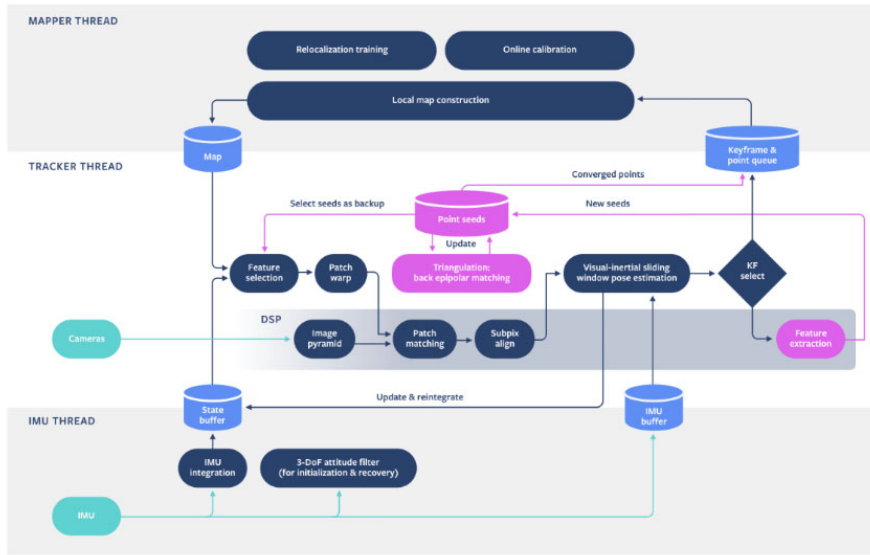
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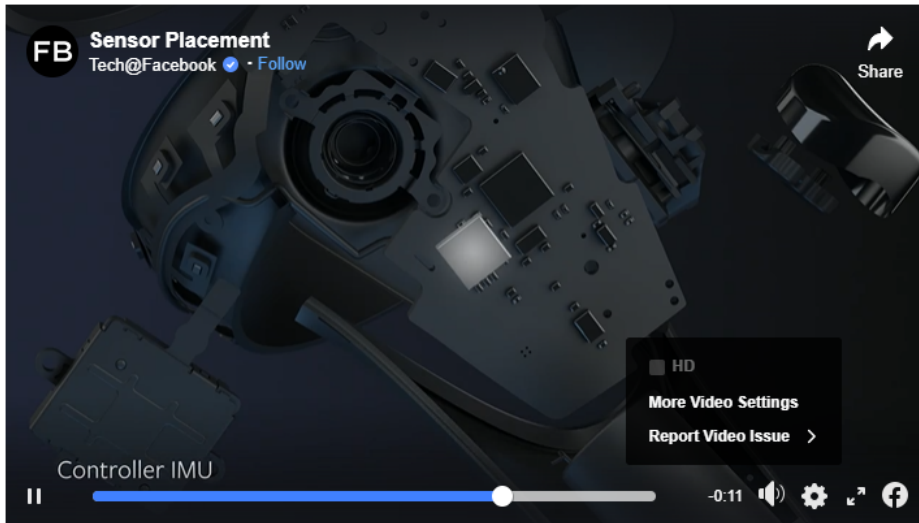


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See also [Oculus Quest](#).



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- Oculus Touch Controllers**
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See also [Oculus Rift S](#).



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The halo headband is redesigned with speed and comfort in mind.
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See also [Lang](#).



Image courtesy BadVR, Jad Meouchy

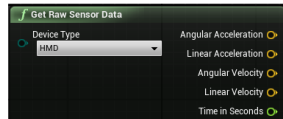
Around the mainboard we can also see the headset's four cameras mounted at very purposeful angles at the corners. The cameras are essential to enabling 6DOF tracking on both the headset and the controllers; their views are also merged together to allow a pass-through vision mode on the headset which is used to trace the boundary of your playspace.

See also Get Raw Sensor Data.

Overview

This blueprint reports raw sensor data from the headset, such as its angular acceleration or linear velocity. If the headset does not support a sensor data reading, then that result will return as zero.

Blueprint



See also Powered by AI.

Academic research has been done on SLAM techniques for several decades, but the technology has only recently become mature enough for consumer applications, such as driverless cars and mobile AR apps. Facebook previously released a version of [SLAM for AR on mobile devices](#) which uses a single camera and inertial measurement unit (IMU) to track a phone's position and enable world-locked content — content that's visually anchored to real objects in the world. Oculus Insight is the second generation of this library, and it incorporates significantly more information from a combination of multiple IMUs and ultra-wide-angle cameras, as well as infrared LEDs to jointly track the 6DoF position of a VR headset and controllers.

The Oculus Insight system uses a custom hardware architecture and advanced computer vision algorithms — including visual-inertial mapping, place recognition, and geometry reconstruction — to establish the location of objects in relation to other objects within a given space. This novel algorithm stack enables a VR device to pinpoint its location, identify aspects of room geometry (such as floor location), and track the positions of the headset and controllers with respect to a 3D map that is generated and constantly updated by Insight. The data used for this process comes from three types of sensors built into the Quest and Rift S hardware:

See also Powered by AI.

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1. Linear acceleration and rotational velocity data from IMUs in the headset and controllers are integrated to track the orientation and position of each with low latency.
2. Image data from cameras in the headset helps generate a 3D map of the room, pinpointing landmarks like the corners of furniture or the patterns on your floor. These landmarks are observed repeatedly, which enables Insight to compensate for drift (a common challenge with IMUs, where even tiny measurement discrepancies build up over time, resulting in inaccurate location tracking).
3. Infrared LEDs in the controllers are detected by the headset cameras, letting the system bound the controller position drift caused by integrating multiple IMUs.

See also id.

At last year's Oculus Connect event we shared some details about [Oculus Insight](#), the cutting-edge technology that powers both Quest and Rift S. Now that both of those products are available, we're providing a deeper look at the AI systems and techniques that power this VR technology. Oculus Insight marks the first time that fully untethered six-degree-of-freedom (6DoF) headset and controller tracking has shipped in a consumer AR/VR device. Built from the ground up, the Insight stack leverages state-of-the-art computer vision (CV) systems and visual-inertial simultaneous localization and mapping, or SLAM.

See also From the Lab.

"We wanted to create a system that lets you move and explore a VR world just as naturally and easily as you would in real life," says Kozminski.

Kozminski joined a team whose mission was to create the first full-featured "inside-out" tracking system for a consumer VR device. The technology would have to track the full range of a person's movements (known as six degrees of freedom) and be able to pinpoint the location of the two handheld controllers as well as the headset.

Previously, VR devices relied on external sensors to track these movements. These cameras attach to a PC, and while they work well, they make VR less portable and more complicated to set up.

"With inside-out tracking in the headset, VR becomes as easy as putting on headphones to listen to music," says Kozminski.

See also id.

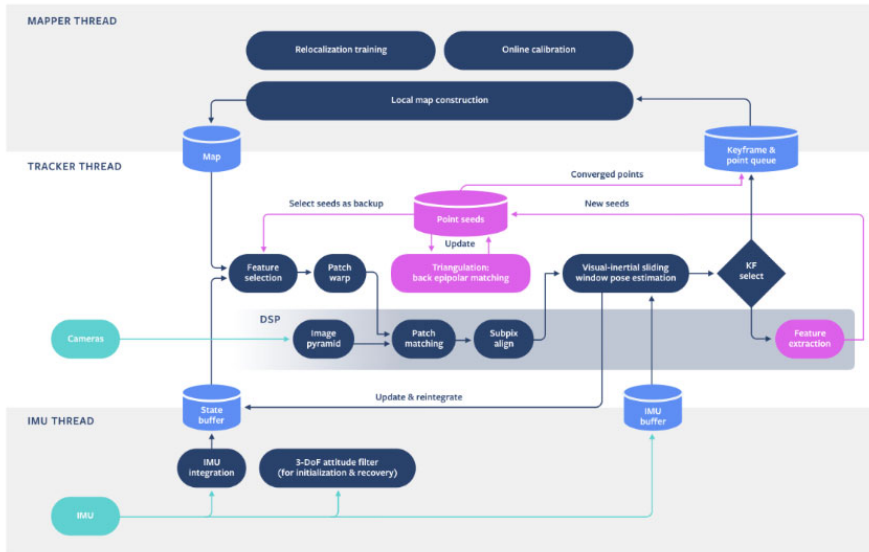
There are other complications, too. The infrared LEDs in the two hand controllers drastically change appearance when they move closer or farther away from the headset as you swing a virtual sword or maneuver a virtual spaceship. Oculus Insight also uses other sensors, drawing acceleration and velocity data from the inertial measurement units (IMUs) located in the headset and controllers. The system must process all of these data points in real time and, in the case of Quest, on a mobile chipset.

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Facebook's VR controllers are tracked via infrared LEDs under the plastic

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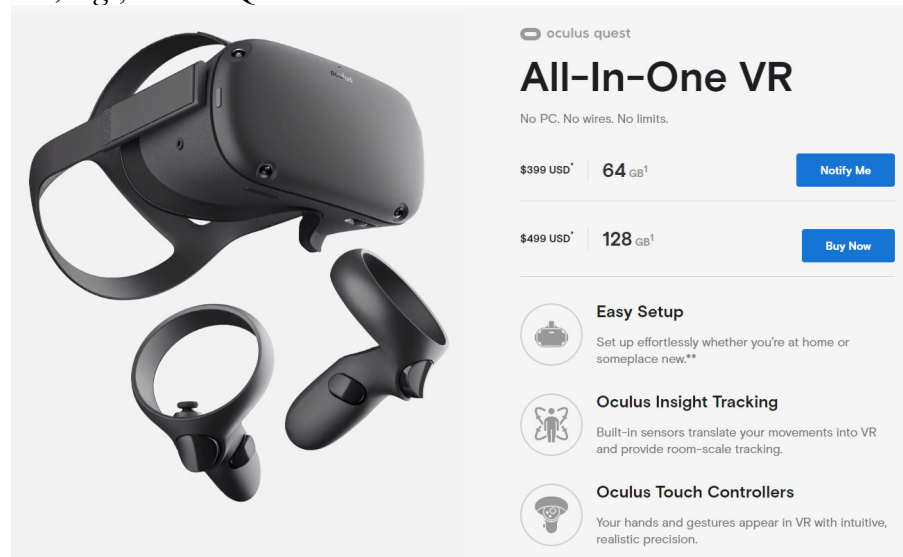
FEATURES

- 3-Axis Gyroscope with Programmable FSR of $\pm 500\text{dps}$, $\pm 100\text{dps}$, $\pm 2000\text{dps}$ and $\pm 4000\text{dps}$
- 3-Axis Accelerometer with Programmable FSR of $\pm 4g$, $\pm 8g$, $\pm 16g$, and $\pm 32g$
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- Wake-on-motion interrupt for low power operation of applications processor
- 512 byte FIFO buffer enables the applications processor to read the data in bursts
- On-Chip 16-bit ADCs and Programmable Filters
- Host interface: 8 MHz SPI or 400k Hz Fast Mode I²C
- Digital-output temperature sensor
- VDD operating range of 1.71 to 3.45V
- MEMS structure hermetically sealed and bonded at wafer level
- RoHS and Green compliant

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See, e.g., Oculus Quest.



The screenshot shows the Oculus Quest product page. On the left is a high-quality image of the Oculus Quest headset and two Touch controllers. On the right, the text reads "oculus quest" at the top, followed by "All-In-One VR" in a large font. Below this, it says "No PC. No wires. No limits." There are two pricing options: "\$399 USD* 64 GB¹" with a "Notify Me" button, and "\$499 USD* 128 GB¹" with a "Buy Now" button. Below the pricing are three feature highlights: "Easy Setup" (Set up effortlessly whether you're at home or someplace new**), "Oculus Insight Tracking" (Built-in sensors translate your movements into VR and provide room-scale tracking), and "Oculus Touch Controllers" (Your hands and gestures appear in VR with intuitive, realistic precision).

See also Oculus Quest Features.



The screenshot shows the Oculus Insight Tracking feature page. The text reads "OCULUS INSIGHT TRACKING" at the top, followed by "Make your move." in a large font. Below this, it says "Oculus Insight translates your movements into VR no matter which way you're facing and provides room-scale tracking without external sensors. Look around, duck for cover and turn the tide of the battle from anywhere in your playspace." On the right is a high-quality image of the Oculus Quest headset with purple and blue light trails around it, illustrating the tracking feature.

See, e.g., Hand Tracking.

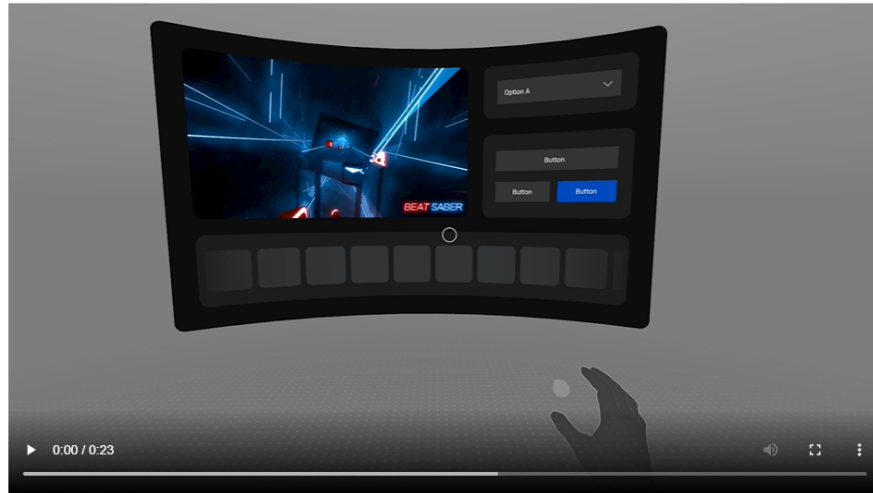
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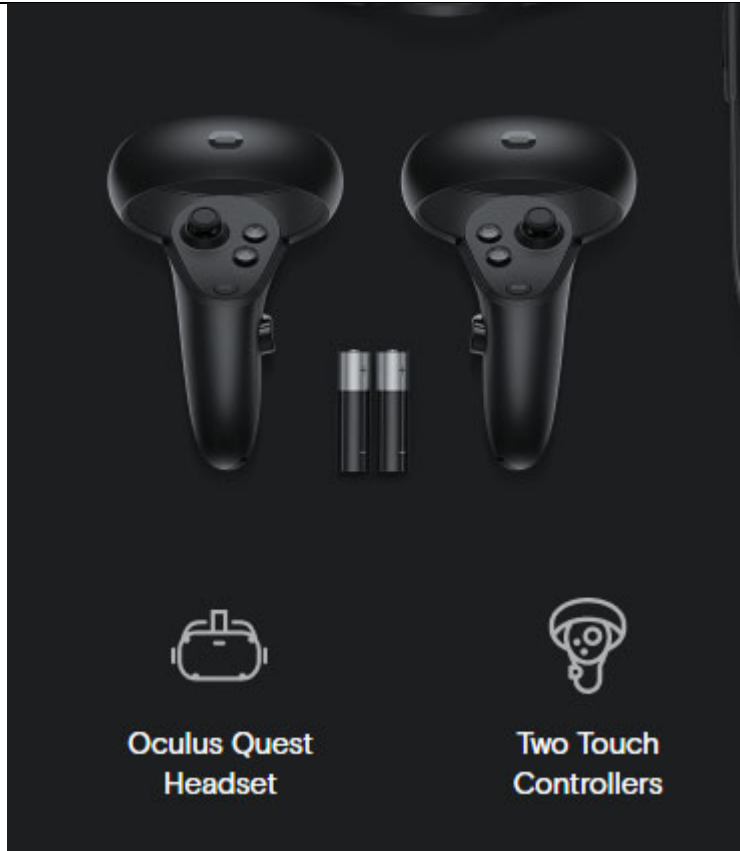
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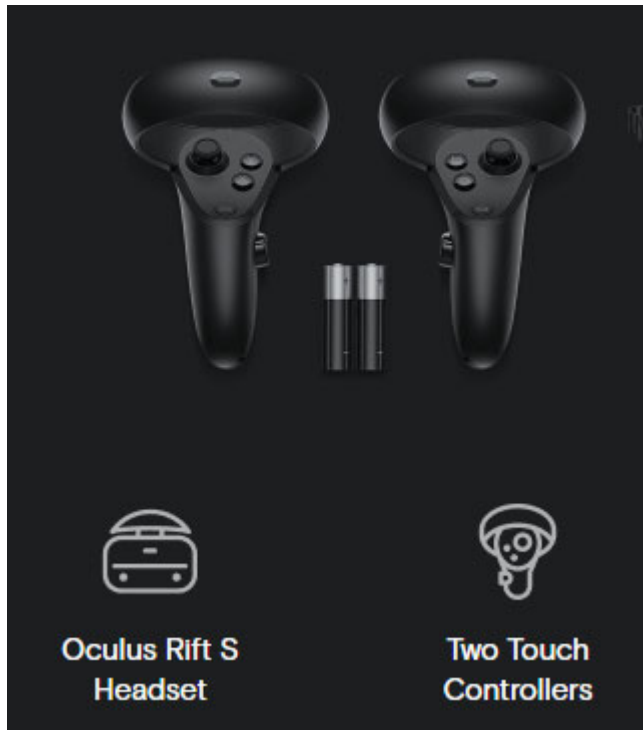
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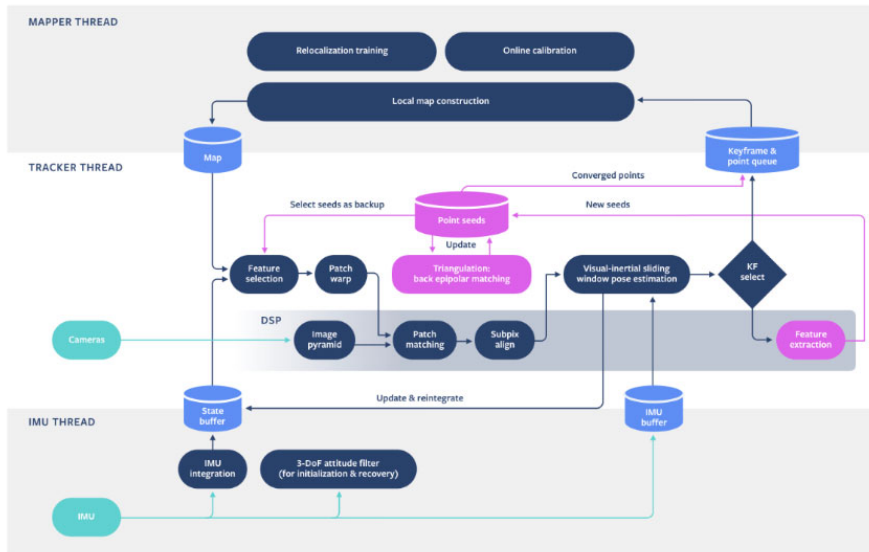
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See also *id.*

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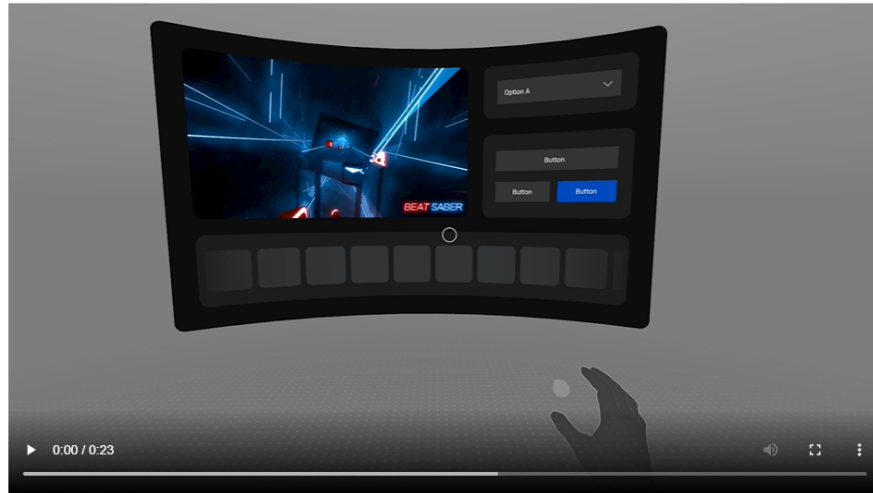
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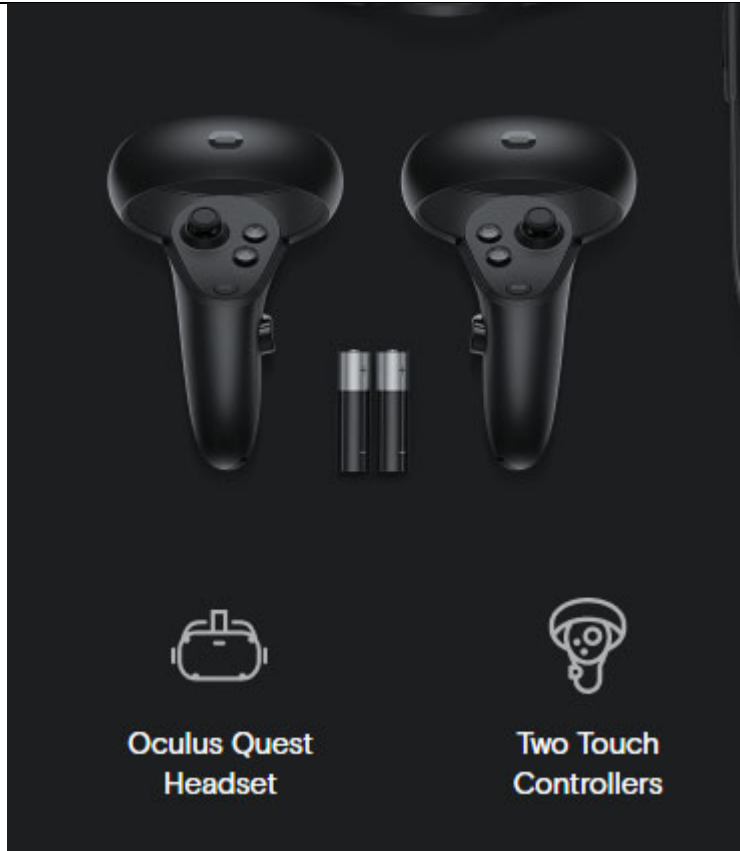
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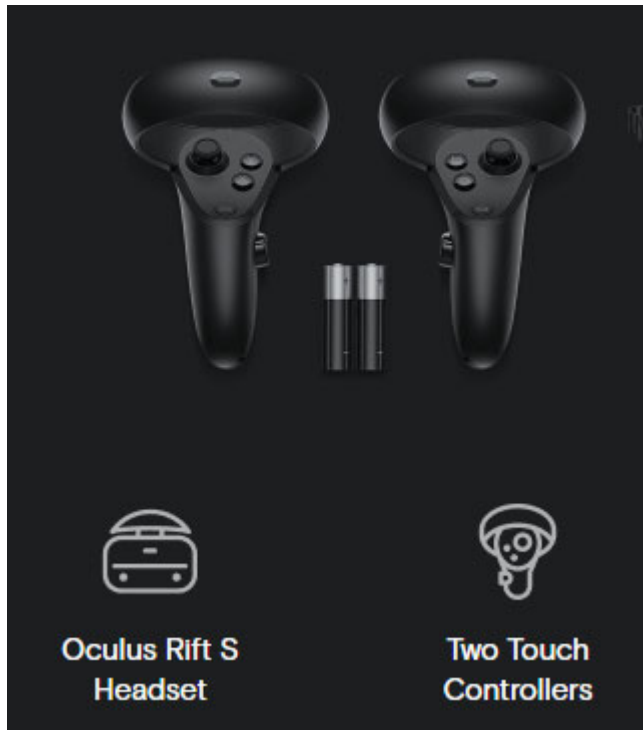
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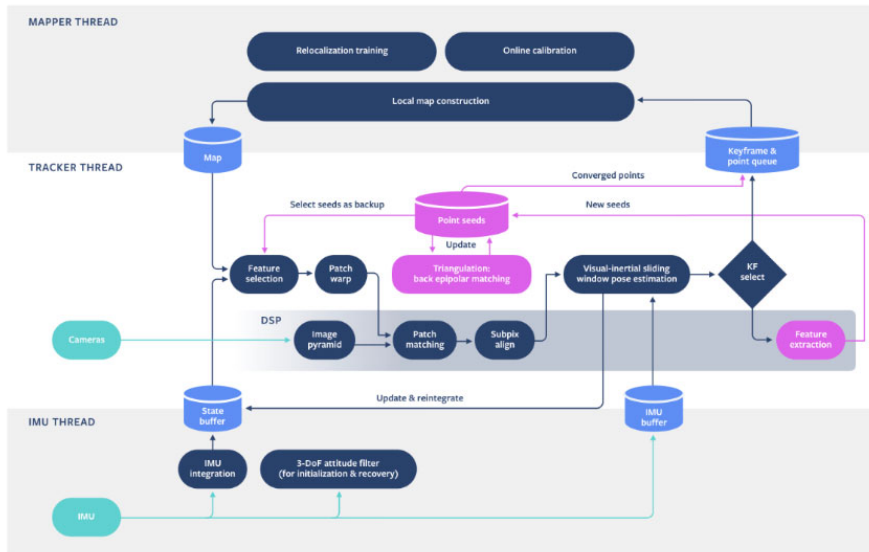
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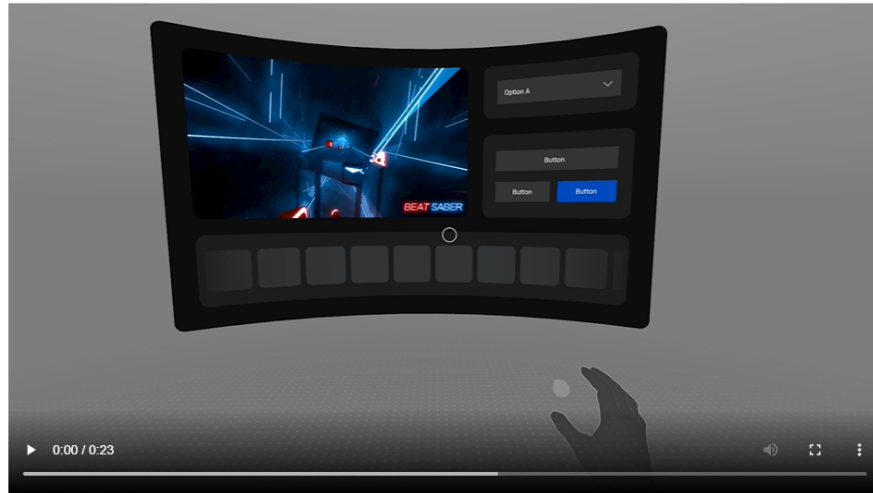
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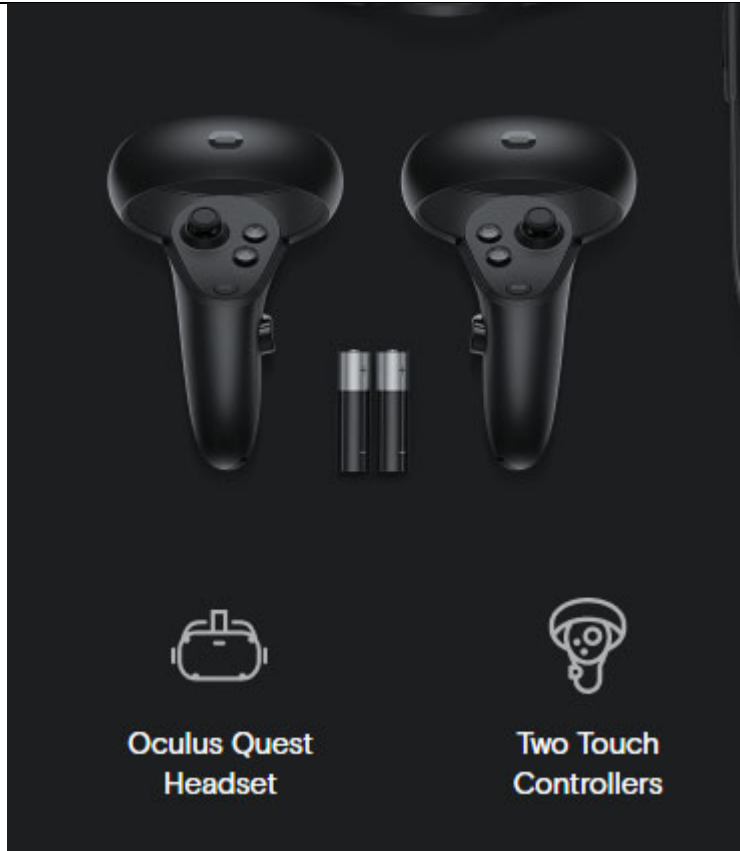
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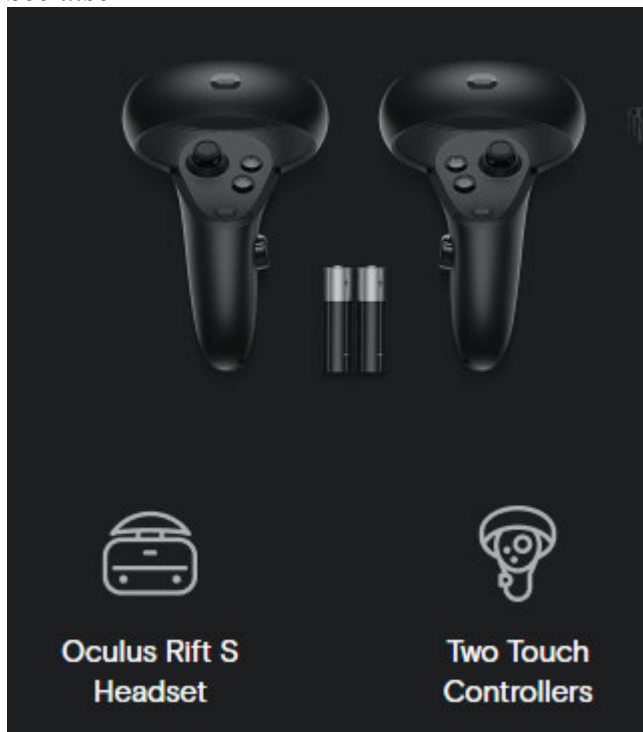
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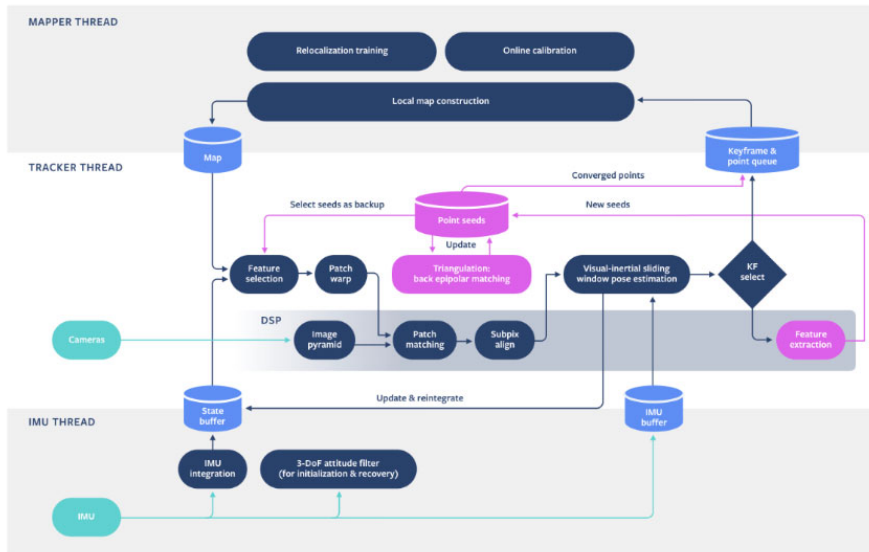
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Claim 31

(31) The sensor module of claim 30 wherein the sensor module is configured to provide information over the communication interface related to an uncertainty in the measurement information.

See supra claim 30. Facebook makes, uses, sells, and/or offers for sale in the United States, and/or imports into the United States, the Accused Products, comprising a sensor module that is configured to provide information over the communication interface related to an uncertainty in the measurement information. For example, on information and belief and subject to discovery which has not yet occurred, the sensor module in the Accused Products (e.g., the headset and Oculus controller(s) and their associated software, including the Oculus Insight tracking system, and/or a computer or other external processor for the Oculus Rift S) is configured to provide information over the communication interface that includes data characterizing the uncertainty in the measurement information received from the measurement sensors (e.g., cameras and/or IMUs within the headset, and/or the IMUs within the Oculus controllers).

Facebook encourages, directs, or promotes users to use the sensor module within the Accused Products (e.g., through its software and/or user instructions, which have not been provided at this stage of the litigation), and its users use the sensor module within the Accused Products. Facebook further provides or sells the Accused Products to third parties (e.g., distributors and retailers) and directs them to sell and/or offer for sale in the United States, or import the Accused Products into the United States. Facebook also makes, uses, sells, and/or offers for sale in the United States, and/or imports into the United States, components (e.g., Oculus controllers) that are especially made and

adapted to be used with the Accused Products, are a material part of the claimed invention, and have no substantial noninfringing uses.

See, e.g., Hand Tracking.

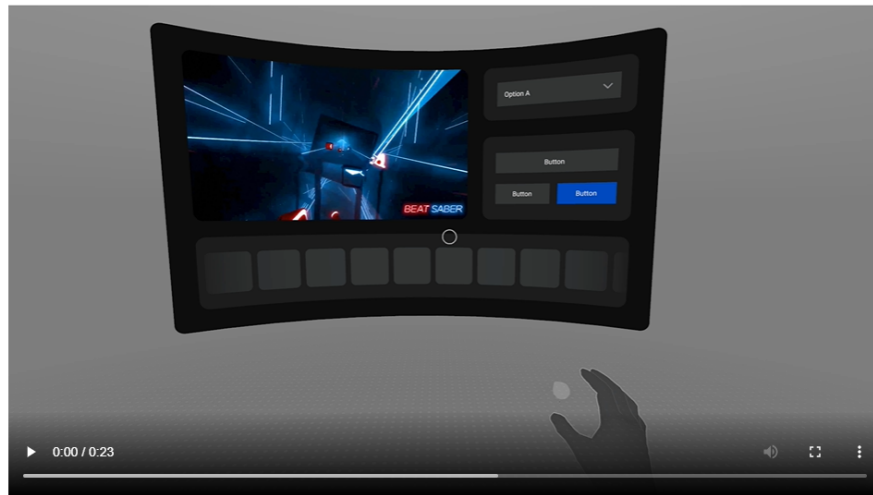
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Hand tracking complements the Touch controllers and is not intended to replace controllers in all scenarios, especially with games or creative tools that require a high degree of precision. By opting-in to hand support, your app also needs to satisfy additional technical requirements specific to hand tracking in order to be accepted on Oculus Store. To submit an app to Oculus Store, the app must support controllers along with hand tracking.

See also Designing for Hands.

Designing for Hands



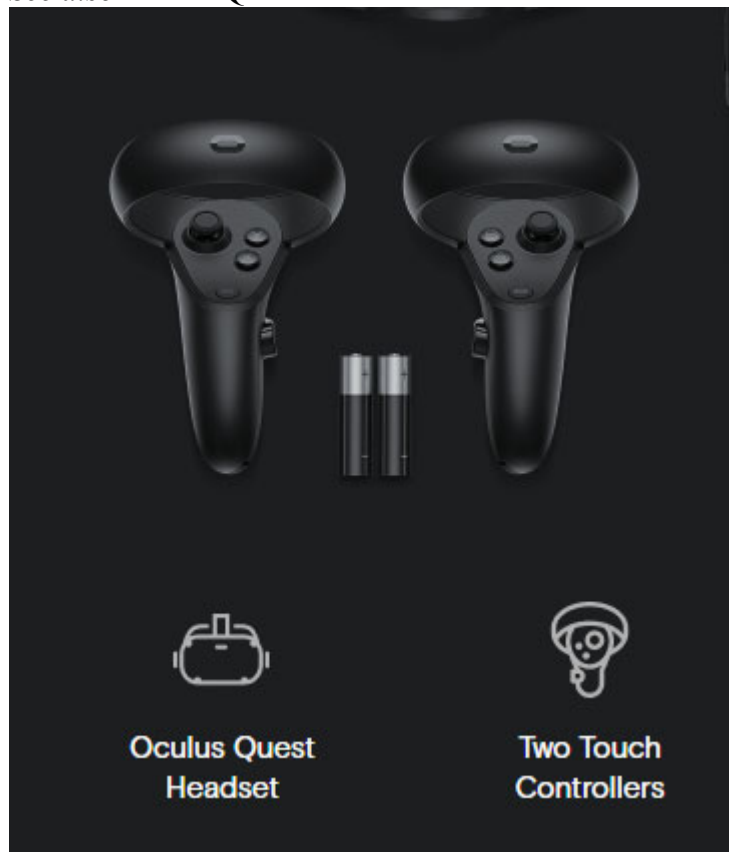
See also Hand Tracking Deep Dive at 4:00–10:00.



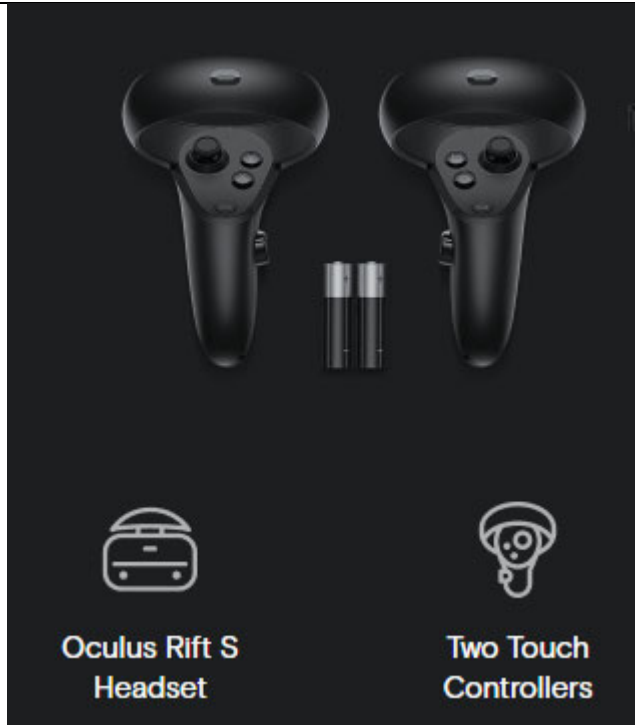
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See also Oculus Quest.



See also Oculus Rift S.



Oculus Rift S
Headset

Two Touch
Controllers

See also From the Lab.

There are other complications, too. The infrared LEDs in the two hand controllers drastically change appearance when they move closer or farther away from the headset as you swing a virtual sword or maneuver a virtual spaceship. Oculus Insight also uses other sensors, drawing acceleration and velocity data from the inertial measurement units (IMUs) located in the headset and controllers. The system must process all of these data points in real time and, in the case of Quest, on a mobile chipset.

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Taking SLAM technology ...

The foundation of Oculus Insight's inside-out tracking is [simultaneous localization and mapping, or SLAM](#), which uses computer vision CV algorithms to essentially fuse incoming data from multiple sensors in order to fix the position of an object within a constantly updated digital map. SLAM has been used in robotics and in [AR camera effects](#) on smartphones and was demoed in the Oculus [Santa Cruz VR headset prototype](#) in 2016. But Oculus Insight required an unprecedented level of precision and efficiency, and that meant adapting the latest research on tracking and computer vision.

"A lot of these technologies really start in academia — inside the lab," Kozminski notes. It's no coincidence, then, that she's part of Facebook's Zurich-based team of engineers, many of whom came from [Zurich Eye](#) — a joint program from the prestigious [ETH University](#) and [University of Zurich](#) that researched self-navigating systems.

To build a new, more advanced version of SLAM, the engineering team drew from Facebook's years of AI research and engineering work, building systems to understand the objects and actions that appear in videos and creating highly efficient computer vision algorithms that work well on mobile devices.

See also Powered by AI.

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See also Powered by AI.

SLAM addresses these challenges by automatically recognizing features in the environment, letting Oculus Insight incorporate the player's current position into a VR display. Insight also uses an extrapolation function with dynamic damping to help predict where the user's head and hands will move in the milliseconds ahead. This provides a number of benefits, including reducing the visual stuttering effect known as jitter, which is the key metric that tracking systems are measured against. To help enable a comfortable VR experience, tracking should be in the submillimeter range, meaning that the system can track with precision greater than a single millimeter. Insight exceeds this target in most environments.

Another major factor to avoid in delivering immersive experiences is latency — any lag between physical movements and their VR equivalents can disorient the user and degrade the sense of realism. By using low-latency IMU data and a kinematic model that predicts a user's motion into the future, Insight is able to effectively eliminate the apparent latency. We'll go into more detail in the next section about the sensor fusion process that incorporates SLAM data, but reducing both jitter and latency is central to Insight's ability to deliver a new level of realism within VR.

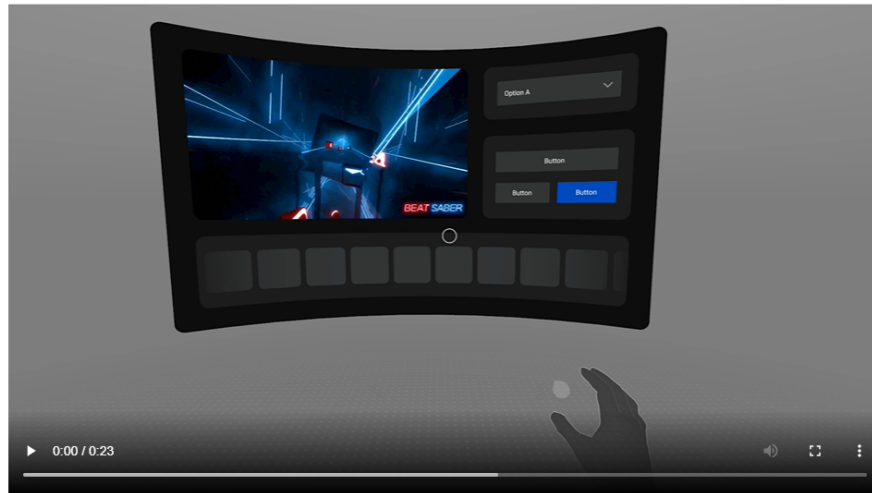
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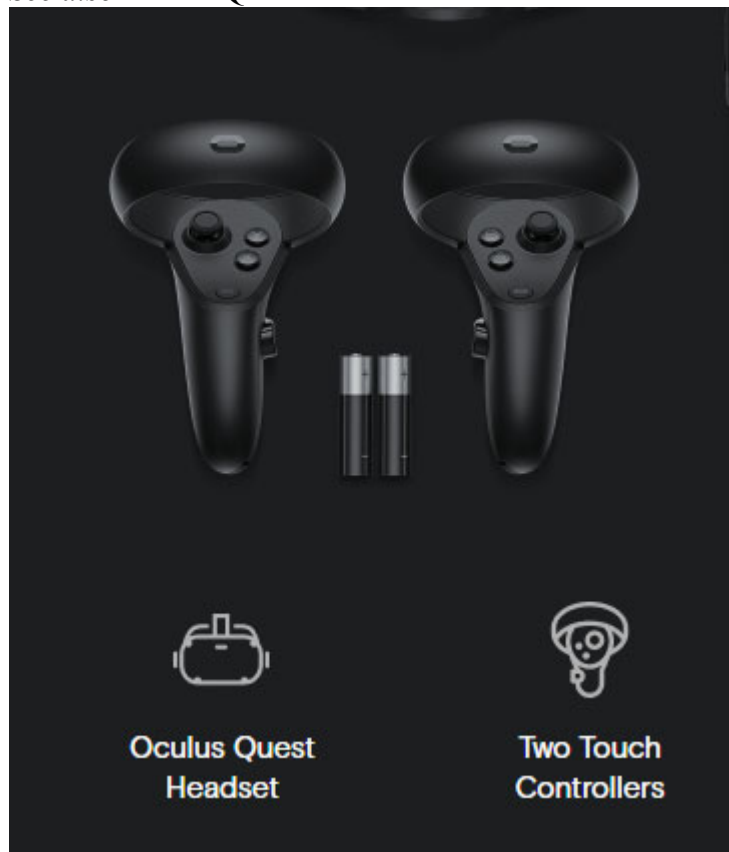
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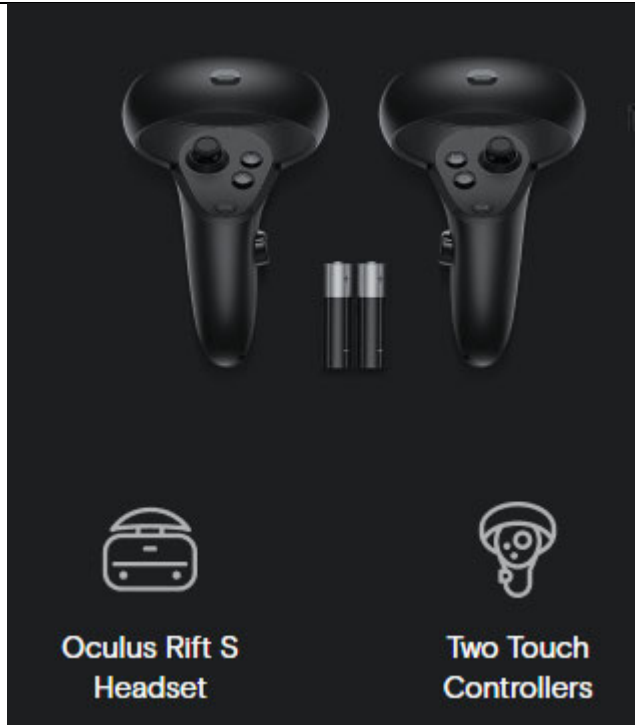
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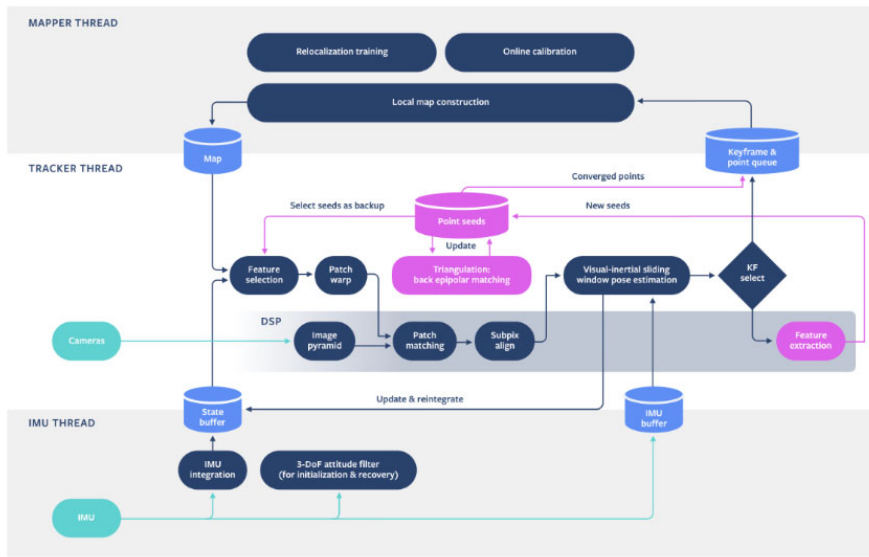
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See also id.

Headset tracking compute architecture



Oculus Insight processes multiple threads of data at once, in real-time — the mapper thread modifies the map, sending updated copies to the tracker thread, which uses camera frames to estimate poses in the mapper-provided frames, while the IMU thread uses measurements from the IMUs to update the latest SLAM state.

Claim 33

(33a) A method comprising: enumerating a set of sensing elements available to a tracking system that includes an estimation subsystem that estimates a position or orientation of an object;

Facebook encourages, directs, or promotes users to use the Accused Products to carry out the claimed method, and Facebook performs the claimed method. In particular, Facebook encourages, directs, or promotes users to enumerate a set of sensing elements (e.g., cameras and/or IMUs within the HMD, the IMUs within the Oculus controller(s), and/or the Oculus controller(s)) available to a tracking system (e.g., the headset and/or controllers) that includes an estimation subsystem (e.g., the Oculus Insight tracking system) that estimates a position or orientation of an object (e.g., the user's hand(s) and/or the Oculus controller(s)), and Facebook performs such step itself. For example, the Accused Products enumerate sensing elements available to the headset and/or controllers, including optical sensors (e.g., cameras) and inertial sensors (e.g., IMUs). As a further example, when the Accused Products are in the no controller configuration, only the HMD cameras are enumerated to track the user's hand location based on features on the hands. If one or both controllers are used, then the HMD cameras detect the infrared LEDs on the controllers held by the user and the HMD receives inertial signals from the controller IMUs to determine the location of the user's hand(s).

The Accused Products are especially adapted to carry out this method, which is a material part of the claimed invention, and have no substantial noninfringing uses. Further, on information and belief, Facebook conditions a user's use of the Accused Products, and therefore the user's receipt of the benefits of the Accused Products, upon this method and establishes the manner or timing of that use (e.g., through its software and/or user instructions, which have not been provided at this stage of the litigation).

See, e.g., From the Lab.

There are other complications, too. The infrared LEDs in the two hand controllers drastically change appearance when they move closer or farther away from the headset as you swing a virtual sword or maneuver a virtual spaceship. Oculus Insight also uses other sensors, drawing acceleration and velocity data from the inertial measurement units (IMUs) located in the headset and controllers. The system must process all of these data points in real time and, in the case of Quest, on a mobile chipset.

See also Oculus Rift S.

Is your PC VR Ready?

Your PC is the engine that powers Oculus Rift S. Show off the true potential of high-performance VR gameplay with our recommended level of hardware.

See also Hand Tracking.

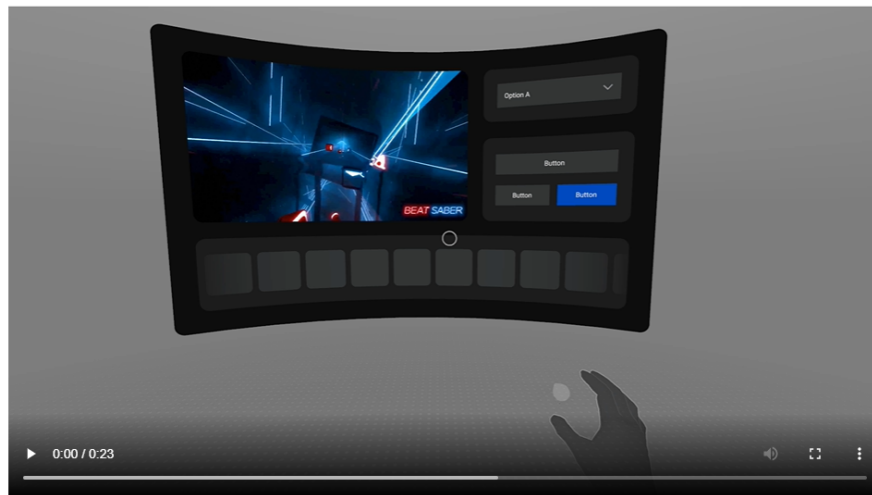
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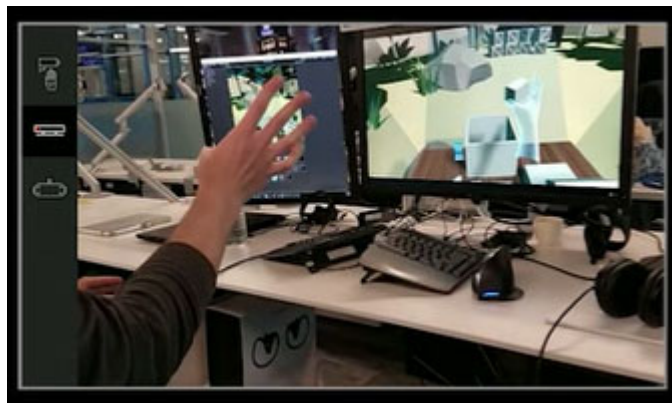
Designing for Hands



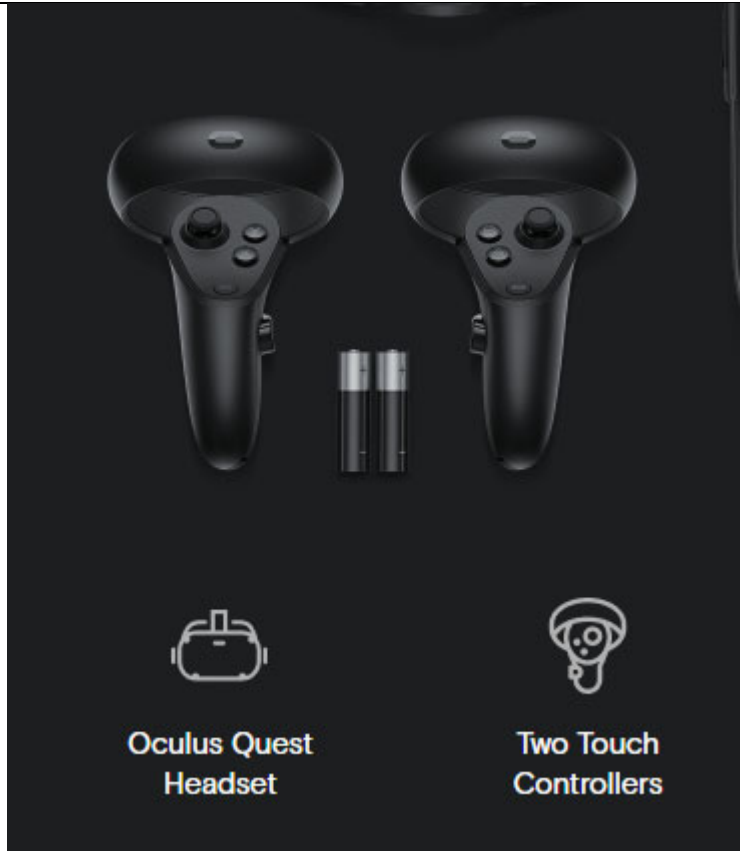
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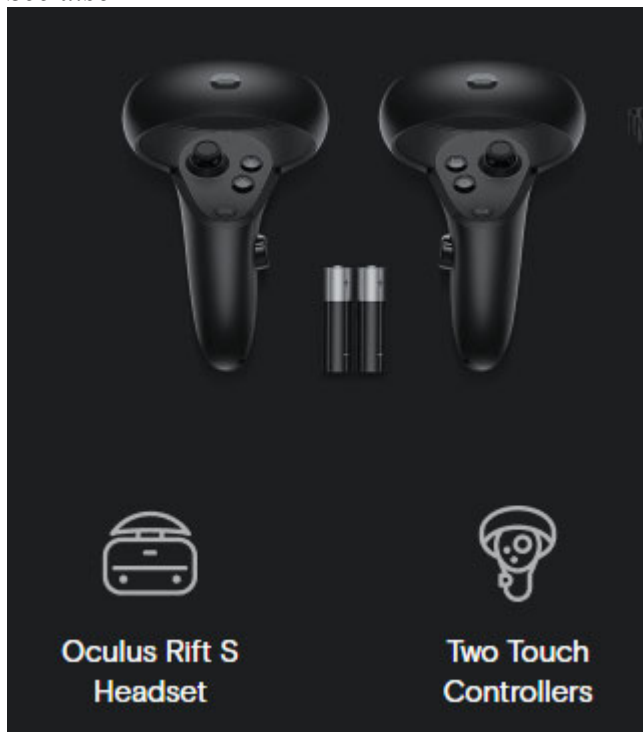
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The Oculus Insight system uses a custom hardware architecture and advanced computer vision algorithms — including visual-inertial mapping, place recognition, and geometry reconstruction — to establish the location of objects in relation to other objects within a given space. This novel algorithm stack enables a VR device to pinpoint its location, identify aspects of room geometry (such as floor location), and track the positions of the headset and controllers with respect to a 3D map that is generated and constantly updated by Insight. The data used for this process comes from three types of sensors built into the Quest and Rift S hardware:

See also id.

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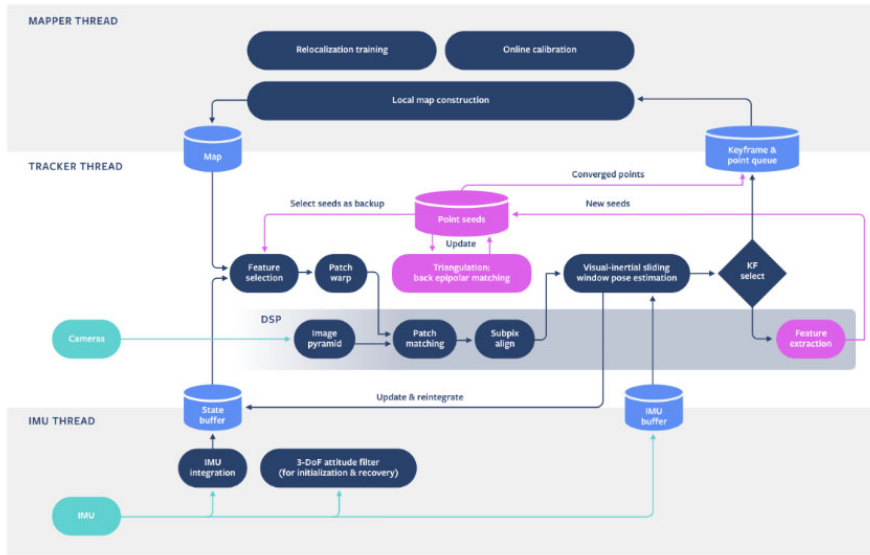
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See also *From the Lab*, Sensor Placement at 0:23.



See also *From the Lab*, Sensor Placement at 0:30.



See also Heaney.

More Precise Tracking

A function for infrared LED calibration exists, suggesting this controller is optically tracked in the same way as the current Touch— cameras on the headset follow the movement of the LED constellation, and this is fused with the accelerometer readings to achieve sub-mm precision.



Facebook's VR controllers are tracked via infrared LEDs under the plastic

See also id.

The driver also reveals the series model number of the controller's inertial measurement unit (IMU)- the chip within all VR controllers which contains the accelerometer.

Teardowns and the [FCC filings](#) for the current Touch showed it uses TDK's ICM-20601 IMU from late 2015.



The IMU in the current Touch controllers for Rift S and Quest

See also ICM-20601 Specification.

FEATURES

- 3-Axis Gyroscope with Programmable FSR of $\pm 500\text{dps}$, $\pm 100\text{dps}$, $\pm 2000\text{dps}$ and $\pm 4000\text{dps}$
- 3-Axis Accelerometer with Programmable FSR of $\pm 4g$, $\pm 8g$, $\pm 16g$, and $\pm 32g$
- User-programmable interrupts
- Wake-on-motion interrupt for low power operation of applications processor
- 512 byte FIFO buffer enables the applications processor to read the data in bursts
- On-Chip 16-bit ADCs and Programmable Filters
- Host interface: 8 MHz SPI or 400k Hz Fast Mode I²C
- Digital-output temperature sensor
- VDD operating range of 1.71 to 3.45V
- MEMS structure hermetically sealed and bonded at wafer level
- RoHS and Green compliant

See also Reddit Single Controller Discussion.

Does the Quest have a single controller mode for any games?

<https://imgur.com/a/1dLoatG>

My stepdad sent his old Oculus Go, it is a lot better than I expected! My good friend who is in the picture absolutely loves the Go. I make sure I bring it every time we hang out since I got it recently. He is able to play some of the games because there is only one controller. He would not be able to operate a controller with his other hand. We are looking at getting him one so we can play together, or both of us upgrading to the Quest. I was wondering if you guys have seen many games you can play with only one controller on the quest, or if we should stick to the Go. My friend would be doing a lot of video but I know he did like the ability to play some of the games. This has been the only video game system he has every really been able to play. I hope the quest will work out for us. Let me know what you guys think, thanks for the help.

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SORT BY BEST

maltakan0 6 points · 1 year ago

Virtual virtual reality can be played with one controller

MRHBK 5 points · 1 year ago

Quest is a bit heavier too if that is a factor

↑ stigzcousin 1 point · 1 year ago

↓ This is something I did not think about. Good to know. Thank you

jebwillnotdivideus 5 points · 1 year ago

Beatsaber and sportsscramble can be played with 1 controller. Other games im not sure.

See also Expert Mode at 2:36.



(33b) providing parameters specific to the set of sensing elements to the tracking system to enable the estimation subsystem to be configured based on the parameters specific to the set of sensing elements; and

Facebook encourages, directs, or promotes users to use the Accused Products to provide parameters specific to the enumerated sensing elements (e.g., the characteristics of the sensing elements and/or the number of controllers in use at a particular time) to the tracking system to enable the estimation subsystem (e.g., the Oculus Insight tracking system) to be configured based on the parameters specific to the enumerated sensing elements. For example, in the Accused Products, parameters specific to the sensing elements enumerated, including optical sensors (e.g., cameras) and inertial sensors (e.g., IMUs), are provided to the tracking system so that the Oculus Insight tracking system can be configured based on parameters specific to the sensing elements enumerated. As a further example, when the Accused Products are in the no controller configuration, only the HMD cameras are enumerated to track the user's hand location based on features on the hands. If one or both controllers are used, then the HMD cameras detect the infrared LEDs on the controllers held by the user and the HMD receives inertial signals from the controller IMUs to determine the location of the user's hand(s) and/or the Oculus controller(s).

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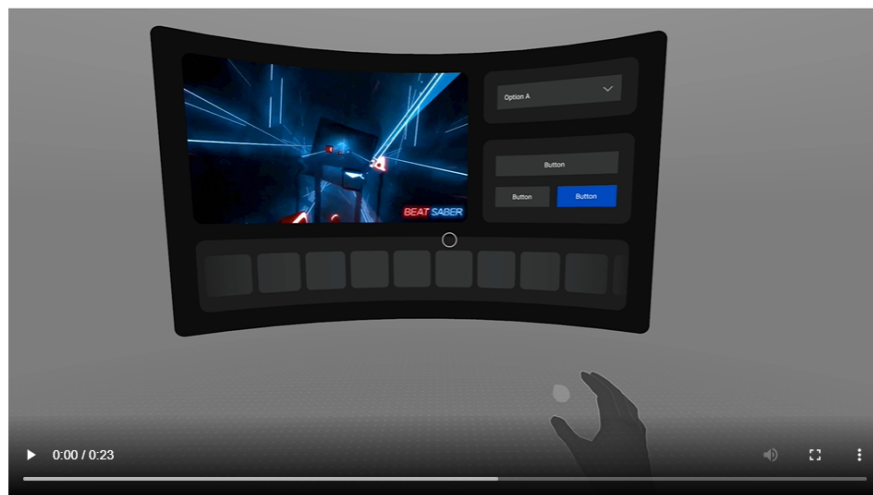
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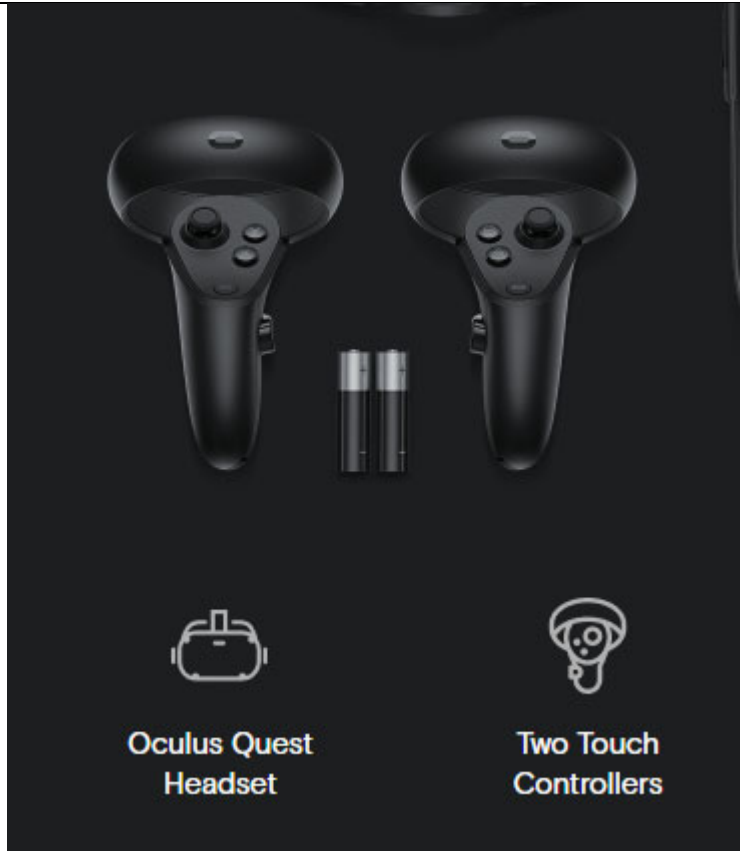
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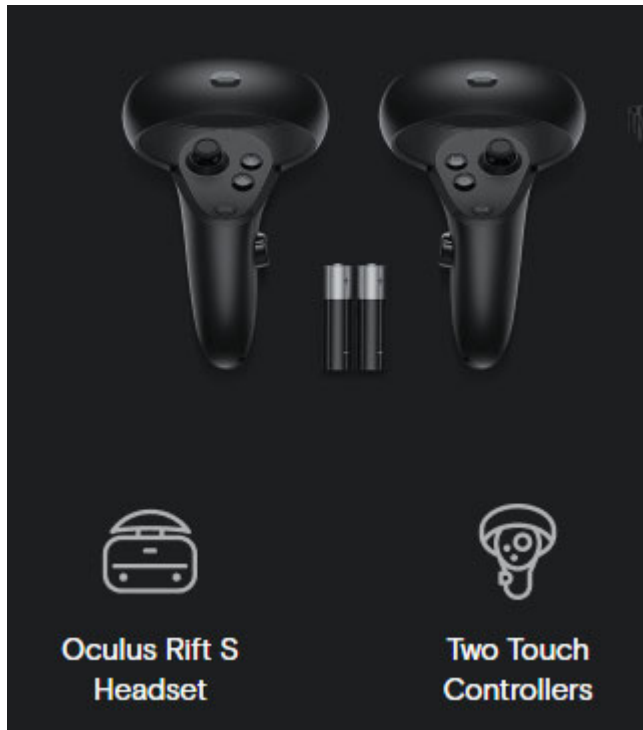
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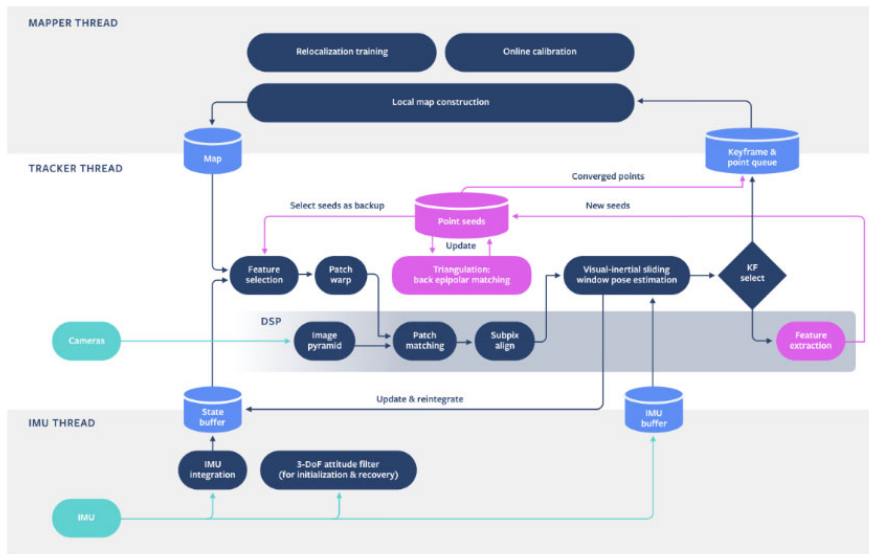
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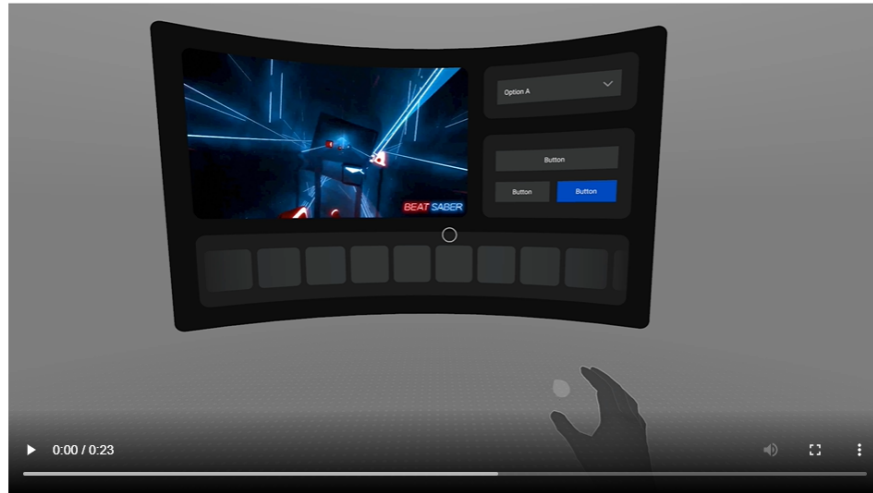
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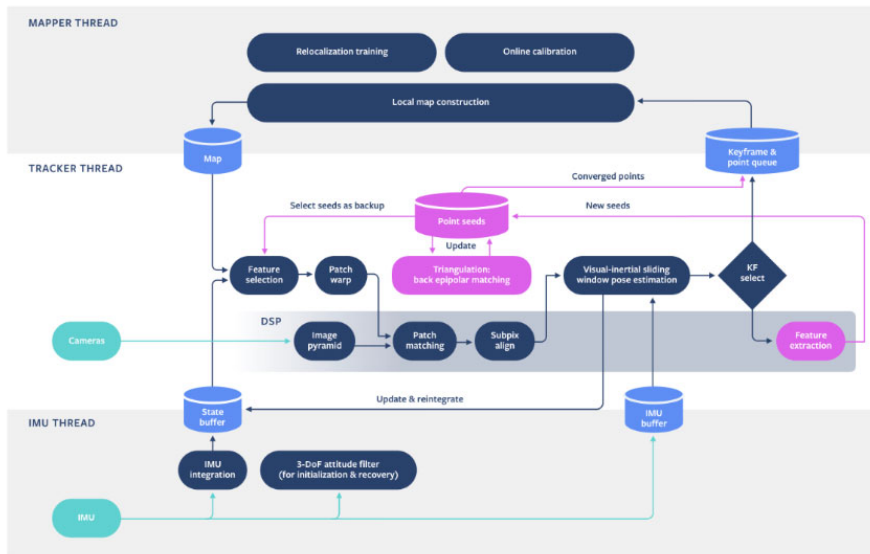
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Claim 34

(34) The method of claim 33, further comprising selecting a pair of sensing elements from the sequence of candidates, the selected pair of sensing elements being ready to make a measurement at the time of selection of the pair or at a predefined time after the time of selection of the pair, the selected pair having highest expected utility of a measurement among the sequence of candidates.

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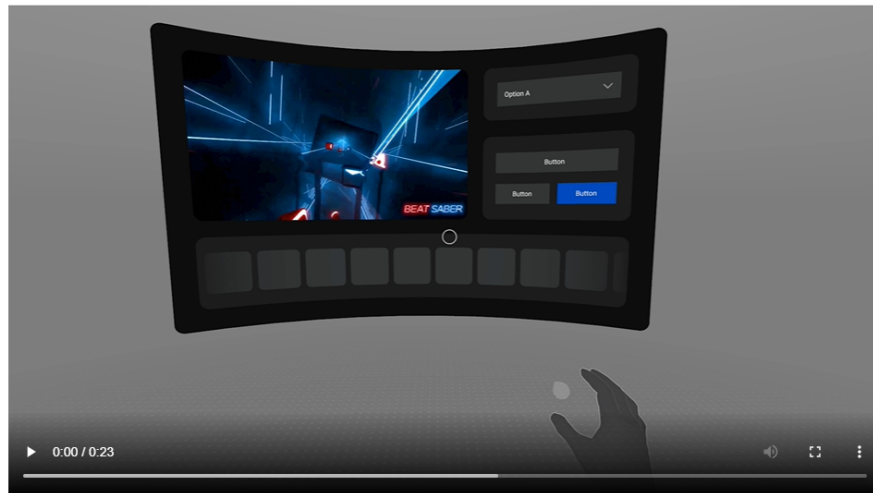
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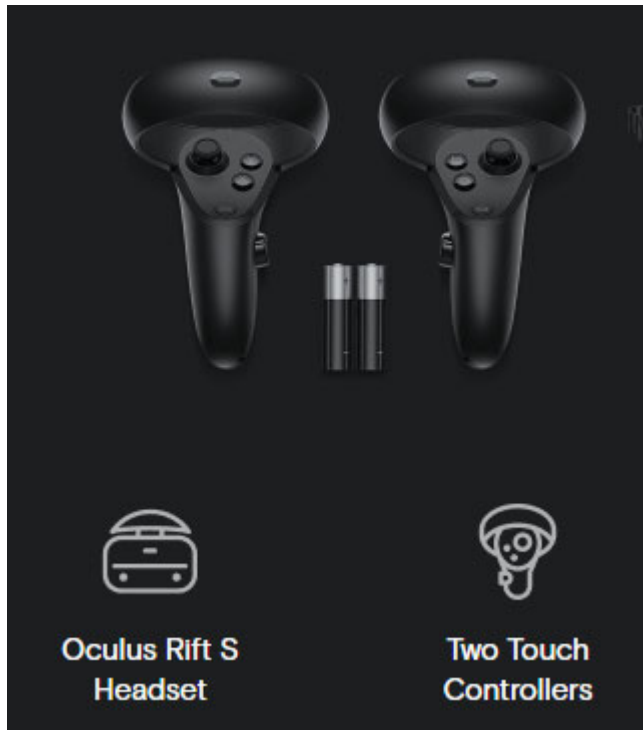
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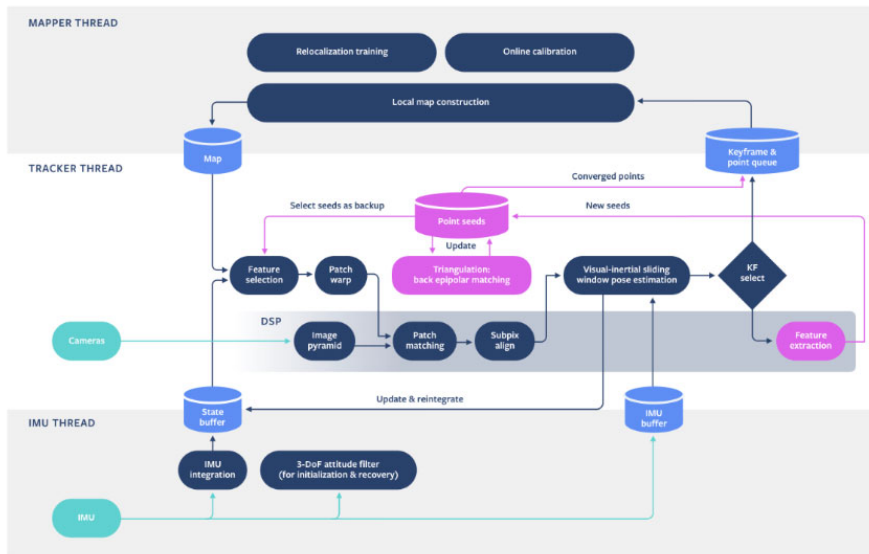
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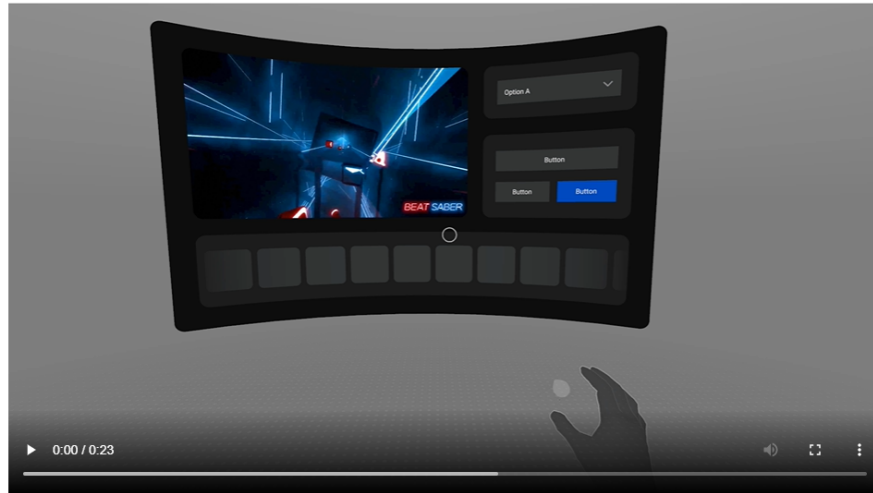
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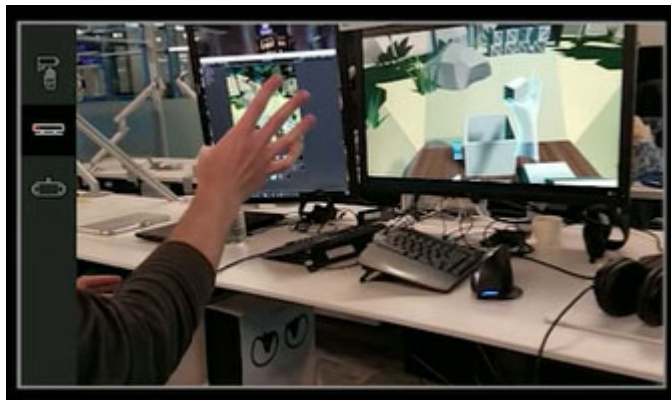
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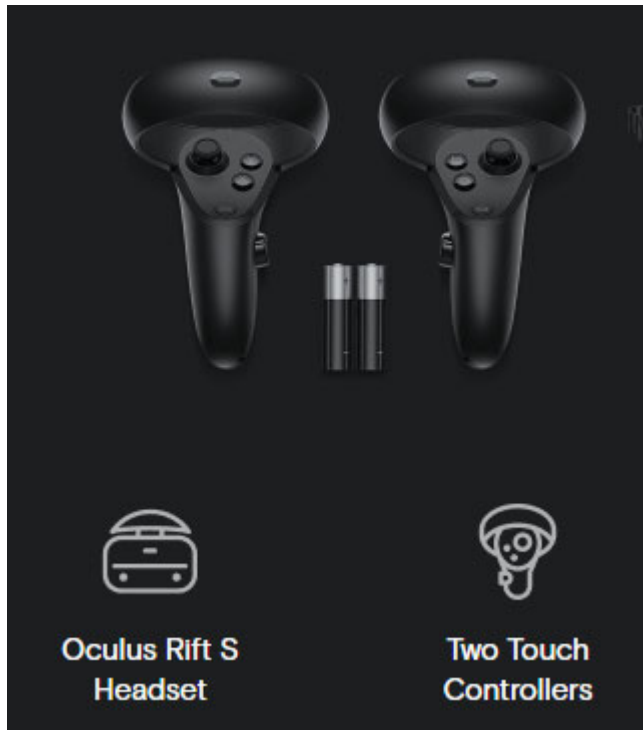
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At last year's Oculus Connect event we shared some details about [Oculus Insight](#), the cutting-edge technology that powers both Quest and Rift S. Now that both of those products are available, we're providing a deeper look at the AI systems and techniques that power this VR technology. Oculus Insight marks the first time that fully untethered six-degree-of-freedom (6DoF) headset and controller tracking has shipped in a consumer AR/VR device. Built from the ground up, the Insight stack leverages state-of-the-art computer vision (CV) systems and visual-inertial simultaneous localization and mapping, or SLAM.

See also From the Lab.

"We wanted to create a system that lets you move and explore a VR world just as naturally and easily as you would in real life," says Kozminski.

Kozminski joined a team whose mission was to create the first full-featured "inside-out" tracking system for a consumer VR device. The technology would have to track the full range of a person's movements (known as six degrees of freedom) and be able to pinpoint the location of the two handheld controllers as well as the headset.

Previously, VR devices relied on external sensors to track these movements. These cameras attach to a PC, and while they work well, they make VR less portable and more complicated to set up.

"With inside-out tracking in the headset, VR becomes as easy as putting on headphones to listen to music," says Kozminski.

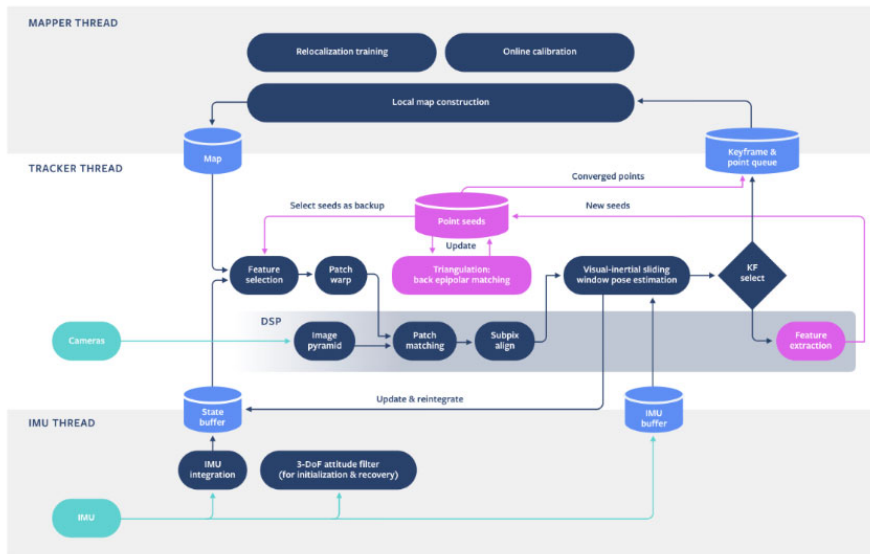
See also Powered by AI.

headset and controllers with respect to a 3D map that is generated and constantly updated by Insight. The data used for this process comes from three types of sensors built into the Quest and Rift S hardware:

1. Linear acceleration and rotational velocity data from IMUs in the headset and controllers are integrated to track the orientation and position of each with low latency.
2. Image data from cameras in the headset helps generate a 3D map of the room, pinpointing landmarks like the corners of furniture or the patterns on your floor. These landmarks are observed repeatedly, which enables Insight to compensate for drift (a common challenge with IMUs, where even tiny measurement discrepancies build up over time, resulting in inaccurate location tracking).
3. Infrared LEDs in the controllers are detected by the headset cameras, letting the system bound the controller position drift caused by integrating multiple IMUs.

See also id.

Headset tracking compute architecture

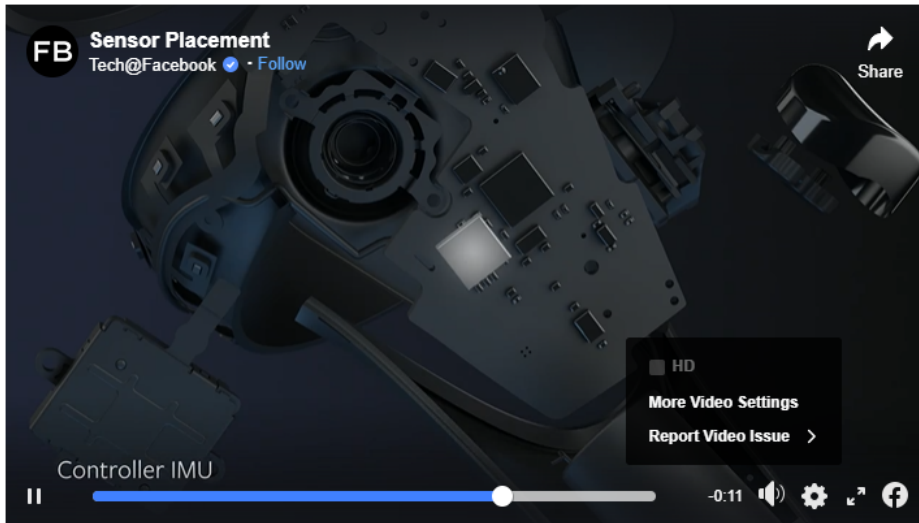


Oculus Insight processes multiple threads of data at once, in real-time — the mapper thread modifies the map, sending updated copies to the tracker thread, which uses camera frames to estimate poses in the mapper-provided frames, while the IMU thread uses measurements from the IMUs to update the latest SLAM state.

See also *From the Lab*, Sensor Placement at 0:23.



See also *From the Lab*, Sensor Placement at 0:30.



See also Heaney.

More Precise Tracking

A function for infrared LED calibration exists, suggesting this controller is optically tracked in the same way as the current Touch— cameras on the headset follow the movement of the LED constellation, and this is fused with the accelerometer readings to achieve sub-mm precision.



Facebook's VR controllers are tracked via infrared LEDs under the plastic

See also id.

The driver also reveals the series model number of the controller's inertial measurement unit (IMU)- the chip within all VR controllers which contains the accelerometer.

Teardowns and the [FCC filings](#) for the current Touch showed it uses TDK's ICM-20601 IMU from late 2015.



The IMU in the current Touch controllers for Rift S and Quest

See also [ICM-20601 Specification](#).

FEATURES

- 3-Axis Gyroscope with Programmable FSR of $\pm 500\text{dps}$, $\pm 100\text{dps}$, $\pm 2000\text{dps}$ and $\pm 4000\text{dps}$
- 3-Axis Accelerometer with Programmable FSR of $\pm 4g$, $\pm 8g$, $\pm 16g$, and $\pm 32g$
- User-programmable interrupts
- Wake-on-motion interrupt for low power operation of applications processor
- 512 byte FIFO buffer enables the applications processor to read the data in bursts
- On-Chip 16-bit ADCs and Programmable Filters
- Host interface: 8 MHz SPI or 400k Hz Fast Mode I²C
- Digital-output temperature sensor
- VDD operating range of 1.71 to 3.45V
- MEMS structure hermetically sealed and bonded at wafer level
- RoHS and Green compliant

See also [Reddit Single Controller Discussion](#).

Does the Quest have a single controller mode for any games?

<https://imgur.com/a/1dLoatG>

My stepdad sent his old Oculus Go, it is a lot better than I expected! My good friend who is in the picture absolutely loves the Go. I make sure I bring it every time we hang out since I got it recently. He is able to play some of the games because there is only one controller. He would not be able to operate a controller with his other hand. We are looking at getting him one so we can play together, or both of us upgrading to the Quest. I was wondering if you guys have seen many games you can play with only one controller on the quest, or if we should stick to the Go. My friend would be doing a lot of video but I know he did like the ability to play some of the games. This has been the only video game system he has every really been able to play. I hope the quest will work out for us. Let me know what you guys think, thanks for the help.

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SORT BY BEST

maltakan0 6 points · 1 year ago

Virtual virtual reality can be played with one controller

MRHBK 5 points · 1 year ago

Quest is a bit heavier too if that is a factor

↑ stigzcousin 1 point · 1 year ago

↓ This is something I did not think about. Good to know. Thank you

jebwillnotdivideus 5 points · 1 year ago

Beatsaber and sportsscramble can be played with 1 controller. Other games im not sure.

See also Expert Mode at 2:36.



Claim 36

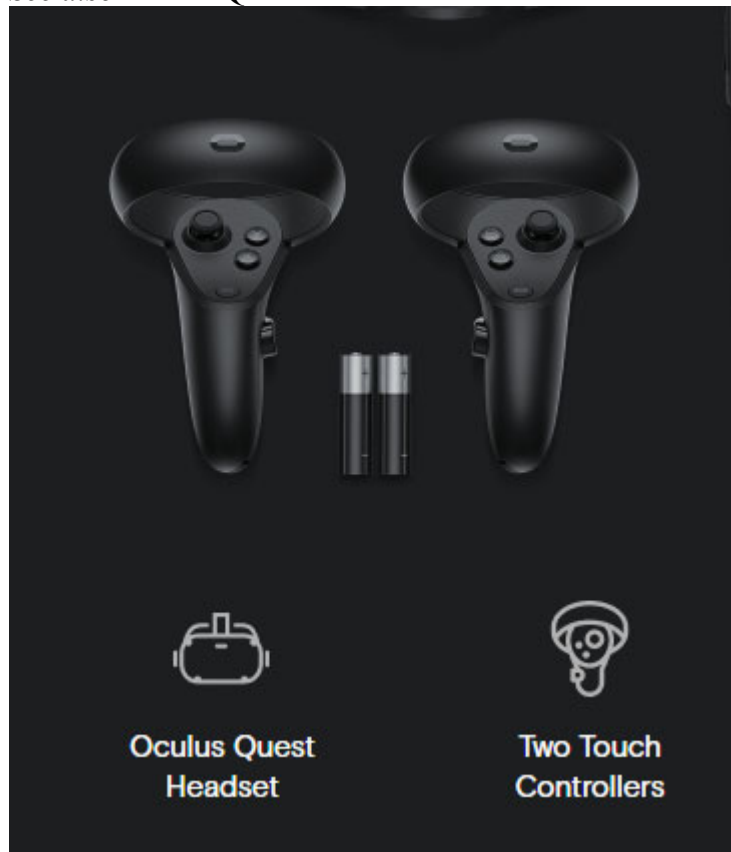
(35) The method of claim 35 wherein the target comprises a natural feature in an environment.

See supra claims 33, 35. Facebook encourages, directs, or promotes users to use the Accused Products to perform the method of claim 35 in which the target comprises a natural feature in an environment (e.g., landmarks like the corners of furniture or the patterns on the floor). The Accused Products are especially adapted to carry out this method, which is a material part of the claimed invention, and have no substantial noninfringing uses. Further, Facebook conditions a user’s use of the Accused Products, and therefore the user’s receipt of the benefits of the Accused Products, upon this method and establishes the manner or timing of that use.

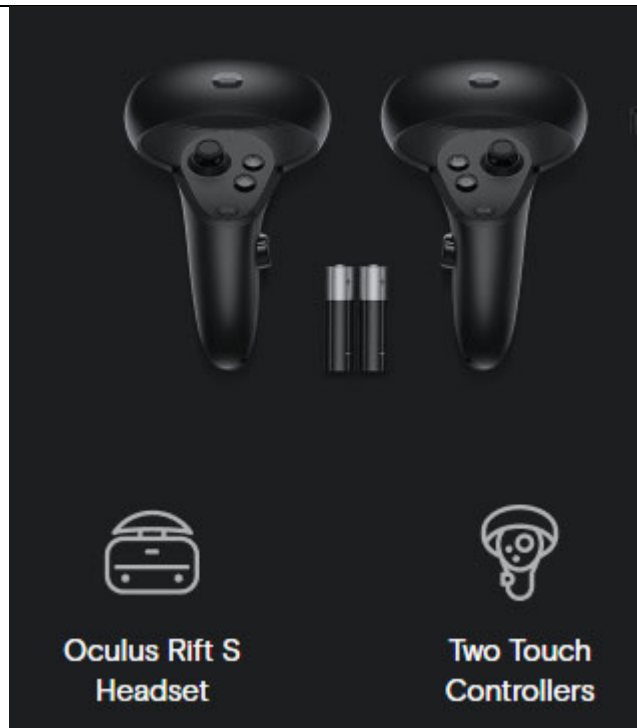
See, e.g., From the Lab.

There are other complications, too. The infrared LEDs in the two hand controllers drastically change appearance when they move closer or farther away from the headset as you swing a virtual sword or maneuver a virtual spaceship. Oculus Insight also uses other sensors, drawing acceleration and velocity data from the inertial measurement units (IMUs) located in the headset and controllers. The system must process all of these data points in real time and, in the case of Quest, on a mobile chipset.

See also Oculus Quest.



See also Oculus Rift S.



See also Powered by AI.

Academic research has been done on SLAM techniques for several decades, but the technology has only recently become mature enough for consumer applications, such as driverless cars and mobile AR apps. Facebook previously released a version of [SLAM for AR on mobile devices](#) which uses a single camera and inertial measurement unit (IMU) to track a phone's position and enable world-locked content — content that's visually anchored to real objects in the world. Oculus Insight is the second generation of this library, and it incorporates significantly more information from a combination of multiple IMUs and ultra-wide-angle cameras, as well as infrared LEDs to jointly track the 6DoF position of a VR headset and controllers.

The Oculus Insight system uses a custom hardware architecture and advanced computer vision algorithms — including visual-inertial mapping, place recognition, and geometry reconstruction — to establish the location of objects in relation to other objects within a given space. This novel algorithm stack enables a VR device to pinpoint its location, identify aspects of room geometry (such as floor location), and track the positions of the headset and controllers with respect to a 3D map that is generated and constantly updated by Insight. The data used for this process comes from three types of sensors built into the Quest and Rift S hardware:

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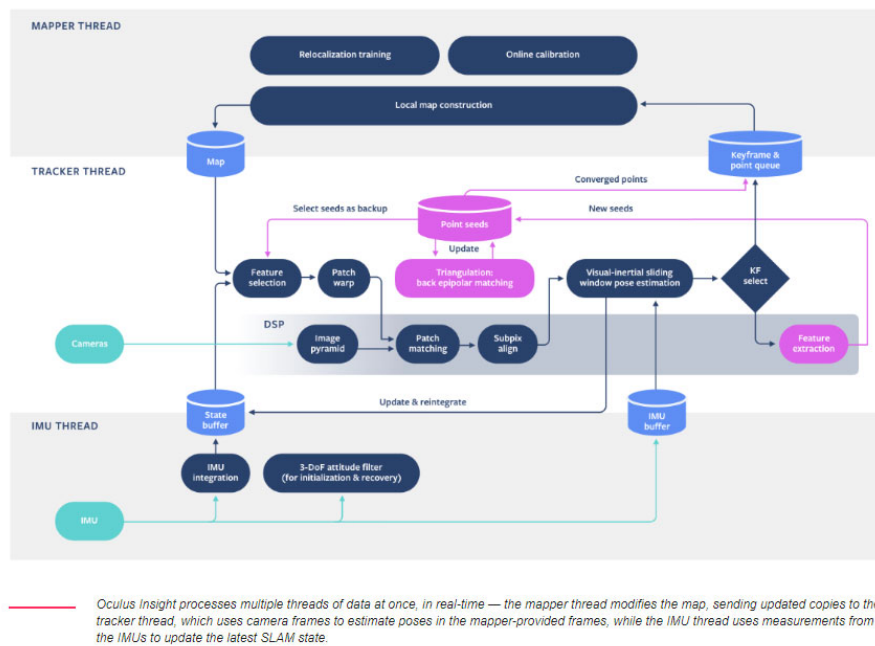
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3. Infrared LEDs in the controllers are detected by the headset cameras, letting the system bound the controller position drift caused by integrating multiple IMUs.

See also *id.*

Headset tracking compute architecture



Claim 44

(44a) A method comprising: estimating a calibration parameter of a sensing element that is either a sensor or a target, the sensing element being fixed either to an environment or to an object being tracked;

Facebook encourages, directs, or promotes users to use the Accused Products to carry out the claimed method, and Facebook performs the claimed method. For example, the Accused Products take measurements to use for calibration, including with respect to the cameras and/or IMUs in the headset, and/or the IMUs in the Oculus controller(s), which are sensors or targets and which are fixed to the user's head, the user's hand(s), and/or the Oculus controller(s).

The Accused Products are especially adapted to carry out this method, which is a material part of the claimed invention, and have no substantial noninfringing uses. Further, on information and belief, Facebook conditions a user's use of the Accused Products, and therefore the user's receipt of the benefits of the Accused Products, upon this method and establishes the manner or timing of that use (e.g., through its software and/or user instructions, which have not been provided at this stage of the litigation).

See, e.g., Hand Tracking.

The hand tracking feature enables the use of hands as an input method for the Oculus Quest device. It delivers a new sense of presence, enhances social engagement, and delivers more natural interactions with fully tracked hands and articulated fingers. Integrated hands can perform object interactions by using simple hand gestures such as pinch, unpinch, and pinch and hold.

The hand tracking feature lets you operate with hands and controllers interchangeably. When you opt to use hands, the hand's pose drives a laser cursor-pointer that behaves like the standard controller cursor. You can use the cursor-pointer to highlight, select, click, or write your own app-level event logic.

Hand tracking complements the Touch controllers and is not intended to replace controllers in all scenarios, especially with games or creative tools that require a high degree of precision. By opting-in to hand support, your app also needs to satisfy additional technical requirements specific to hand tracking in order to be accepted on Oculus Store. To submit an app to Oculus Store, the app must support controllers along with hand tracking.

See also Designing for Hands. **Designing for Hands**



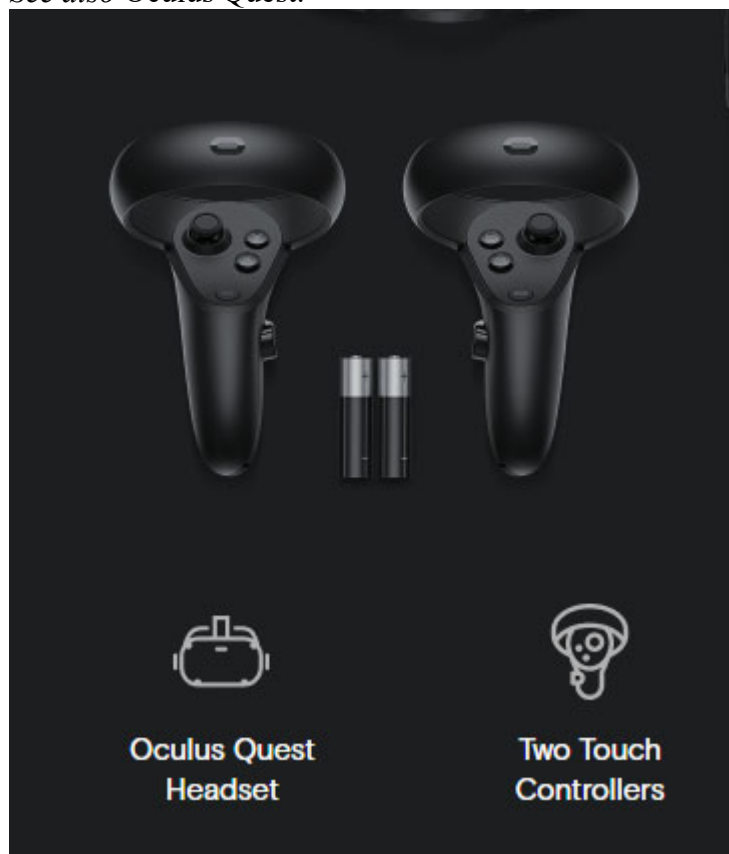
See also Hand Tracking Deep Dive at 4:00–10:00.



See also id. at 4:00–10:00.



See also Oculus Quest.



See also Oculus Rift S.



Oculus Rift S
Headset

Two Touch
Controllers

See also From the Lab.

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See also From the Lab.

Taking SLAM technology ...

The foundation of Oculus Insight's inside-out tracking is [simultaneous localization and mapping, or SLAM](#), which uses computer vision CV algorithms to essentially fuse incoming data from multiple sensors in order to fix the position of an object within a constantly updated digital map. SLAM has been used in robotics and in [AR camera effects](#) on smartphones and was demoed in the Oculus [Santa Cruz VR headset prototype](#) in 2016. But Oculus Insight required an unprecedented level of precision and efficiency, and that meant adapting the latest research on tracking and computer vision.

"A lot of these technologies really start in academia — inside the lab," Kozminski notes. It's no coincidence, then, that she's part of Facebook's Zurich-based team of engineers, many of whom came from [Zurich Eye](#) — a joint program from the prestigious [ETH University](#) and [University of Zurich](#) that researched self-navigating systems.

To build a new, more advanced version of SLAM, the engineering team drew from Facebook's years of AI research and engineering work, building systems to understand the objects and actions that appear in videos and creating highly efficient computer vision algorithms that work well on mobile devices.

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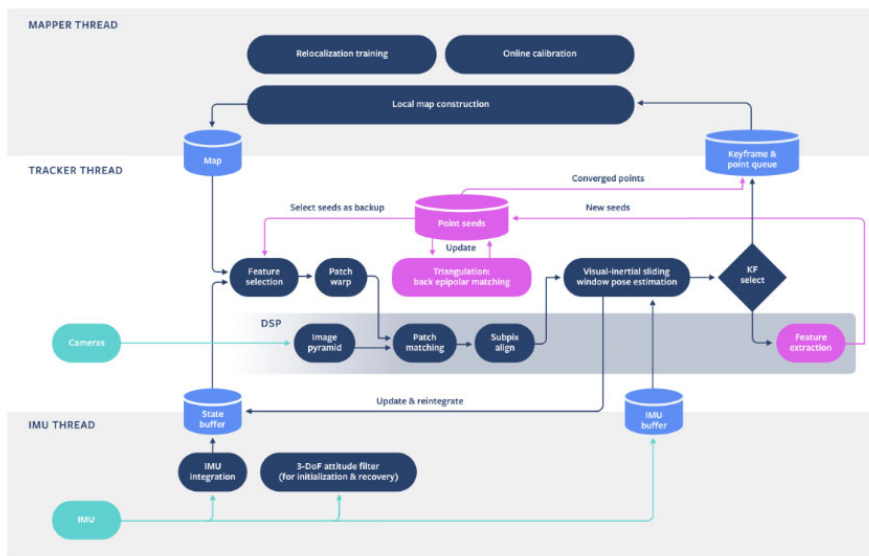
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SLAM addresses these challenges by automatically recognizing features in the environment, letting Oculus Insight incorporate the player's current position into a VR display. Insight also uses an extrapolation function with dynamic damping to help predict where the user's head and hands will move in the milliseconds ahead. This provides a number of benefits, including reducing the visual stuttering effect known as jitter, which is the key metric that tracking systems are measured against. To help enable a comfortable VR experience, tracking should be in the submillimeter range, meaning that the system can track with precision greater than a single millimeter. Insight exceeds this target in most environments.

Another major factor to avoid in delivering immersive experiences is latency — any lag between physical movements and their VR equivalents can disorient the user and degrade the sense of realism. By using low-latency IMU data and a kinematic model that predicts a user's motion into the future, Insight is able to effectively eliminate the apparent latency. We'll go into more detail in the next section about the sensor fusion process that incorporates SLAM data, but reducing both jitter and latency is central to Insight's ability to deliver a new level of realism within VR.

See also id.

Headset tracking compute architecture



Oculus Insight processes multiple threads of data at once, in real-time — the mapper thread modifies the map, sending updated copies to the tracker thread, which uses camera frames to estimate poses in the mapper-provided frames, while the IMU thread uses measurements from the IMUs to update the latest SLAM state.

(44b) determining whether the sensing element is the sensor or the target; and

Facebook encourages, directs, or promotes users to use the Accused Products to determine whether the sensing element is the sensor or the target. For example, on information and belief and subject to discovery which has not yet occurred, the Accused Products determine whether the cameras and/or IMUs in the headset, and/or the IMUs in the Oculus controller(s), are the sensor or the target. The Accused Products are especially adapted to carry out this method, which is a material part of the claimed invention, and have no substantial noninfringing uses. Further, Facebook conditions a user's use of the Accused Products, and therefore the user's receipt of the benefits of the Accused Products, upon this method and establishes the manner or timing of that use.

See, e.g., Hand Tracking.

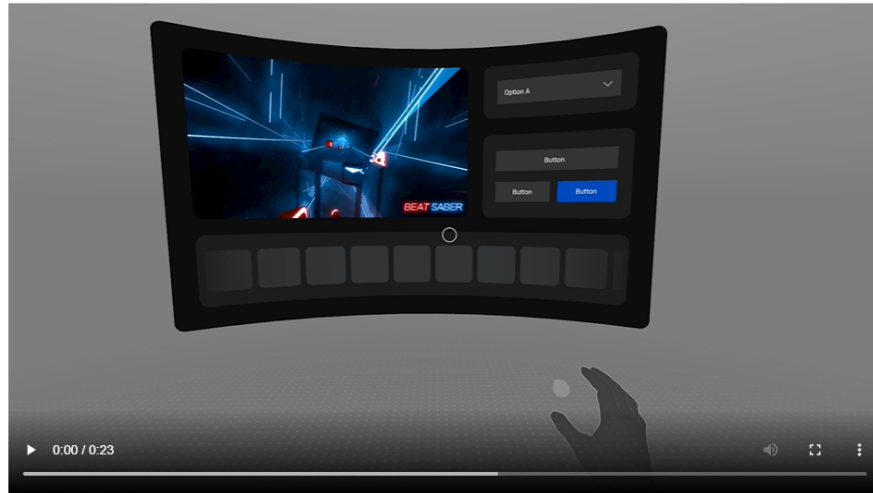
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Designing for Hands



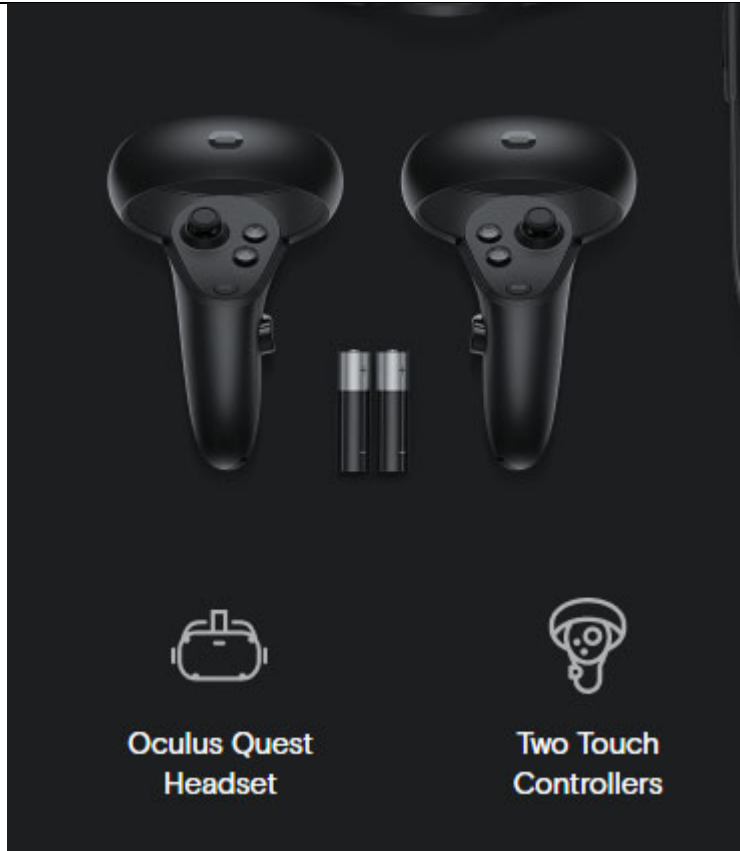
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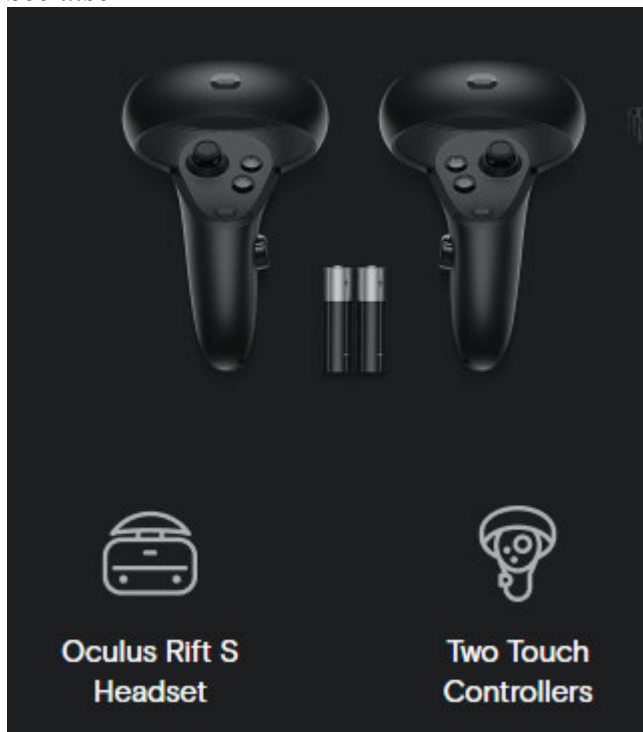
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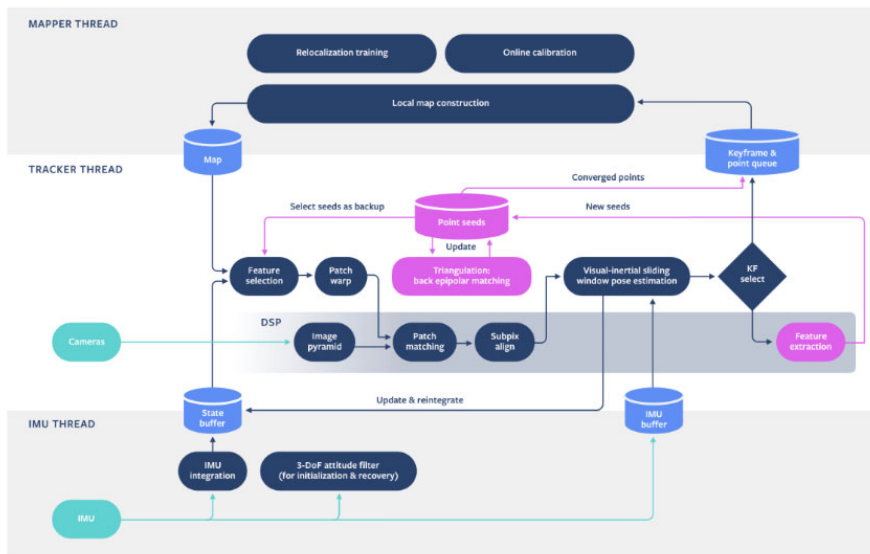
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To the extent this limitation is not met literally, the Accused Products also satisfy this limitation under the doctrine of equivalents. Any difference between the Accused Products and the claim element is insubstantial.

See, e.g., Hand Tracking.

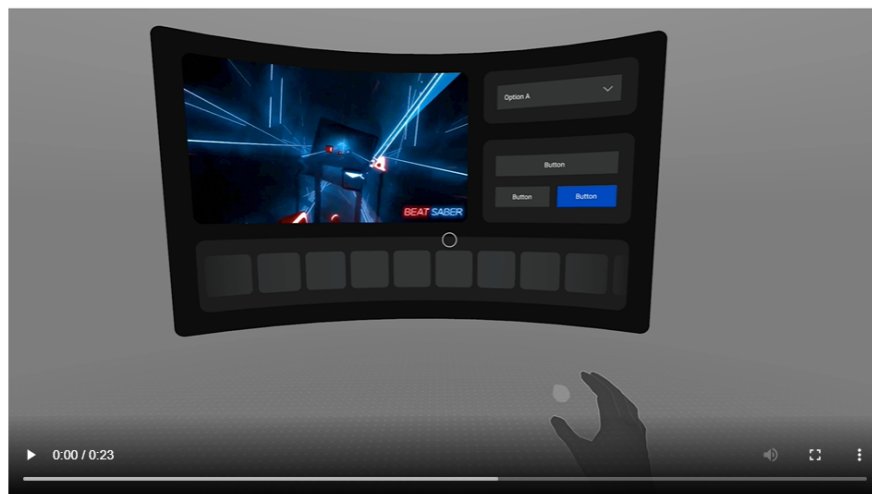
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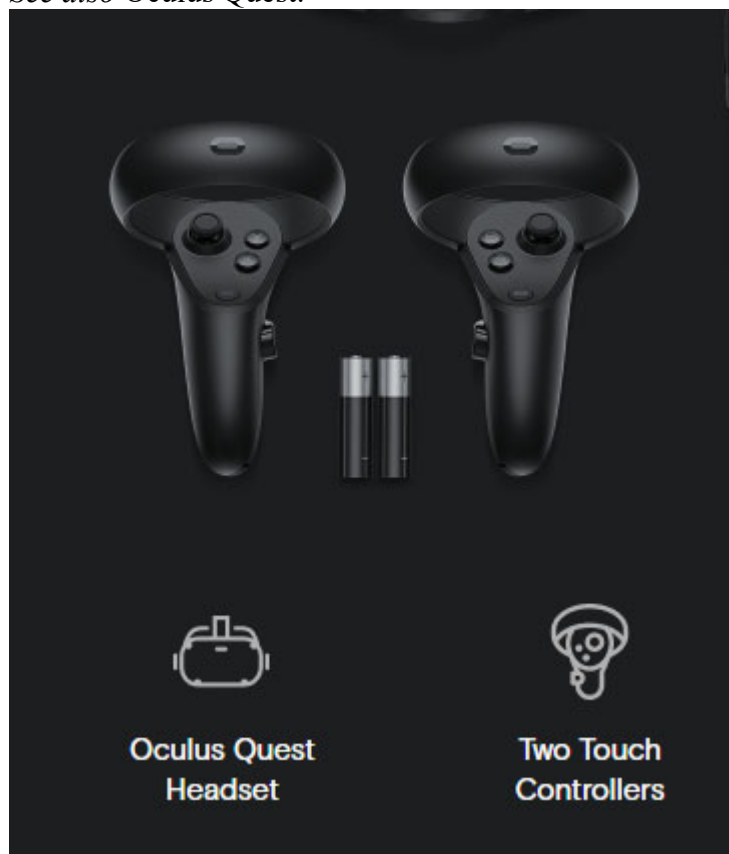
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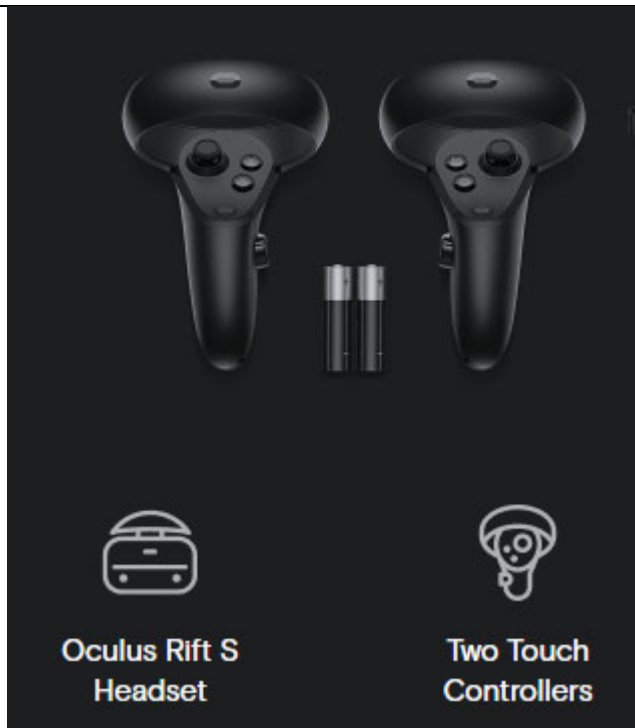
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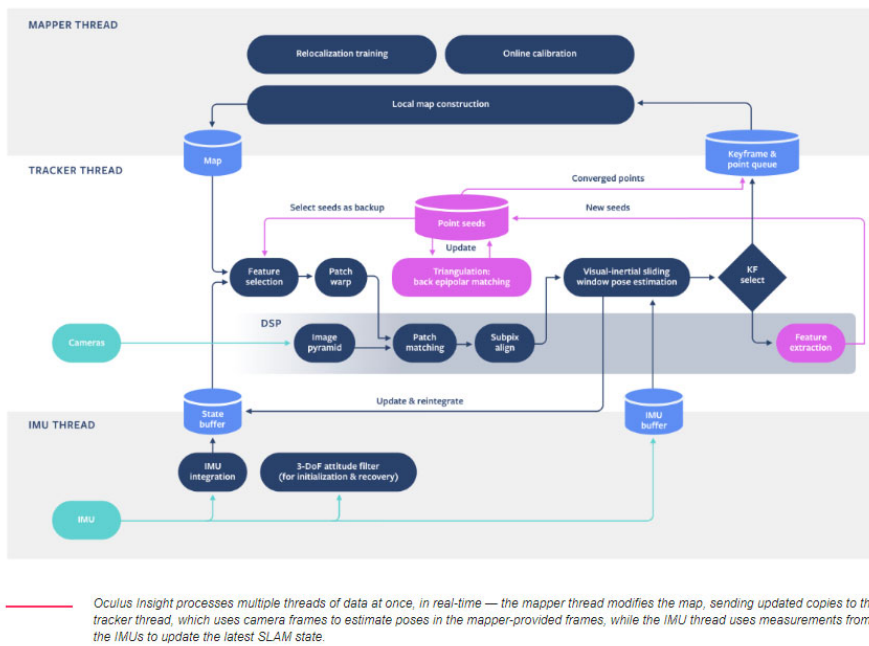
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Another major factor to avoid in delivering immersive experiences is latency — any lag between physical movements and their VR equivalents can disorient the user and degrade the sense of realism. By using low-latency IMU data and a kinematic model that predicts a user's motion into the future, Insight is able to effectively eliminate the apparent latency. We'll go into more detail in the next section about the sensor fusion process that incorporates SLAM data, but reducing both jitter and latency is central to Insight's ability to deliver a new level of realism within VR.

See also id.

Headset tracking compute architecture



Claim 45

(45) The method of claim 44, further comprising assigning the calibration parameter as a target calibration parameter when the sensing element is a target, and generating an innovation of a measurement of the sensing element made by a sensor based in part on the target calibration parameter.

See supra claim 44. Facebook encourages, directs, or promotes users to use the Accused Products to perform the method of claim 44 further comprising assigning the calibration parameter as a target calibration parameter when the sensing element is a target, and generating an innovation of a measurement of the sensing element made by a sensor based in part on the target calibration parameter. For example, on information and belief and subject to discovery which has not yet occurred, the Accused Products assign parameters to calibrate for measurement discrepancies as target calibration parameters when the sensing element is a target (e.g., the user's head, the user's hand(s), and/or the Oculus controller(s), and/or landmarks like the corners of furniture or the patterns on the floor). The Accused Products then generate an innovation of a measurement of the sensing element made by a sensor (e.g., the cameras and/or IMUs in the headset, and/or the IMUs in the Oculus controller(s)) based in part on the calibration parameters. The Accused Products are especially adapted to carry out this method, which is a material part of the claimed invention, and have no substantial noninfringing uses. Further, Facebook conditions a user's use of the Accused Products, and therefore the user's receipt of the benefits of the Accused Products, upon this method and establishes the manner or timing of that use.

To the extent this limitation is not met literally, the Accused Products also satisfy this limitation under the doctrine of equivalents. Any difference between the Accused Products and the claim element is insubstantial.

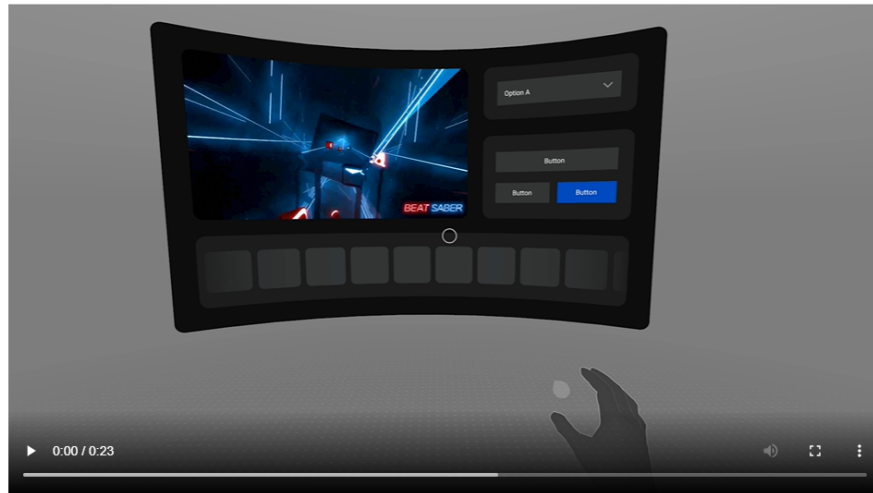
See, e.g., Hand Tracking.

The hand tracking feature enables the use of hands as an input method for the Oculus Quest device. It delivers a new sense of presence, enhances social engagement, and delivers more natural interactions with fully tracked hands and articulated fingers. Integrated hands can perform object interactions by using simple hand gestures such as pinch, unpinch, and pinch and hold.

The hand tracking feature lets you operate with hands and controllers interchangeably. When you opt to use hands, the hand's pose drives a laser cursor-pointer that behaves like the standard controller cursor. You can use the cursor-pointer to highlight, select, click, or write your own app-level event logic.

Hand tracking complements the Touch controllers and is not intended to replace controllers in all scenarios, especially with games or creative tools that require a high degree of precision. By opting-in to hand support, your app also needs to satisfy additional technical requirements specific to hand tracking in order to be accepted on Oculus Store. To submit an app to Oculus Store, the app must support controllers along with hand tracking.

See also Designing for Hands.
Designing for Hands



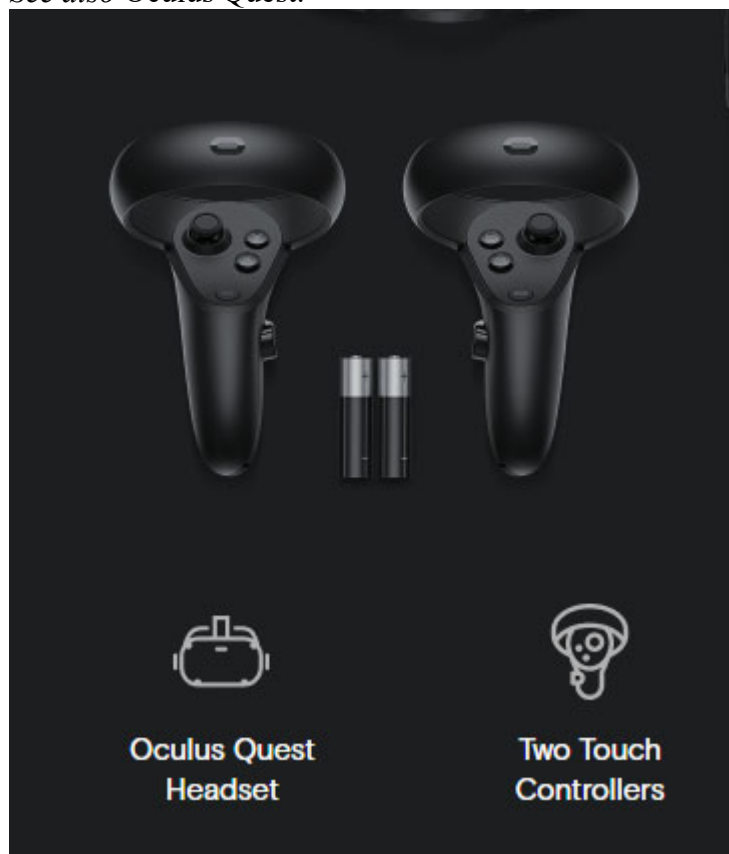
See also Hand Tracking Deep Dive at 4:00–10:00.



See also id. at 4:00–10:00.



See also Oculus Quest.



See also Oculus Rift S.



Oculus Rift S
Headset

Two Touch
Controllers

See also From the Lab.

There are other complications, too. The infrared LEDs in the two hand controllers drastically change appearance when they move closer or farther away from the headset as you swing a virtual sword or maneuver a virtual spaceship. Oculus Insight also uses other sensors, drawing acceleration and velocity data from the inertial measurement units (IMUs) located in the headset and controllers. The system must process all of these data points in real time and, in the case of Quest, on a mobile chipset.

See also From the Lab.

Taking SLAM technology ...

The foundation of Oculus Insight's inside-out tracking is [simultaneous localization and mapping, or SLAM](#), which uses computer vision CV algorithms to essentially fuse incoming data from multiple sensors in order to fix the position of an object within a constantly updated digital map. SLAM has been used in robotics and in [AR camera effects](#) on smartphones and was demoed in the Oculus [Santa Cruz VR headset prototype](#) in 2016. But Oculus Insight required an unprecedented level of precision and efficiency, and that meant adapting the latest research on tracking and computer vision.

"A lot of these technologies really start in academia — inside the lab," Kozminski notes. It's no coincidence, then, that she's part of Facebook's Zurich-based team of engineers, many of whom came from [Zurich Eye](#) — a joint program from the prestigious [ETH University](#) and [University of Zurich](#) that researched self-navigating systems.

To build a new, more advanced version of SLAM, the engineering team drew from Facebook's years of AI research and engineering work, building systems to understand the objects and actions that appear in videos and creating highly efficient computer vision algorithms that work well on mobile devices.

See also Powered by AI.

headset and controllers with respect to a 3D map that is generated and constantly updated by Insight. The data used for this process comes from three types of sensors built into the Quest and Rift S hardware:

1. Linear acceleration and rotational velocity data from IMUs in the headset and controllers are integrated to track the orientation and position of each with low latency.
2. Image data from cameras in the headset helps generate a 3D map of the room, pinpointing landmarks like the corners of furniture or the patterns on your floor. These landmarks are observed repeatedly, which enables Insight to compensate for drift (a common challenge with IMUs, where even tiny measurement discrepancies build up over time, resulting in inaccurate location tracking).
3. Infrared LEDs in the controllers are detected by the headset cameras, letting the system bound the controller position drift caused by integrating multiple IMUs.

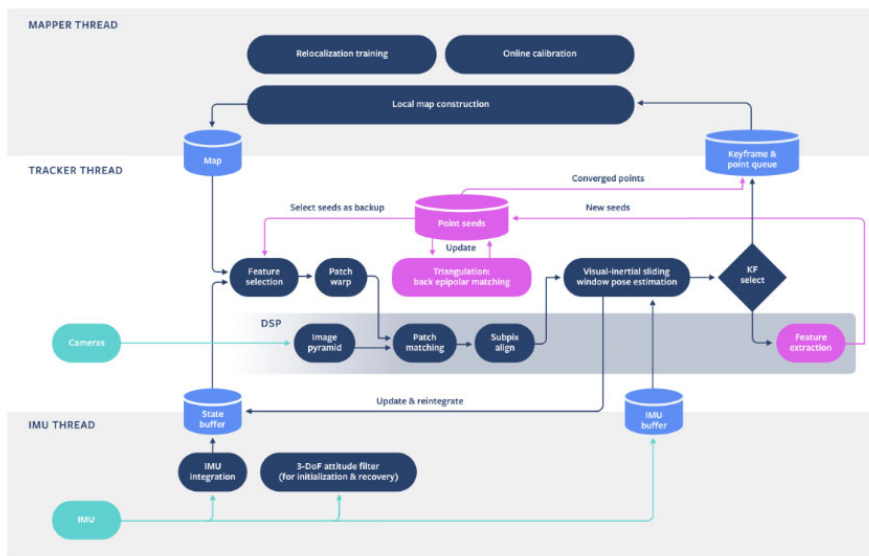
See also Powered by AI.

SLAM addresses these challenges by automatically recognizing features in the environment, letting Oculus Insight incorporate the player's current position into a VR display. Insight also uses an extrapolation function with dynamic damping to help predict where the user's head and hands will move in the milliseconds ahead. This provides a number of benefits, including reducing the visual stuttering effect known as jitter, which is the key metric that tracking systems are measured against. To help enable a comfortable VR experience, tracking should be in the submillimeter range, meaning that the system can track with precision greater than a single millimeter. Insight exceeds this target in most environments.

Another major factor to avoid in delivering immersive experiences is latency — any lag between physical movements and their VR equivalents can disorient the user and degrade the sense of realism. By using low-latency IMU data and a kinematic model that predicts a user's motion into the future, Insight is able to effectively eliminate the apparent latency. We'll go into more detail in the next section about the sensor fusion process that incorporates SLAM data, but reducing both jitter and latency is central to Insight's ability to deliver a new level of realism within VR.

See also id.

Headset tracking compute architecture



Oculus Insight processes multiple threads of data at once, in real-time — the mapper thread modifies the map, sending updated copies to the tracker thread, which uses camera frames to estimate poses in the mapper-provided frames, while the IMU thread uses measurements from the IMUs to update the latest SLAM state.

Claim 47

(47pre) A method of using multiple sensors in a tracking system comprising:

Facebook encourages, directs, or promotes users to use the Accused Products to carry out the claimed method, and Facebook performs the claimed method. For example, Facebook uses, and encourages users to use, multiple sensors (e.g., the cameras and/or IMUs within the headset, and/or the IMUs within the Oculus controller(s)) and use a position tracker (e.g., a headset-controller system) to track the position of an object (e.g., the user's hand(s) and/or Oculus controller(s)). The Accused Products are especially adapted to carry out this method, which is a material part of the claimed invention, and have no substantial noninfringing uses. Further, on information and belief, Facebook conditions a user's use of the Accused Products, and therefore the user's receipt of the benefits of the Accused Products, upon this method and establishes the manner or timing of that use (e.g., through its software and/or user instructions, which have not been provided at this stage of the litigation).

See, e.g., *Compare Headsets*.



Oculus Quest
All-In-One VR Gaming

TRACKING

Six Degrees of Freedom

With 6DOF, the headset tracks the movement of both your head and body, then translates them into VR with realistic precision. No external sensors required.



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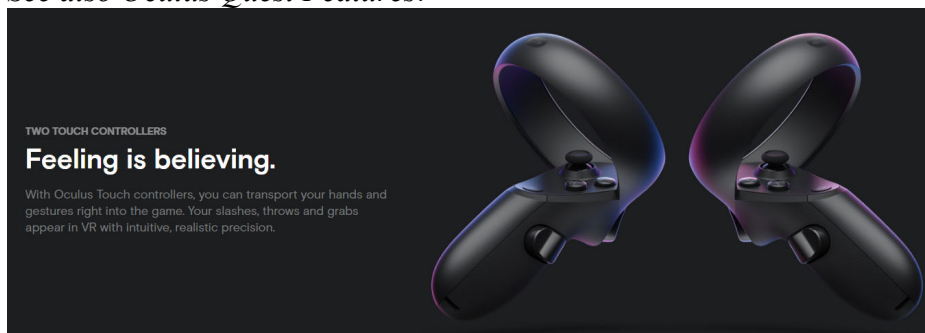
Oculus Rift S
PC-Powered VR Gaming

TRACKING

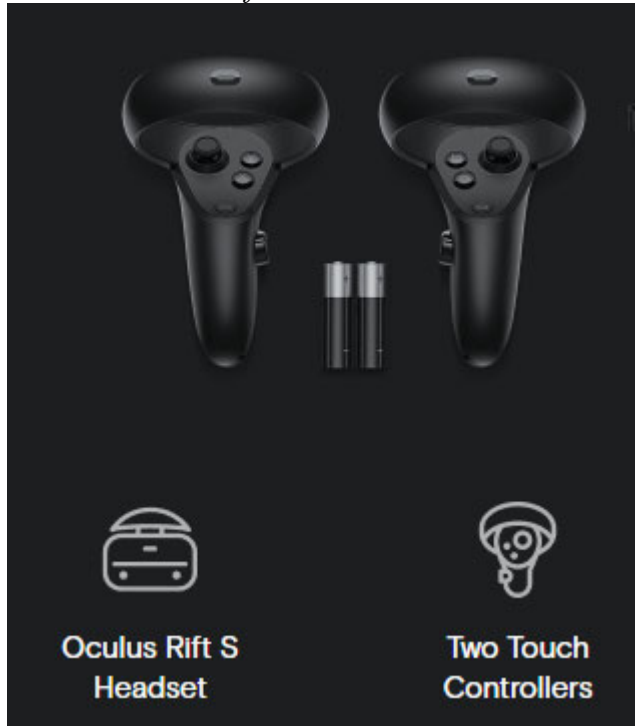
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See also Oculus Quest Features.



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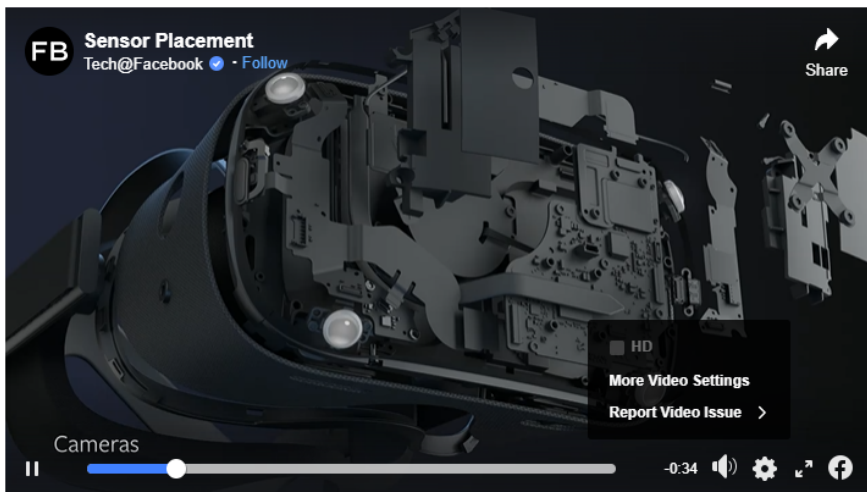
(47a) providing an estimation module;

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See, e.g., Oculus Quest Features.



See also From the Lab.



See also Oculus Rift S.

 A promotional graphic for the Oculus Rift S. On the left is a high-quality product photograph of the VR headset and its two Touch controllers. On the right is a text-based promotional area. At the top, it says "oculus rift s" in a small font. Below that is the main heading "PC-Powered VR Gaming" in a large, bold font. Underneath the heading is the subtext "Step into our best VR games." There are three buttons: a blue "Buy Now" button, a "\$399 USD*" button, and a "View PC requirements" button. Below these are three feature highlights, each with an icon and a short description:

- Improved Optics**: Improved optics deliver bright, vivid colors and reduced "screen-door" effect.
- Ergonomic Design**: The halo headband is redesigned with speed and comfort in mind.
- Oculus Touch Controllers**: Your slashes, throws and grabs appear in VR with intuitive, realistic precision.

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See also Oculus for Developers.

Oculus Quest 2

- Panel Type: Single Fast-Switch LCD, 1832×1920px per eye
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- USB Connector: 1x USB-C
- Tracking: Inside out, 6DOF

See also id.

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See also Lang.



Image courtesy BadVR, Jad Meouchy

Around the mainboard we can also see the headset's four cameras mounted at very purposeful angles at the corners. The cameras are essential to enabling 6DOF tracking on both the headset and the controllers; their views are also merged together to allow a pass-through vision mode on the headset which is used to trace the boundary of your playspace.

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The Oculus Insight system uses a custom hardware architecture and advanced computer vision algorithms — including visual-inertial mapping, place recognition, and geometry reconstruction — to establish the location of objects in relation to other objects within a given space. This novel algorithm stack enables a VR device to pinpoint its location, identify aspects of room geometry (such as floor location), and track the positions of the headset and controllers with respect to a 3D map that is generated and constantly updated by Insight. The data used for this process comes from three types of sensors built into the Quest and Rift S hardware:

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Kozminski joined a team whose mission was to create the first full-featured "inside-out" tracking system for a consumer VR device. The technology would have to track the full range of a person's movements (known as six degrees of freedom) and be able to pinpoint the location of the two handheld controllers as well as the headset.

Previously, VR devices relied on external sensors to track these movements. These cameras attach to a PC, and while they work well, they make VR less portable and more complicated to set up.

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See also Oculus Quest 2.



See also Compare Headsets.



Oculus Quest
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See also Heaney.

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Facebook's VR controllers are tracked via infrared LEDs under the plastic

See also Heaney.

The driver also reveals the series model number of the controller's inertial measurement unit (IMU)- the chip within all VR controllers which contains the accelerometer.

Teardowns and the FCC filings for the current Touch showed it uses TDK's ICM-20601 IMU from late 2015.



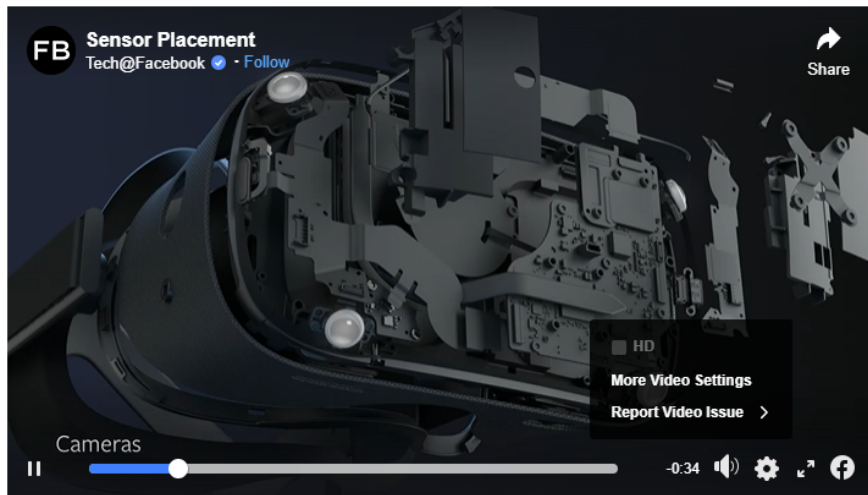
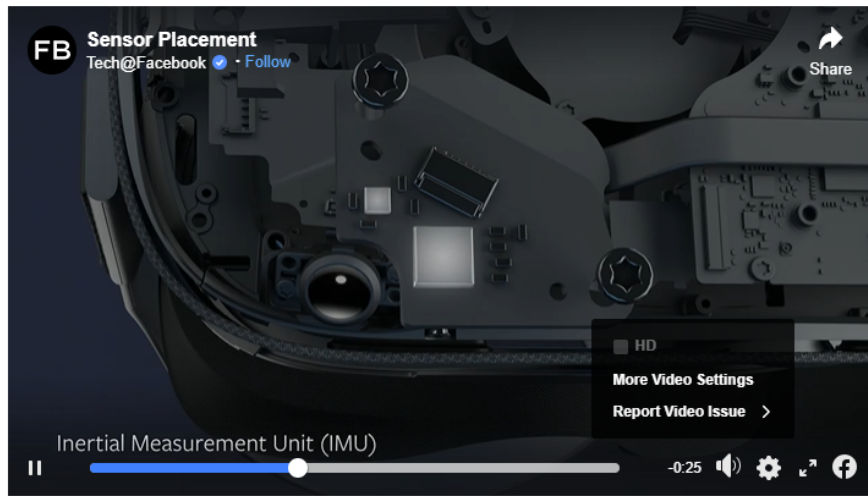
The IMU in the current Touch controllers for Rift S and Quest

See also ICM-20601 Specification.


	<p>FEATURES</p> <ul style="list-style-type: none"> • 3-Axis Gyroscope with Programmable FSR of $\pm 500\text{dps}$, $\pm 100\text{dps}$, $\pm 2000\text{dps}$ and $\pm 4000\text{dps}$ • 3-Axis Accelerometer with Programmable FSR of $\pm 4g$, $\pm 8g$, $\pm 16g$, and $\pm 32g$ • User-programmable interrupts • Wake-on-motion interrupt for low power operation of applications processor • 512 byte FIFO buffer enables the applications processor to read the data in bursts • On-Chip 16-bit ADCs and Programmable Filters • Host interface: 8 MHz SPI or 400k Hz Fast Mode I²C • Digital-output temperature sensor • VDD operating range of 1.71 to 3.45V • MEMS structure hermetically sealed and bonded at wafer level • RoHS and Green compliant
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See also From the Lab.



See also Oculus Rift S.






oculus rift s

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- 
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- 
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The driver also reveals the series model number of the controller's inertial measurement unit (IMU)- the chip within all VR controllers which contains the accelerometer.

Teardowns and the FCC filings for the current Touch showed it uses TDK's ICM-20601 IMU from late 2015.



The IMU in the current Touch controllers for Rift S and Quest

See also ICM-20601 Specification.

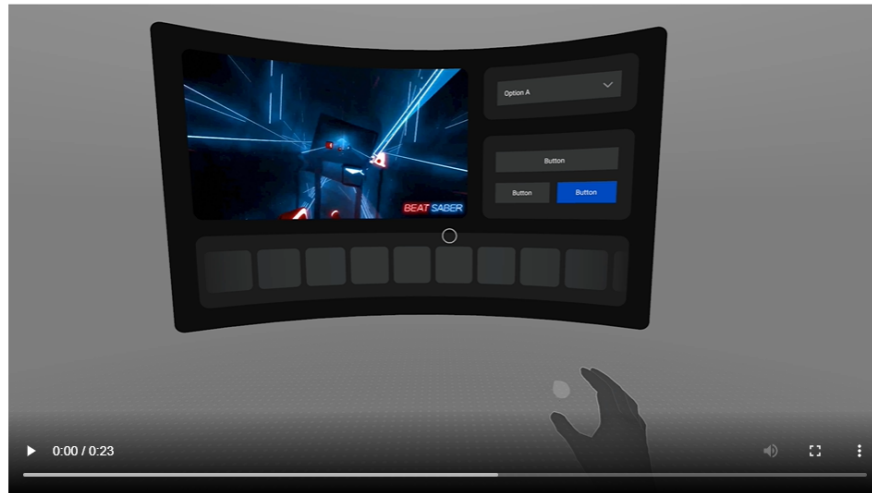
	<p>FEATURES</p> <ul style="list-style-type: none"> • 3-Axis Gyroscope with Programmable FSR of $\pm 500\text{dps}$, $\pm 100\text{dps}$, $\pm 2000\text{dps}$ and $\pm 4000\text{dps}$ • 3-Axis Accelerometer with Programmable FSR of $\pm 4g$, $\pm 8g$, $\pm 16g$, and $\pm 32g$ • User-programmable interrupts • Wake-on-motion interrupt for low power operation of applications processor • 512 byte FIFO buffer enables the applications processor to read the data in bursts • On-Chip 16-bit ADCs and Programmable Filters • Host interface: 8 MHz SPI or 400k Hz Fast Mode I²C • Digital-output temperature sensor • VDD operating range of 1.71 to 3.45V • MEMS structure hermetically sealed and bonded at wafer level • RoHS and Green compliant
<p>(47c) configuring the tracking system, including providing configuration information from each of the sensor modules to the estimation module regarding the characteristics of the sensors associated with the sensor module, and configuring the estimation module using the provided configuration information;</p>	<p>Facebook encourages, directs, or promotes users to use the Accused Products to configure the tracking system, including providing configuration information from each of the sensor modules to the estimation module regarding the characteristics of the sensors associated with the sensor module, and configuring the estimation module using the provided configuration information, and Facebook performs such step itself. For example, in the Accused Products, information regarding the characteristics of the available sensors, including optical sensors (e.g., cameras) and inertial sensors (e.g., IMUs), is provided to the tracking system so that the Oculus Insight tracking system can be configured using the applicable configuration information of the sensors in use at a given time. As a further example, the Accused Products can operate using both controllers, a single controller, or no controller at all, and this configuration information regarding the characteristics of the sensors is provided from each of the software components associated with the sensors to the Oculus Insight tracking system. The Accused Products are especially adapted to carry out this method, which is a material part of the claimed invention, and have no substantial noninfringing uses. Further, Facebook conditions a user's use of the Accused Products, and therefore the user's receipt of the benefits of the Accused Products, upon this method and establishes the manner or timing of that use.</p> <p><i>See, e.g., Hand Tracking.</i></p>

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See also Designing for Hands.
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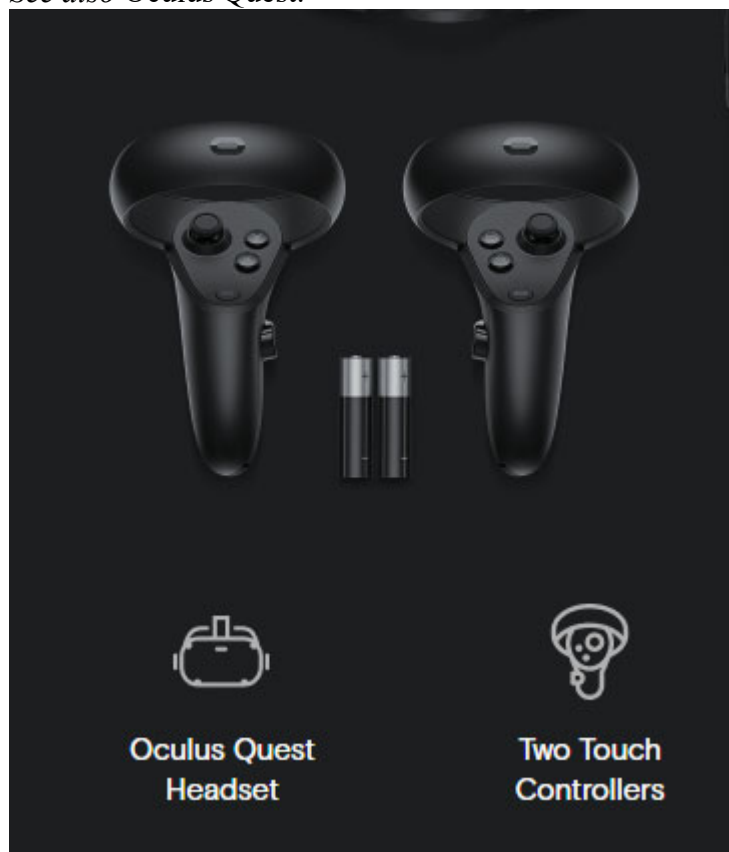
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Oculus Rift S
Headset

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Controllers

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There are other complications, too. The infrared LEDs in the two hand controllers drastically change appearance when they move closer or farther away from the headset as you swing a virtual sword or maneuver a virtual spaceship. Oculus Insight also uses other sensors, drawing acceleration and velocity data from the inertial measurement units (IMUs) located in the headset and controllers. The system must process all of these data points in real time and, in the case of Quest, on a mobile chipset.

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Taking SLAM technology ...

The foundation of Oculus Insight's inside-out tracking is [simultaneous localization and mapping, or SLAM](#), which uses computer vision CV algorithms to essentially fuse incoming data from multiple sensors in order to fix the position of an object within a constantly updated digital map. SLAM has been used in robotics and in [AR camera effects](#) on smartphones and was demoed in the Oculus [Santa Cruz VR headset prototype](#) in 2016. But Oculus Insight required an unprecedented level of precision and efficiency, and that meant adapting the latest research on tracking and computer vision.

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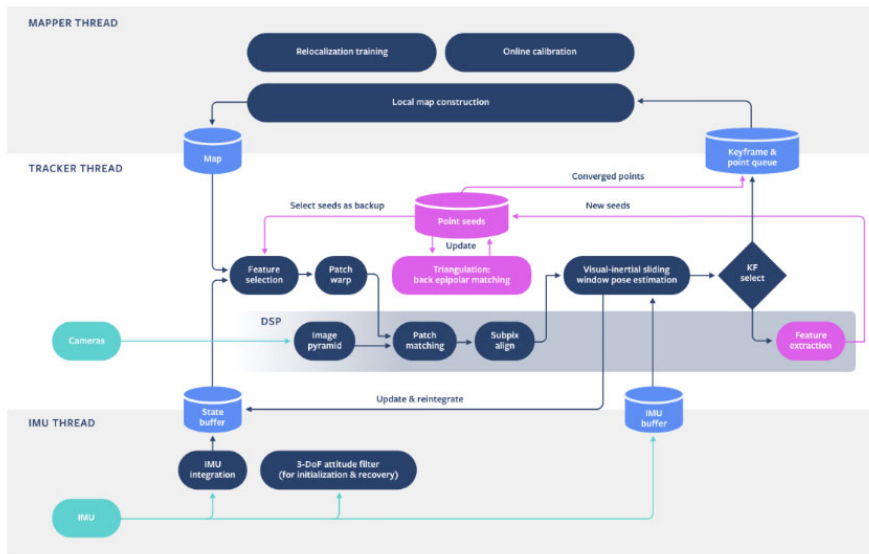
See also Powered by AI.

headset and controllers with respect to a 3D map that is generated and constantly updated by Insight. The data used for this process comes from three types of sensors built into the Quest and Rift S hardware:

1. Linear acceleration and rotational velocity data from IMUs in the headset and controllers are integrated to track the orientation and position of each with low latency.
2. Image data from cameras in the headset helps generate a 3D map of the room, pinpointing landmarks like the corners of furniture or the patterns on your floor. These landmarks are observed repeatedly, which enables Insight to compensate for drift (a common challenge with IMUs, where even tiny measurement discrepancies build up over time, resulting in inaccurate location tracking).
3. Infrared LEDs in the controllers are detected by the headset cameras, letting the system bound the controller position drift caused by integrating multiple IMUs.

See also id.

Headset tracking compute architecture

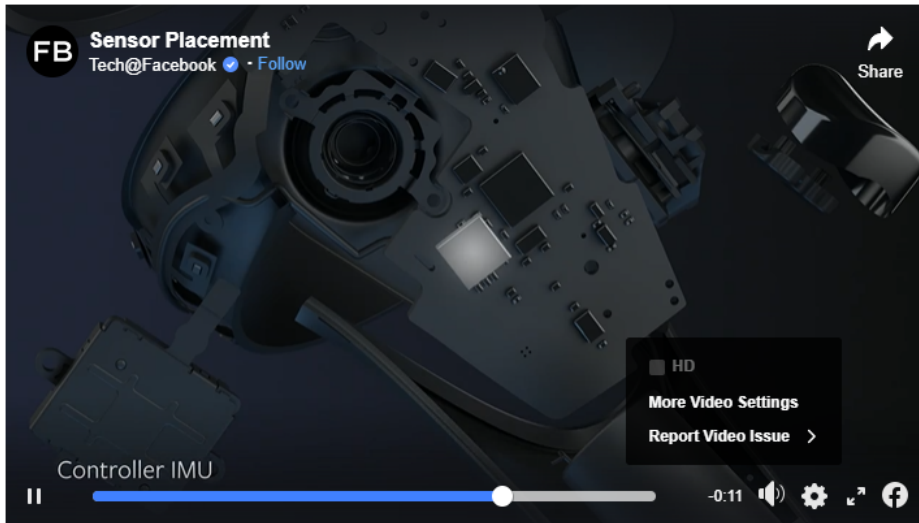


Oculus Insight processes multiple threads of data at once, in real-time — the mapper thread modifies the map, sending updated copies to the tracker thread, which uses camera frames to estimate poses in the mapper-provided frames, while the IMU thread uses measurements from the IMUs to update the latest SLAM state.

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More Precise Tracking

A function for infrared LED calibration exists, suggesting this controller is optically tracked in the same way as the current Touch— cameras on the headset follow the movement of the LED constellation, and this is fused with the accelerometer readings to achieve sub-mm precision.



Facebook's VR controllers are tracked via infrared LEDs under the plastic

See also Reddit Single Controller Discussion.

Does the Quest have a single controller mode for any games?

<https://imgur.com/a/1dLoatG>

My stepdad sent his old Oculus Go, it is a lot better than I expected! My good friend who is in the picture absolutely loves the Go. I make sure I bring it every time we hang out since I got it recently. He is able to play some of the games because there is only one controller. He would not be able to operate a controller with his other hand. We are looking at getting him one so we can play together, or both of us upgrading to the Quest. I was wondering if you guys have seen many games you can play with only one controller on the quest, or if we should stick to the Go. My friend would be doing a lot of video but I know he did like the ability to play some of the games. This has been the only video game system he has every really been able to play. I hope the quest will work out for us. Let me know what you guys think, thanks for the help.

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SORT BY BEST

maltakan0 6 points · 1 year ago

Virtual virtual reality can be played with one controller

MRHBK 5 points · 1 year ago

Quest is a bit heavier too if that is a factor

↑ stigzcousin 1 point · 1 year ago

↓ This is something I did not think about. Good to know. Thank you

jebwillnotdivideus 5 points · 1 year ago

Beatsaber and sportsscramble can be played with 1 controller. Other games im not sure.

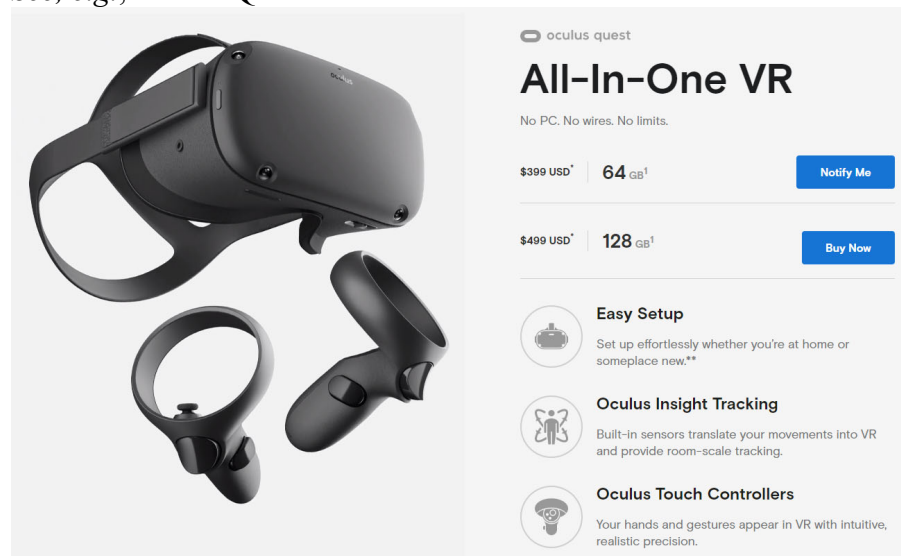
See also Expert Mode at 2:36.



(47d) maintaining estimates of tracking parameters in the estimation module, including repeatedly passing data based on the estimates of the tracking parameters from the estimation module to one or more of the sensor modules, receiving from said one or more sensor modules at the estimation module data based on measurements obtained from the associated sensors, and the data passed to the sensor modules, and combining the data received from said one or more sensor modules and the estimates of the tracking parameters in the estimation module to update the tracking parameters.

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See, e.g., Oculus Quest.



See also Oculus Quest Features.



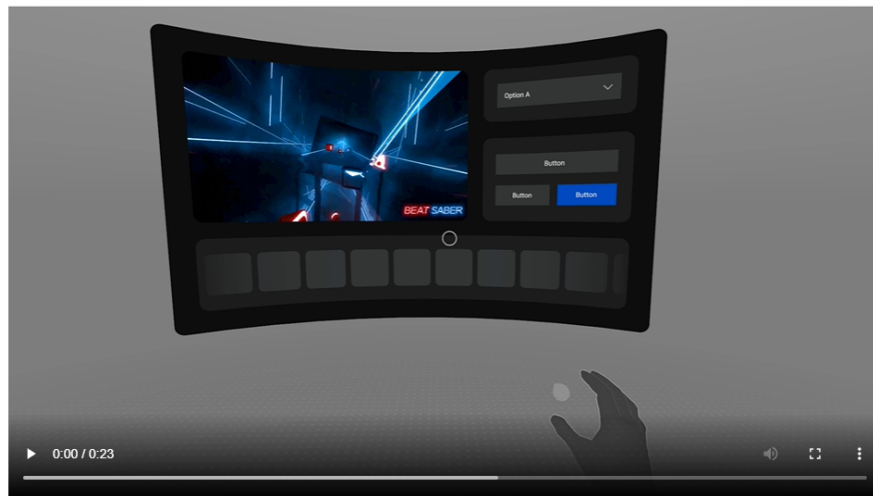
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See also Designing for Hands.
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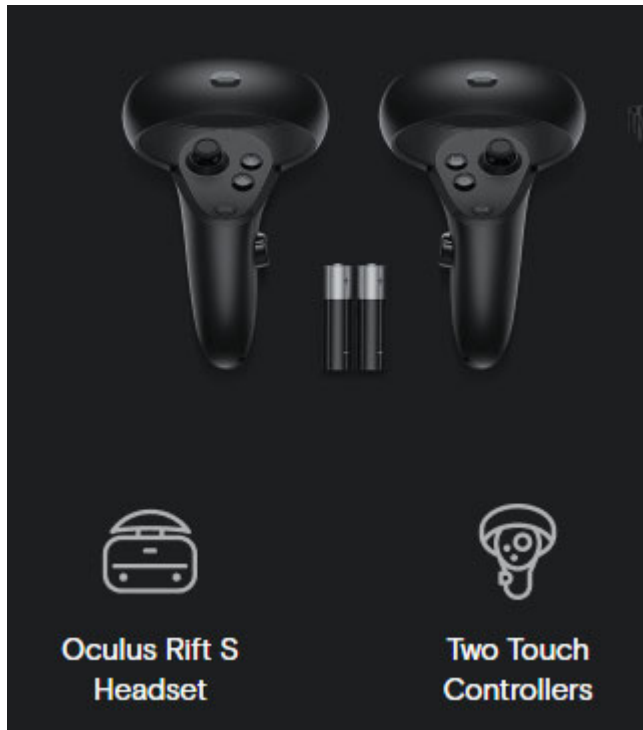
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visually anchored to real objects in the world. Oculus Insight is the second generation of this library, and it incorporates significantly more information from a combination of multiple IMUs and ultra-wide-angle cameras, as well as infrared LEDs to jointly track the 6DoF position of a VR headset and controllers.

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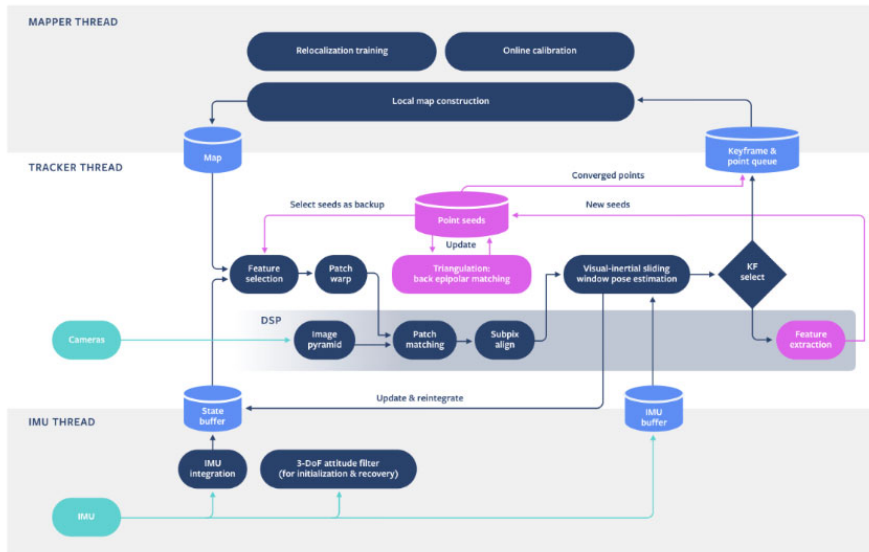
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Another major factor to avoid in delivering immersive experiences is latency — any lag between physical movements and their VR equivalents can disorient the user and degrade the sense of realism. By using low-latency IMU data and a kinematic model that predicts a user's motion into the future, Insight is able to effectively eliminate the apparent latency. We'll go into more detail in the next section about the sensor fusion process that incorporates SLAM data, but reducing both jitter and latency is central to Insight's ability to deliver a new level of realism within VR.

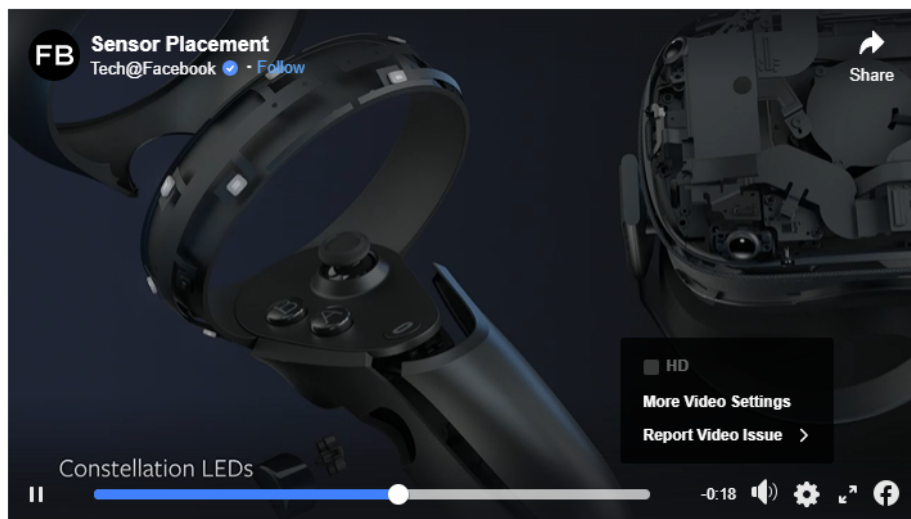
See also *id.*

Headset tracking compute architecture



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The IMU in the current Touch controllers for Rift S and Quest

See also ICM-20601 Specification.

Claim 48

(48) The method of claim 47 wherein the data passed from the estimation module to one or more of the sensor modules includes an estimate of the pose of a target relative to a sensor that was calculated by the estimation module using an estimate of the pose of a tracked object relative to a frame of reference fixed to an environment.

See supra claim 47. Facebook encourages, directs, or promotes users to use the Accused Products to perform the method of claim 47 in which the data passed from the estimation module to one or more of the sensor modules includes an estimate of the pose of a target relative to a sensor that was calculated by the estimation module using an estimate of the pose of a tracked object relative to a frame of reference fixed to an environment, and Facebook performs such step itself. For example, in the Accused Products, the estimation module (e.g., the Oculus Insight tracking system) passes data to one or more of the sensor modules (e.g., the software components associated with the cameras and/or IMUs in the headset and/or the IMUs in the Oculus controllers, and/or a computer or other external processor for the Oculus Rift S) that includes an estimate of the pose of a target relative to a sensor (e.g., the predicted position of the user's hand(s) and/or the Oculus controller(s) relative to the cameras in the headset). To calculate these estimates, the Oculus Insight tracking system uses an estimate of the pose of a tracked object (e.g., the user's hand(s) and/or the Oculus controller(s)) relative to a frame of reference fixed to an environment (e.g., landmarks like the corners of furniture or the patterns on the floor). The Accused Products are especially adapted to carry out this method, which is a material part of the claimed invention, and have no substantial noninfringing uses. Further, Facebook conditions a user's use of the Accused Products, and therefore the user's receipt of the benefits of the Accused Products, upon this method and establishes the manner or timing of that use.

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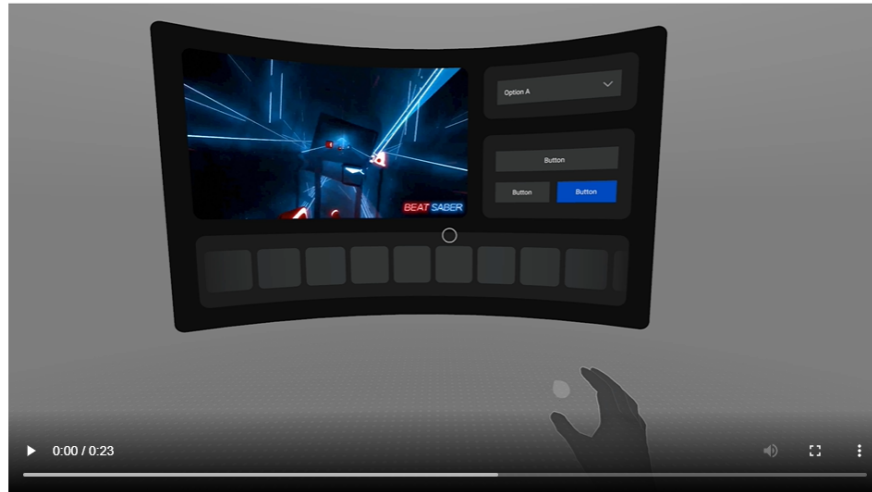
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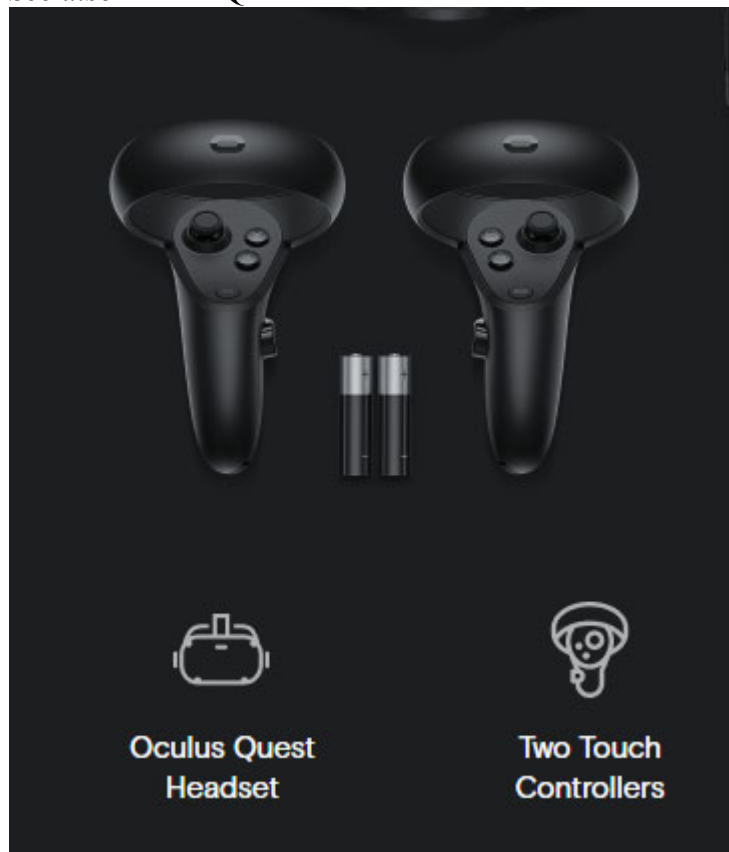
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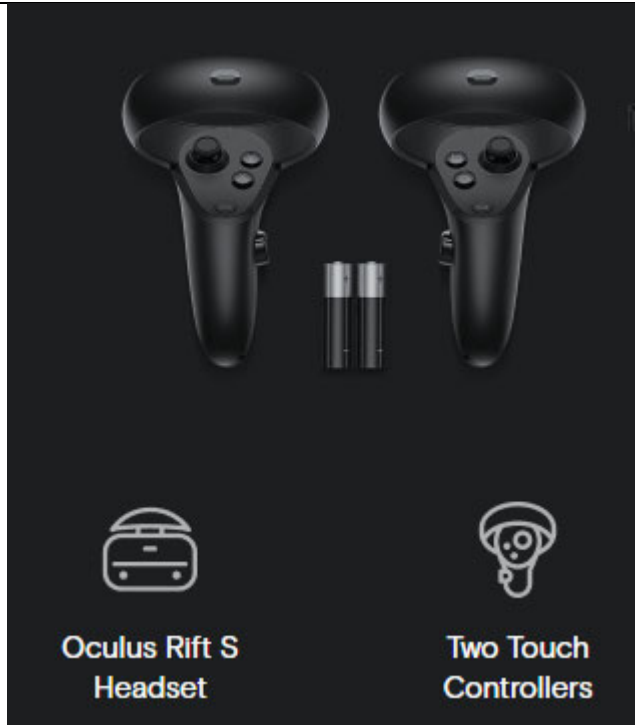
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See also Oculus Rift S.



Oculus Rift S
Headset

Two Touch
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See also Powered by AI.

Academic research has been done on SLAM techniques for several decades, but the technology has only recently become mature enough for consumer applications, such as driverless cars and mobile AR apps. Facebook previously released a version of [SLAM for AR on mobile devices](#) which uses a single camera and inertial measurement unit (IMU) to track a phone's position and enable world-locked content — content that's visually anchored to real objects in the world. Oculus Insight is the second generation of this library, and it incorporates significantly more information from a combination of multiple IMUs and ultra-wide-angle cameras, as well as infrared LEDs to jointly track the 6DoF position of a VR headset and controllers.

The Oculus Insight system uses a custom hardware architecture and advanced computer vision algorithms — including visual-inertial mapping, place recognition, and geometry reconstruction — to establish the location of objects in relation to other objects within a given space. This novel algorithm stack enables a VR device to pinpoint its location, identify aspects of room geometry (such as floor location), and track the positions of the headset and controllers with respect to a 3D map that is generated and constantly updated by Insight. The data used for this process comes from three types of sensors built into the Quest and Rift S hardware:

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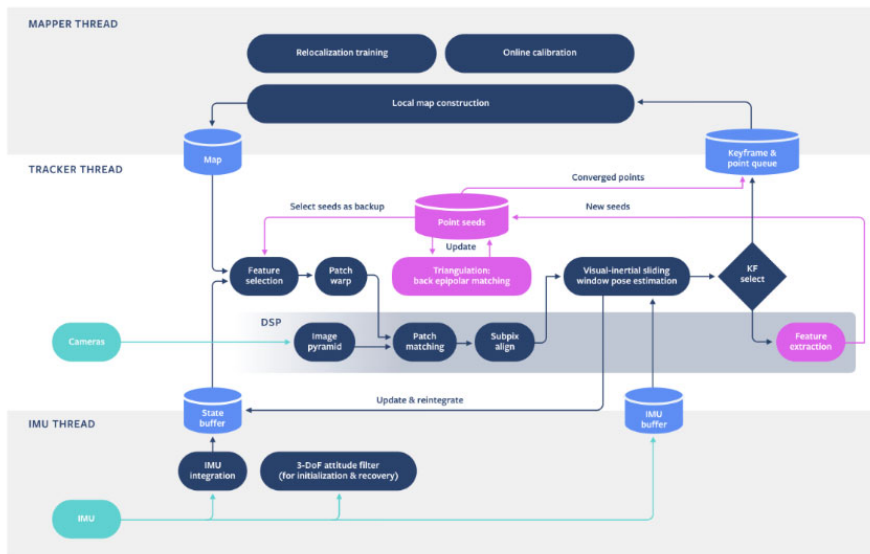
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SLAM addresses these challenges by automatically recognizing features in the environment, letting Oculus Insight incorporate the player's current position into a VR display. Insight also uses an extrapolation function with dynamic damping to help predict where the user's head and hands will move in the milliseconds ahead. This provides a number of benefits, including reducing the visual stuttering effect known as jitter, which is the key metric that tracking systems are measured against. To help enable a comfortable VR experience, tracking should be in the submillimeter range, meaning that the system can track with precision greater than a single millimeter. Insight exceeds this target in most environments.

Another major factor to avoid in delivering immersive experiences is latency — any lag between physical movements and their VR equivalents can disorient the user and degrade the sense of realism. By using low-latency IMU data and a kinematic model that predicts a user's motion into the future, Insight is able to effectively eliminate the apparent latency. We'll go into more detail in the next section about the sensor fusion process that incorporates SLAM data, but reducing both jitter and latency is central to Insight's ability to deliver a new level of realism within VR.

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Claim 49

(49) The method of claim 48 wherein the data passed from the estimation module to one or more of the sensor modules does not include the estimate of the pose of the tracked object relative to the frame

See supra claims 47, 48. Facebook encourages, directs, or promotes users to use the Accused Products to perform the method of claim 48 in which the data passed from the estimation module to one or more of the sensor modules does not include the estimate of the pose of the tracked object relative to the frame of reference fixed to the environment, and Facebook performs such step itself. For example, on information and belief and subject to discovery which has not yet occurred, in the Accused Products, the estimation module (e.g., the Oculus Insight tracking system) passes data to one or more of the sensor modules (e.g., the software components associated with the cameras and/or IMUs in the headset and/or the IMUs in the Oculus controllers, and/or a computer or other external processor for the Oculus Rift S) that does not include the estimate of the pose of a tracked object (e.g., the user's hand(s) and/or the Oculus controller(s)) relative to a

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See, e.g., Hand Tracking.

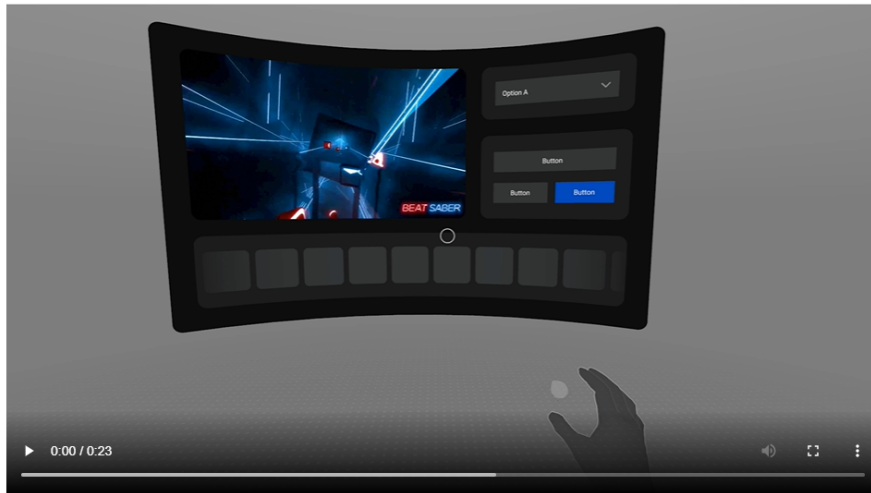
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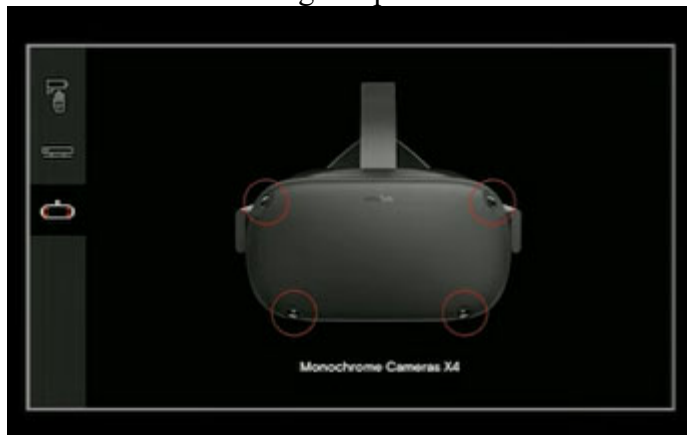
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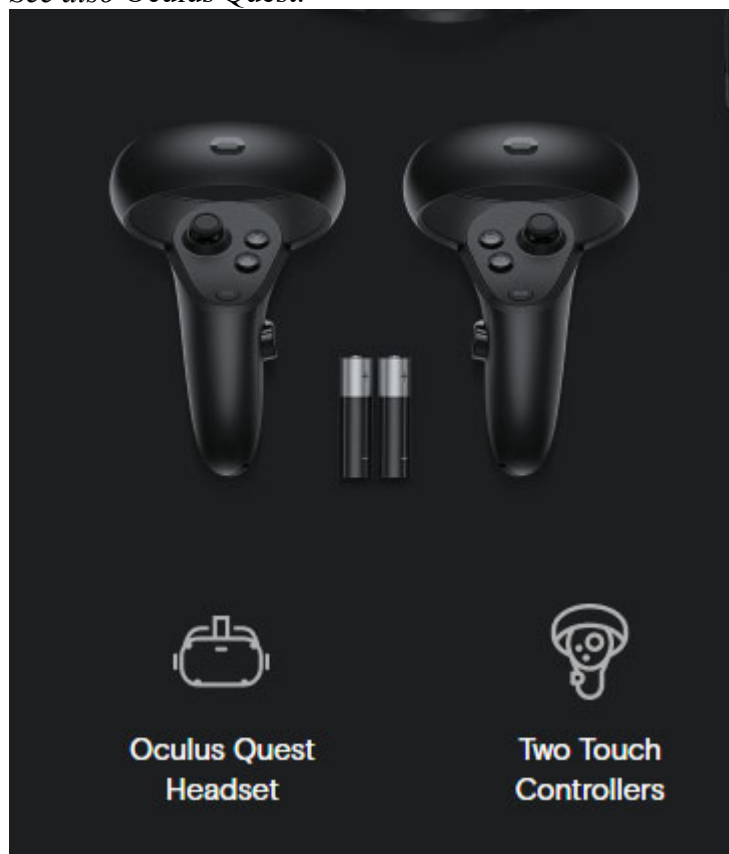
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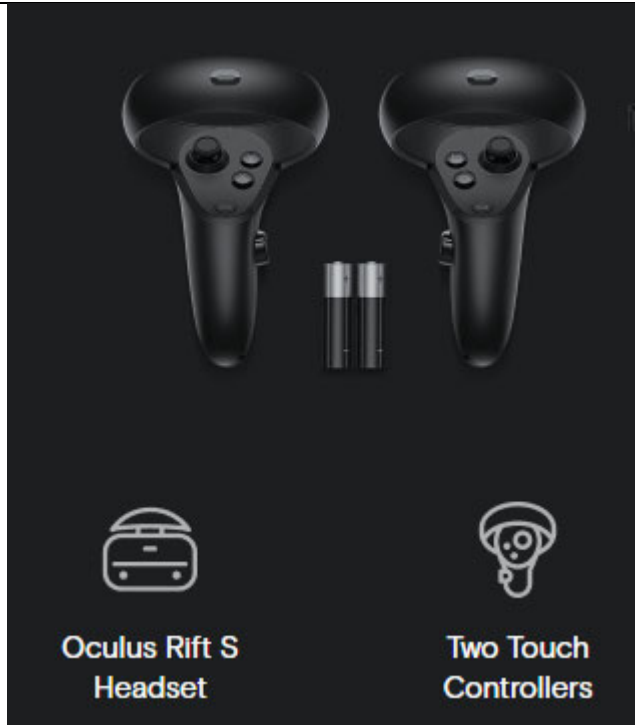
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See also Oculus Rift S.



See also From the Lab.

There are other complications, too. The infrared LEDs in the two hand controllers drastically change appearance when they move closer or farther away from the headset as you swing a virtual sword or maneuver a virtual spaceship. Oculus Insight also uses other sensors, drawing acceleration and velocity data from the inertial measurement units (IMUs) located in the headset and controllers. The system must process all of these data points in real time and, in the case of Quest, on a mobile chipset.

See also From the Lab.

Taking SLAM technology ...

The foundation of Oculus Insight's inside-out tracking is [simultaneous localization and mapping, or SLAM](#), which uses computer vision CV algorithms to essentially fuse incoming data from multiple sensors in order to fix the position of an object within a constantly updated digital map. SLAM has been used in robotics and in [AR camera effects](#) on smartphones and was demoed in the Oculus [Santa Cruz VR headset prototype](#) in 2016. But Oculus Insight required an unprecedented level of precision and efficiency, and that meant adapting the latest research on tracking and computer vision.

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To build a new, more advanced version of SLAM, the engineering team drew from Facebook's years of AI research and engineering work, building systems to understand the objects and actions that appear in videos and creating highly efficient computer vision algorithms that work well on mobile devices.

See also Powered by AI.

Academic research has been done on SLAM techniques for several decades, but the technology has only recently become mature enough for consumer applications, such as driverless cars and mobile AR apps. Facebook previously released a version of [SLAM for AR on mobile devices](#) which uses a single camera and inertial measurement unit (IMU) to track a phone's position and enable world-locked content — content that's visually anchored to real objects in the world. Oculus Insight is the second generation of this library, and it incorporates significantly more information from a combination of multiple IMUs and ultra-wide-angle cameras, as well as infrared LEDs to jointly track the 6DoF position of a VR headset and controllers.

The Oculus Insight system uses a custom hardware architecture and advanced computer vision algorithms — including visual-inertial mapping, place recognition, and geometry reconstruction — to establish the location of objects in relation to other objects within a given space. This novel algorithm stack enables a VR device to pinpoint its location, identify aspects of room geometry (such as floor location), and track the positions of the headset and controllers with respect to a 3D map that is generated and constantly updated by Insight. The data used for this process comes from three types of sensors built into the Quest and Rift S hardware:

See also Powered by AI.

headset and controllers with respect to a 3D map that is generated and constantly updated by Insight. The data used for this process comes from three types of sensors built into the Quest and Rift S hardware:

1. Linear acceleration and rotational velocity data from IMUs in the headset and controllers are integrated to track the orientation and position of each with low latency.
2. Image data from cameras in the headset helps generate a 3D map of the room, pinpointing landmarks like the corners of furniture or the patterns on your floor. These landmarks are observed repeatedly, which enables Insight to compensate for drift (a common challenge with IMUs, where even tiny measurement discrepancies build up over time, resulting in inaccurate location tracking).
3. Infrared LEDs in the controllers are detected by the headset cameras, letting the system bound the controller position drift caused by integrating multiple IMUs.

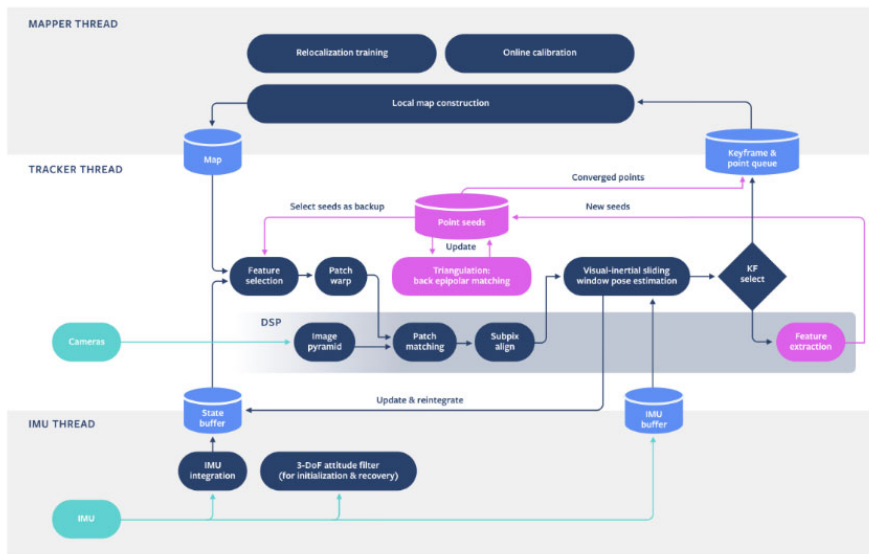
See also Powered by AI.

SLAM addresses these challenges by automatically recognizing features in the environment, letting Oculus Insight incorporate the player's current position into a VR display. Insight also uses an extrapolation function with dynamic damping to help predict where the user's head and hands will move in the milliseconds ahead. This provides a number of benefits, including reducing the visual stuttering effect known as jitter, which is the key metric that tracking systems are measured against. To help enable a comfortable VR experience, tracking should be in the submillimeter range, meaning that the system can track with precision greater than a single millimeter. Insight exceeds this target in most environments.

Another major factor to avoid in delivering immersive experiences is latency — any lag between physical movements and their VR equivalents can disorient the user and degrade the sense of realism. By using low-latency IMU data and a kinematic model that predicts a user's motion into the future, Insight is able to effectively eliminate the apparent latency. We'll go into more detail in the next section about the sensor fusion process that incorporates SLAM data, but reducing both jitter and latency is central to Insight's ability to deliver a new level of realism within VR.

See also id.

Headset tracking compute architecture



Oculus Insight processes multiple threads of data at once, in real-time — the mapper thread modifies the map, sending updated copies to the tracker thread, which uses camera frames to estimate poses in the mapper-provided frames, while the IMU thread uses measurements from the IMUs to update the latest SLAM state.

Claim 50

(50) The method of claim 47 wherein providing the estimation module includes providing a module that is configurable to use different sets of sensor modules coupled to it.

See supra claim 47. Facebook encourages, directs, or promotes users to use the Accused Products to perform the method of claim 47 in which providing the estimation module includes providing a module that is configurable to use different sets of sensor modules coupled to it, and Facebook performs such step itself. For example, in the Accused Products, the Oculus Insight tracking system is configurable to use different sets of sensor modules corresponding to different sensors, including optical sensors (e.g., cameras) and inertial sensors (e.g., IMUs), coupled to it at a given time. As a further example, the Accused Products can operate using both controllers, a single controller, or no controller at all, and this configuration information regarding the characteristics of the sensors is provided from each of the software components associated with the sensors to the Oculus Insight tracking system. The Oculus Insight tracking system in the Accused

Products is then configured to use different sets of sensor modules depending on the sensors available at a given time. The Accused Products are especially adapted to carry out this method, which is a material part of the claimed invention, and have no substantial noninfringing uses. Further, Facebook conditions a user's use of the Accused Products, and therefore the user's receipt of the benefits of the Accused Products, upon this method and establishes the manner or timing of that use.

See, e.g., Hand Tracking.

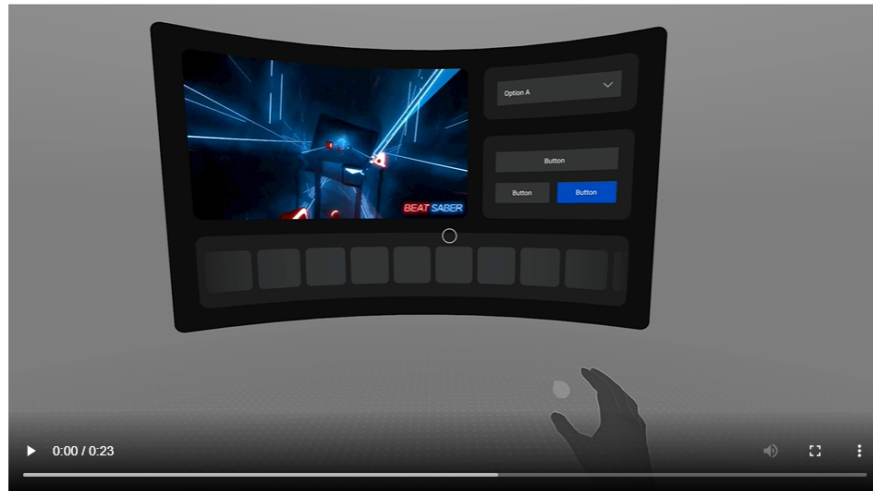
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The hand tracking feature lets you operate with hands and controllers interchangeably. When you opt to use hands, the hand's pose drives a laser cursor-pointer that behaves like the standard controller cursor. You can use the cursor-pointer to highlight, select, click, or write your own app-level event logic.

Hand tracking complements the Touch controllers and is not intended to replace controllers in all scenarios, especially with games or creative tools that require a high degree of precision. By opting-in to hand support, your app also needs to satisfy additional technical requirements specific to hand tracking in order to be accepted on Oculus Store. To submit an app to Oculus Store, the app must support controllers along with hand tracking.

See also Designing for Hands.

Designing for Hands



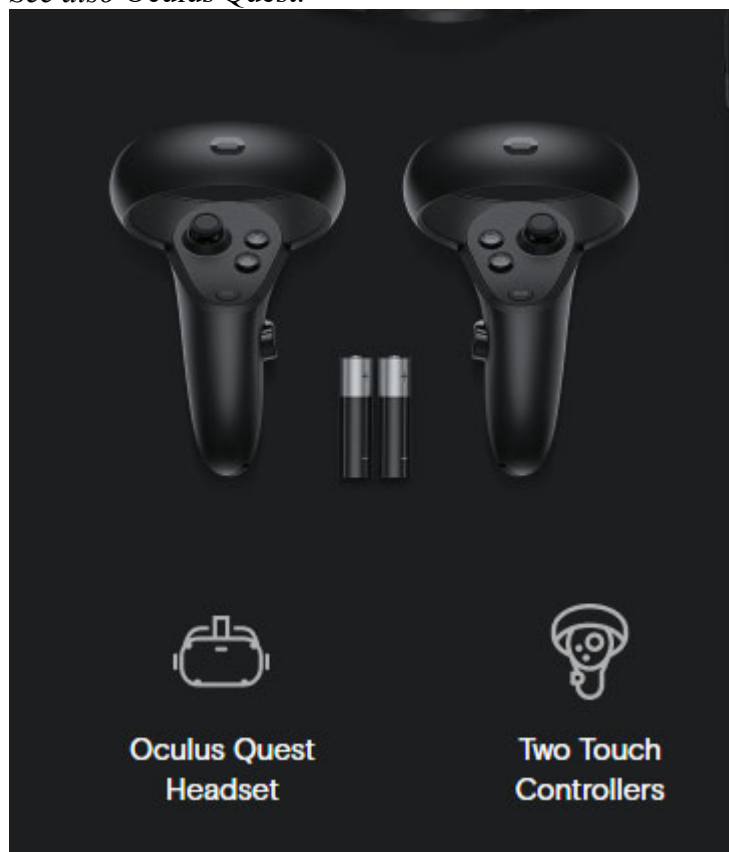
See also Hand Tracking Deep Dive.



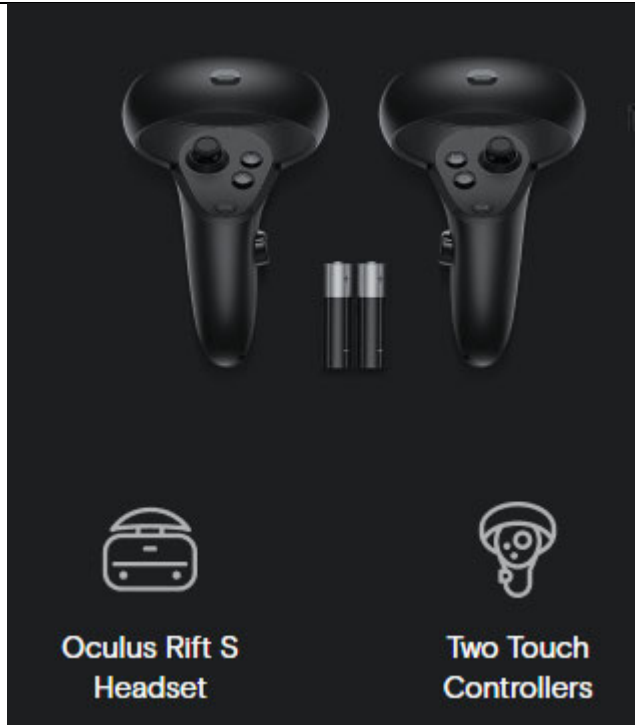
See also id. at 4:00–10:00.



See also Oculus Quest.



See also Oculus Rift S.



Oculus Rift S
Headset

Two Touch
Controllers

See also From the Lab.

There are other complications, too. The infrared LEDs in the two hand controllers drastically change appearance when they move closer or farther away from the headset as you swing a virtual sword or maneuver a virtual spaceship. Oculus Insight also uses other sensors, drawing acceleration and velocity data from the inertial measurement units (IMUs) located in the headset and controllers. The system must process all of these data points in real time and, in the case of Quest, on a mobile chipset.

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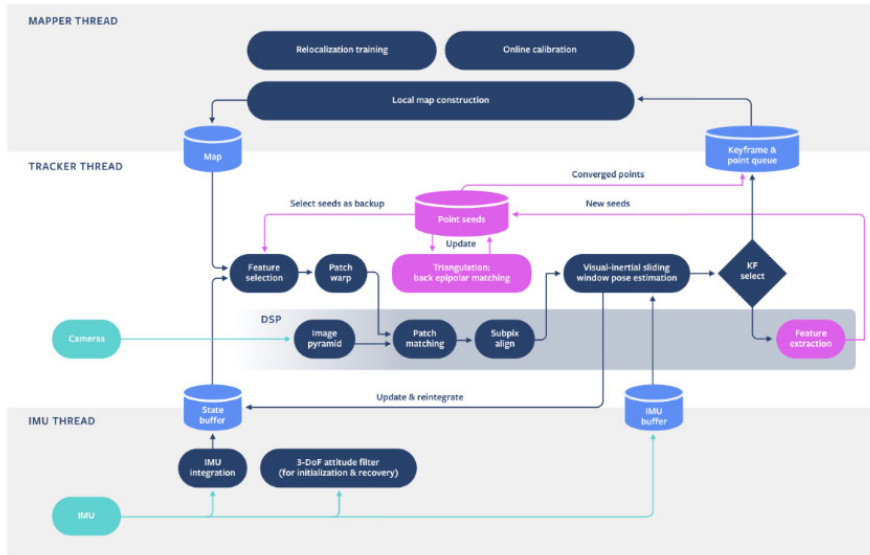
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3. Infrared LEDs in the controllers are detected by the headset cameras, letting the system bound the controller position drift caused by integrating multiple IMUs.

See also id.

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See also *From the Lab*, Sensor Placement at 0:23.



See also *From the Lab*, Sensor Placement at 0:30.



See also Heaney.

More Precise Tracking

A function for infrared LED calibration exists, suggesting this controller is optically tracked in the same way as the current Touch— cameras on the headset follow the movement of the LED constellation, and this is fused with the accelerometer readings to achieve sub-mm precision.



Facebook's VR controllers are tracked via infrared LEDs under the plastic

See also Reddit Single Controller Discussion.

Does the Quest have a single controller mode for any games?

<https://imgur.com/a/1dLoatG>

My stepdad sent his old Oculus Go, it is a lot better than I expected! My good friend who is in the picture absolutely loves the Go. I make sure I bring it every time we hang out since I got it recently. He is able to play some of the games because there is only one controller. He would not be able to operate a controller with his other hand. We are looking at getting him one so we can play together, or both of us upgrading to the Quest. I was wondering if you guys have seen many games you can play with only one controller on the quest, or if we should stick to the Go. My friend would be doing a lot of video but I know he did like the ability to play some of the games. This has been the only video game system he has every really been able to play. I hope the quest will work out for us. Let me know what you guys think, thanks for the help.

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SORT BY BEST

maltakan0 6 points · 1 year ago

Virtual virtual reality can be played with one controller

MRHBK 5 points · 1 year ago

Quest is a bit heavier too if that is a factor

↑ stigzcousin 1 point · 1 year ago

↓ This is something I did not think about. Good to know. Thank you

jebwillnotdivideus 5 points · 1 year ago

Beatsaber and sportsscramble can be played with 1 controller. Other games im not sure.

See also Expert Mode at 2:36.



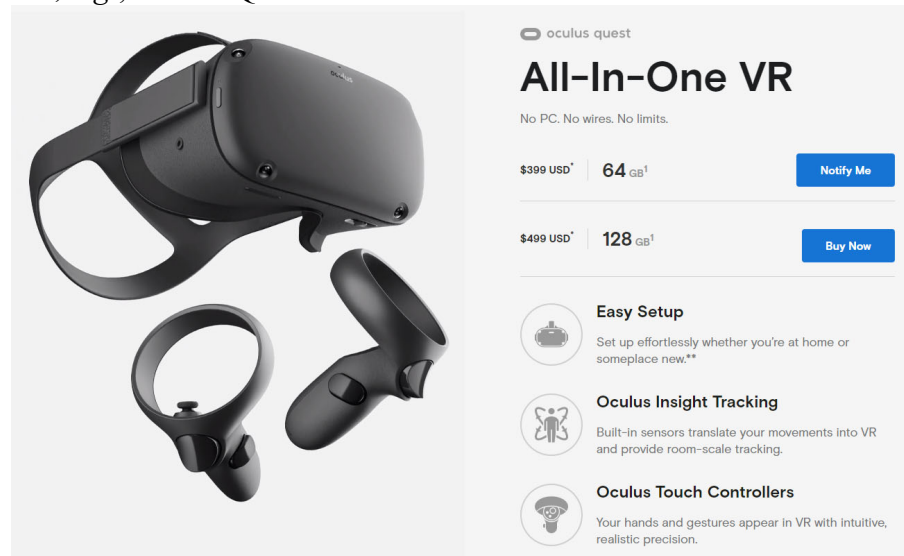
Claim 51

(51) The method of claim 47 wherein maintaining estimates of the tracking parameters in the estimation module includes using a stochastic model in the estimation module.

See supra claim 47. Facebook encourages, directs, or promotes users to use the Accused Products to perform the method of claim 47 in which maintaining estimates of the tracking parameters in the estimation module includes using a stochastic model in the estimation module, and Facebook performs such step itself. For example, on information and belief and subject to discovery which has not yet occurred, the Oculus Insight tracking system in the Accused Products predicts the position of the user’s hand(s) and/or the Oculus controller(s) using a stochastic model. The Accused Products are especially adapted to carry out this method, which is a material part of the claimed invention, and have no substantial noninfringing uses. Further, Facebook conditions a user’s use of the Accused Products, and therefore the user’s receipt of the benefits of the Accused Products, upon this method and establishes the manner or timing of that use.

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See, e.g., Oculus Quest.



See also Oculus Quest Features.



See, e.g., **Hand Tracking.**

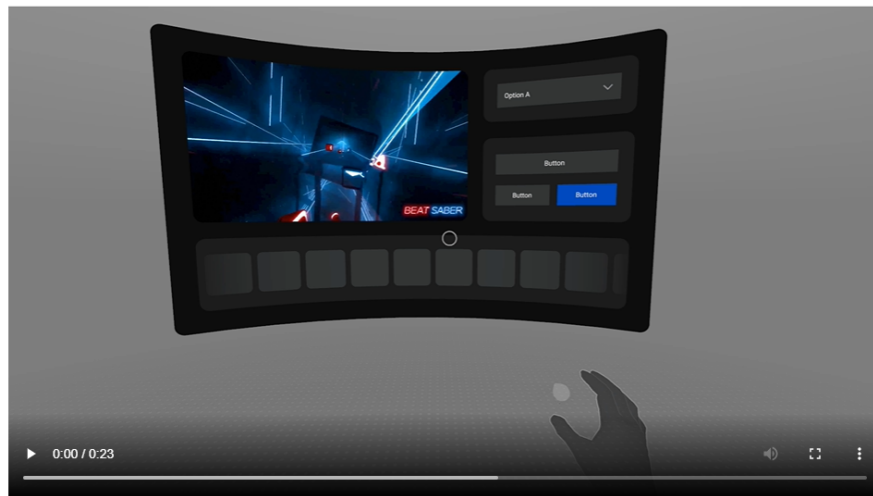
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See also **Designing for Hands.**

Designing for Hands



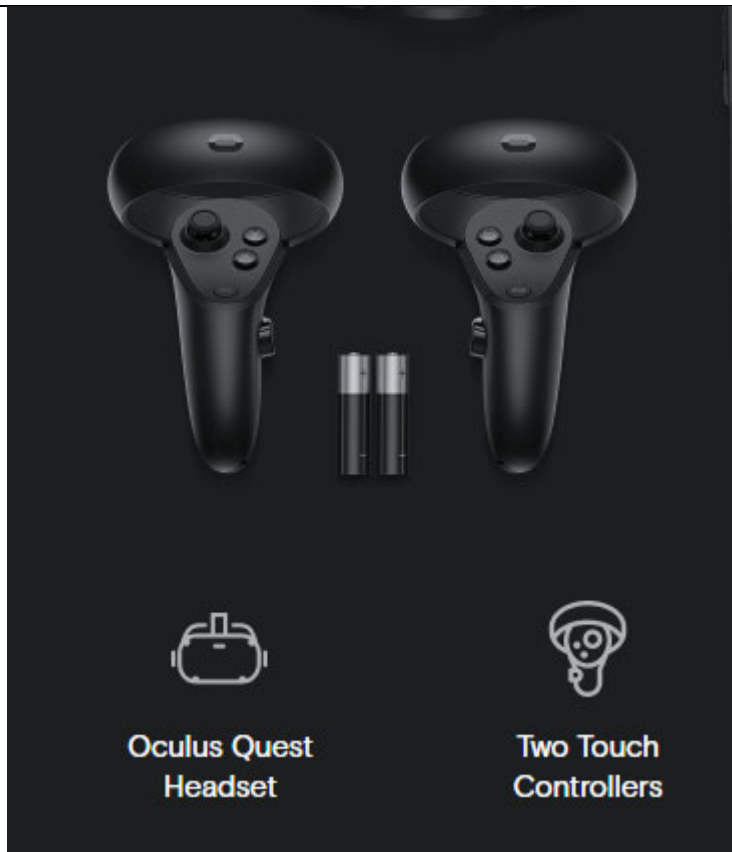
See also **Hand Tracking Deep Dive at 4:00–10:00.**



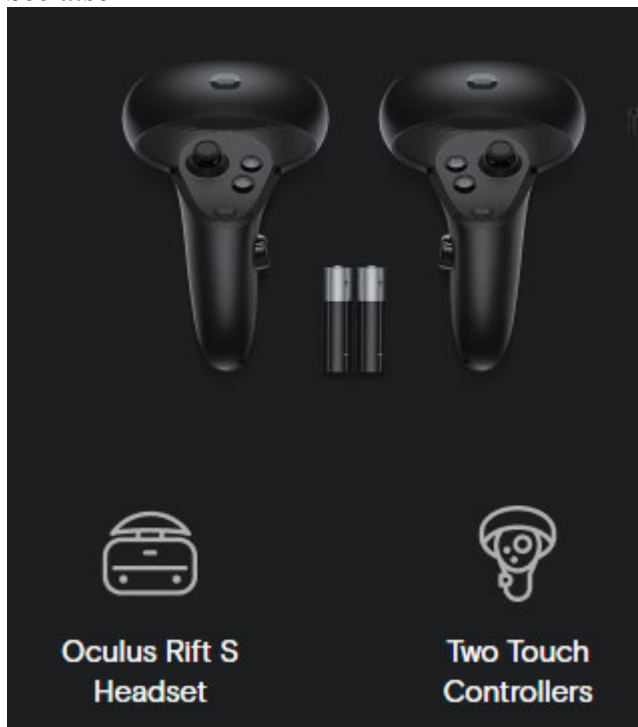
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See also Oculus Quest.



See also Oculus Rift S.



See also From the Lab.

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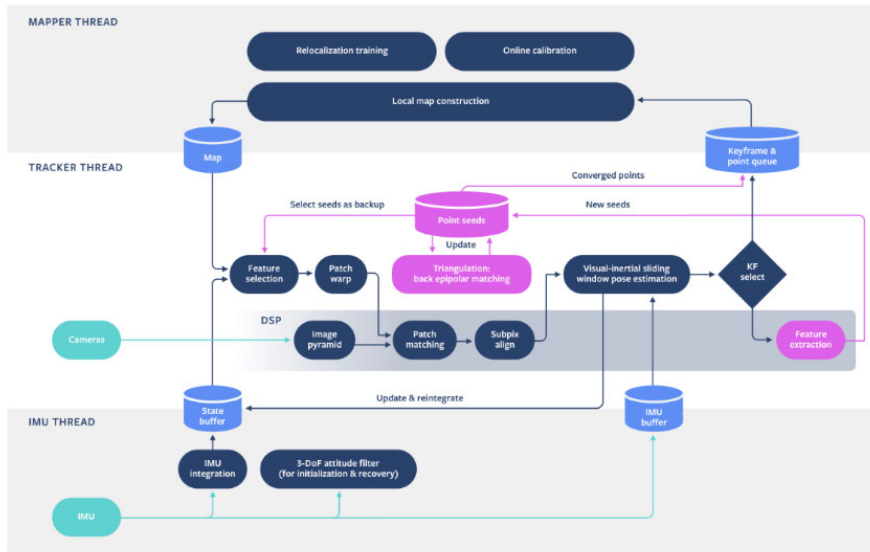
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See also *id.*

Headset tracking compute architecture

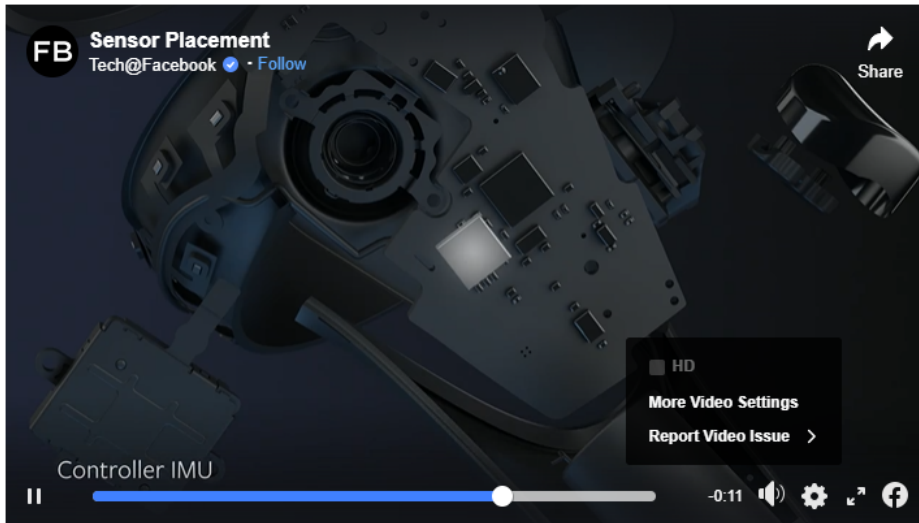


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A function for infrared LED calibration exists, suggesting this controller is optically tracked in the same way as the current Touch— cameras on the headset follow the movement of the LED constellation, and this is fused with the accelerometer readings to achieve sub-mm precision.



Facebook's VR controllers are tracked via infrared LEDs under the plastic

See also id.

The driver also reveals the series model number of the controller's inertial measurement unit (IMU)- the chip within all VR controllers which contains the accelerometer.

Teardowns and the [FCC filings](#) for the current Touch showed it uses TDK's ICM-20601 IMU from late 2015.



The IMU in the current Touch controllers for Rift S and Quest

See also ICM-20601 Specification.

Claim 52

(52) The method of claim 51 wherein using a stochastic model includes implementing some or all of a Kalman filter in the estimation module.

See supra claims 47, 51. Facebook encourages, directs, or promotes users to use the Accused Products to perform the method of claim 51 in which using a stochastic model includes implementing some or all of a Kalman filter in the estimation module, and Facebook performs such step itself. For example, on information and belief and subject to discovery which has not yet occurred, the Oculus Insight tracking system in the Accused Products implements some or all of a Kalman filter to update the estimated positions and orientations of objects (e.g., the user's head, the user's hand(s), and/or the Oculus controller(s)). The Accused Products are especially adapted to carry out this method, which is a material part of the claimed invention, and have no substantial noninfringing uses. Further, Facebook conditions a user's use of the Accused Products, and therefore the user's receipt of the benefits of the Accused Products, upon this method and establishes the manner or timing of that use.

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See also Designing for Hands.
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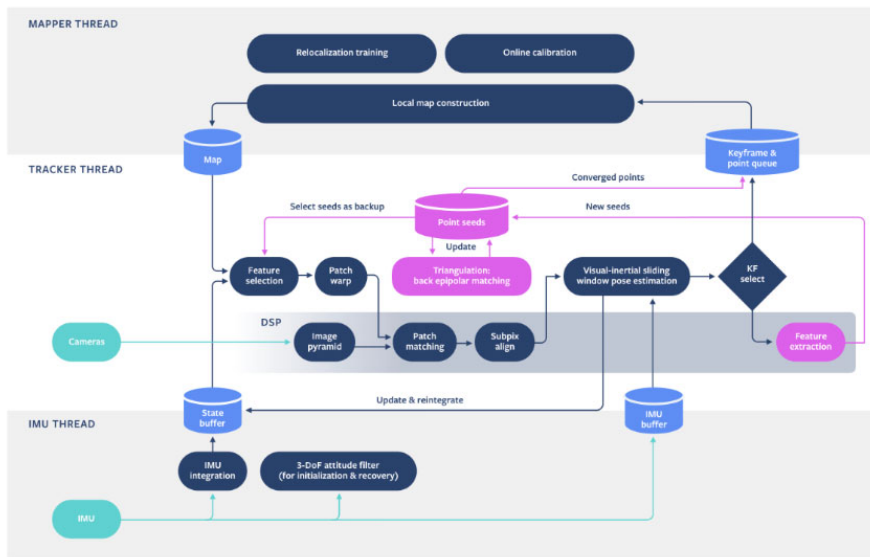
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Claim 53

(53) The method of claim 52 wherein implementing some or all of the Kalman filter includes updating error estimates using linearized models of the sensor system.

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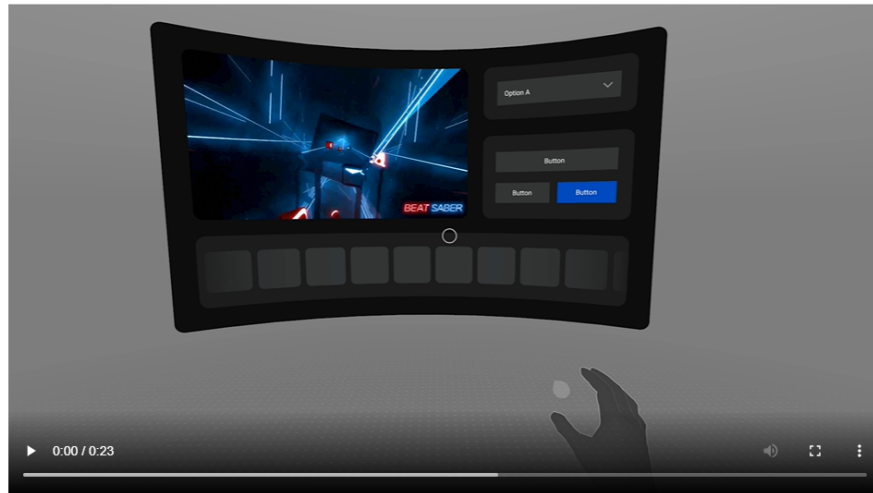
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See also Powered by AI.

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See also id.

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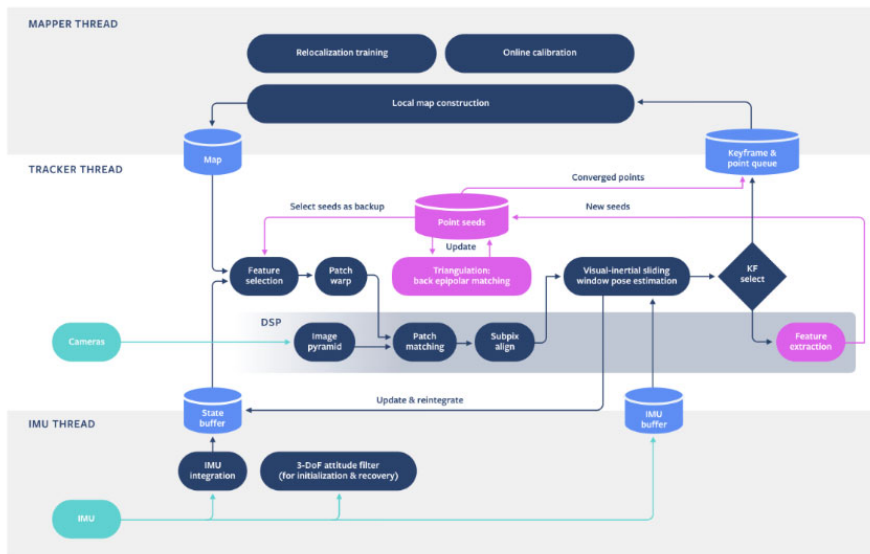
1. Linear acceleration and rotational velocity data from IMUs in the headset and controllers are integrated to track the orientation and position of each with low latency.
2. Image data from cameras in the headset helps generate a 3D map of the room, pinpointing landmarks like the corners of furniture or the patterns on your floor. These landmarks are observed repeatedly, which enables Insight to compensate for drift (a common challenge with IMUs, where even tiny measurement discrepancies build up over time, resulting in inaccurate location tracking).
3. Infrared LEDs in the controllers are detected by the headset cameras, letting the system bound the controller position drift caused by integrating multiple IMUs.

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Another major factor to avoid in delivering immersive experiences is latency — any lag between physical movements and their VR equivalents can disorient the user and degrade the sense of realism. By using low-latency IMU data and a kinematic model that predicts a user's motion into the future, Insight is able to effectively eliminate the apparent latency. We'll go into more detail in the next section about the sensor fusion process that incorporates SLAM data, but reducing both jitter and latency is central to Insight's ability to deliver a new level of realism within VR.

See also id.

Headset tracking compute architecture



Oculus Insight processes multiple threads of data at once, in real-time — the mapper thread modifies the map, sending updated copies to the tracker thread, which uses camera frames to estimate poses in the mapper-provided frames, while the IMU thread uses measurements from the IMUs to update the latest SLAM state.

See also Heaney.

More Precise Tracking

A function for infrared LED calibration exists, suggesting this controller is optically tracked in the same way as the current Touch— cameras on the headset follow the movement of the LED constellation, and this is fused with the accelerometer readings to achieve sub-mm precision.



Facebook's VR controllers are tracked via infrared LEDs under the plastic

Claim 54

(54) The method of claim 52 wherein implementing some or all of the Kalman filter includes implementing a distributed Kalman filter, wherein each of a plurality of components of the distributed Kalman filter is associated with a different subset of the sensor modules.

See supra claims 47, 51, 52. Facebook encourages, directs, or promotes users to use the Accused Products to perform the method of claim 52 in which implementing some or all of the Kalman filter includes implementing a distributed Kalman filter, wherein each of a plurality of components of the distributed Kalman filter is associated with a different subset of the sensor modules, and Facebook performs such step itself. For example, on information and belief and subject to discovery which has not yet occurred, the Oculus Insight tracking system in the Accused Products implements a distributed Kalman filter to update the estimated positions and orientations of objects (e.g., the user's head, the user's hand(s), and/or the Oculus controller(s)), in which each of the components of the distributed Kalman filter is associated with a different subset of the sensor modules corresponding to the available sensors (e.g., the cameras and/or IMUs in the headset and/or the IMUs in the Oculus controllers). The Accused Products are especially adapted to carry out this method, which is a material part of the claimed invention, and have no substantial noninfringing uses. Further, Facebook conditions a user's use of the Accused Products, and therefore the user's receipt of the benefits of the Accused Products, upon this method and establishes the manner or timing of that use.

To the extent this limitation is not met literally, the Accused Products also satisfy this limitation under the doctrine of equivalents. Any difference between the Accused Products and the claim element is insubstantial.

See, e.g., Hand Tracking.

The hand tracking feature enables the use of hands as an input method for the Oculus Quest device. It delivers a new sense of presence, enhances social engagement, and delivers more natural interactions with fully tracked hands and articulated fingers. Integrated hands can perform object interactions by using simple hand gestures such as pinch, unpinch, and pinch and hold.

The hand tracking feature lets you operate with hands and controllers interchangeably. When you opt to use hands, the hand's pose drives a laser cursor-pointer that behaves like the standard controller cursor. You can use the cursor-pointer to highlight, select, click, or write your own app-level event logic.

Hand tracking complements the Touch controllers and is not intended to replace controllers in all scenarios, especially with games or creative tools that require a high degree of precision. By opting-in to hand support, your app also needs to satisfy additional technical requirements specific to hand tracking in order to be accepted on Oculus Store. To submit an app to Oculus Store, the app must support controllers along with hand tracking.

See also Designing for Hands.
Designing for Hands



See also Hand Tracking Deep Dive at 4:00–10:00.



See also id. at 4:00–10:00.



See also From the Lab.

There are other complications, too. The infrared LEDs in the two hand controllers drastically change appearance when they move closer or farther away from the headset as you swing a virtual sword or maneuver a virtual spaceship. Oculus Insight also uses other sensors, drawing acceleration and velocity data from the inertial measurement units (IMUs) located in the headset and controllers. The system must process all of these data points in real time and, in the case of Quest, on a mobile chipset.

See also id.

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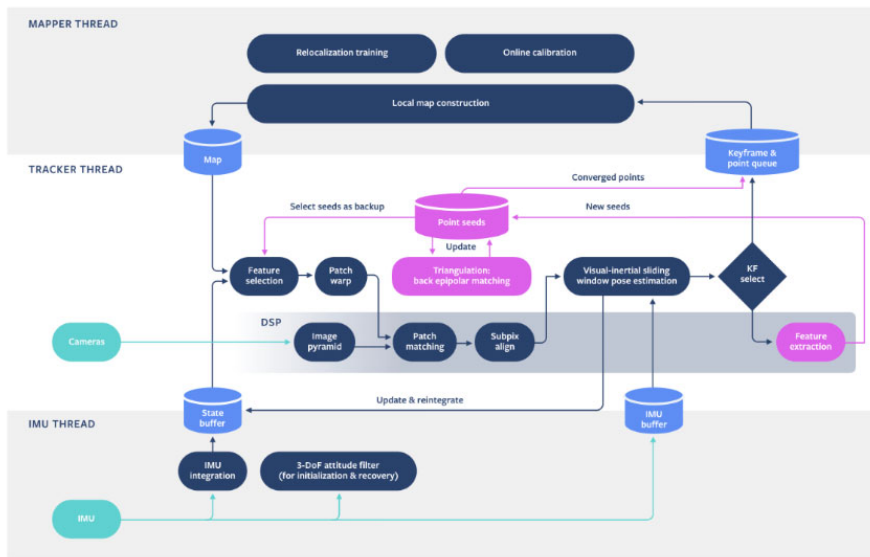
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Facebook's VR controllers are tracked via infrared LEDs under the plastic

Claim 55

(55) The method of claim 54 wherein one of the components of the distributed Kalman filter is associated with a subset of sensor modules consisting of sensor modules that are affixed to a tracked object.

See supra claims 47, 51, 52, 54. Facebook encourages, directs, or promotes users to use the Accused Products to perform the method of claim 54 in which one of the components of the distributed Kalman filter is associated with a subset of sensor modules consisting of sensor modules that are affixed to a tracked object, and Facebook performs such step itself. For example, on information and belief and subject to discovery which has not yet occurred, the Oculus Insight tracking system in the Accused Products implements a distributed Kalman filter to update the estimated positions and orientations of objects (e.g., the user's head, the user's hand(s), and/or the Oculus controller(s)). One of the components of the distributed Kalman filter are associated with the sensor modules corresponding to the IMUs in the Oculus controller(s), which are tracked objects. The Accused Products are especially adapted to carry out this method, which is a material part of the claimed invention, and have no substantial noninfringing uses. Further, Facebook conditions a user's use of the Accused Products, and therefore the user's receipt of the benefits of the Accused Products, upon this method and establishes the manner or timing of that use.

To the extent this limitation is not met literally, the Accused Products also satisfy this limitation under the doctrine of equivalents. Any difference between the Accused Products and the claim element is insubstantial.

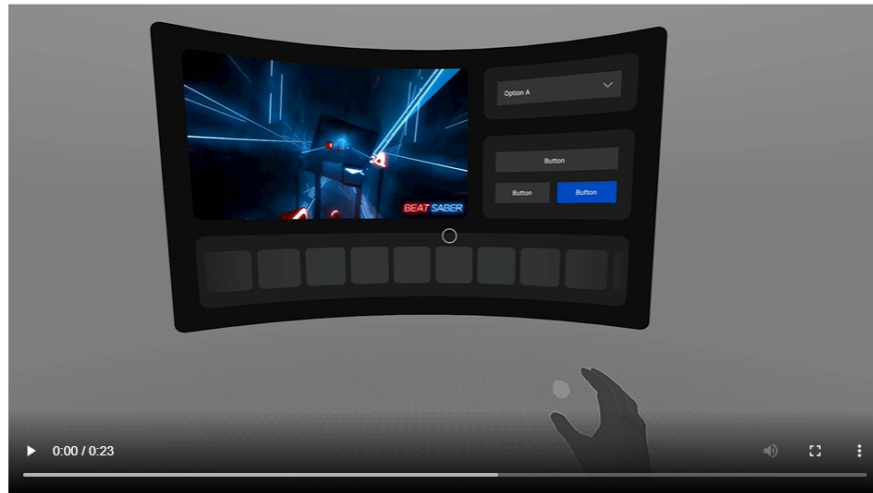
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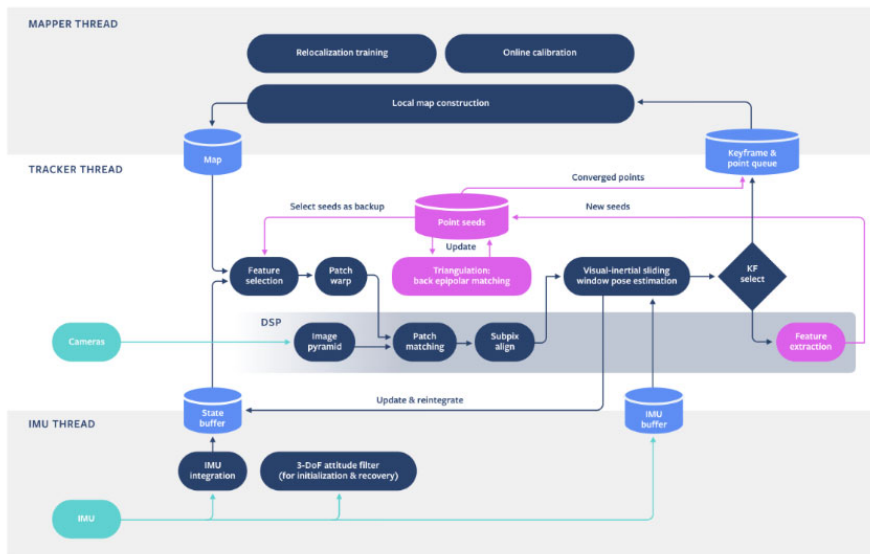
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Facebook's VR controllers are tracked via infrared LEDs under the plastic

Claim 57

(57) The method of claim 54 wherein one of the components of the distributed Kalman filter is not associated with any sensor modules.

See supra claims 47, 51, 52, 54. Facebook encourages, directs, or promotes users to use the Accused Products to perform the method of claim 54 in which one of the components of the distributed Kalman filter is not associated with any sensor modules, and Facebook performs such step itself. For example, on information and belief and subject to discovery which has not yet occurred, the Oculus Insight tracking system in the Accused Products implements a distributed Kalman filter to update the estimated positions and orientations of objects (e.g., the user's head, the user's hand(s), and/or the Oculus controller(s)). At least one of the components of the distributed Kalman filter is the predicted positions of the user's hand(s) and/or the Oculus controller(s), which are not associated with any sensor modules. The Accused Products are especially adapted to carry out this method, which is a material part of the claimed invention, and have no substantial noninfringing uses. Further, Facebook conditions a user's use of the Accused Products, and therefore the user's receipt of the benefits of the Accused Products, upon this method and establishes the manner or timing of that use.

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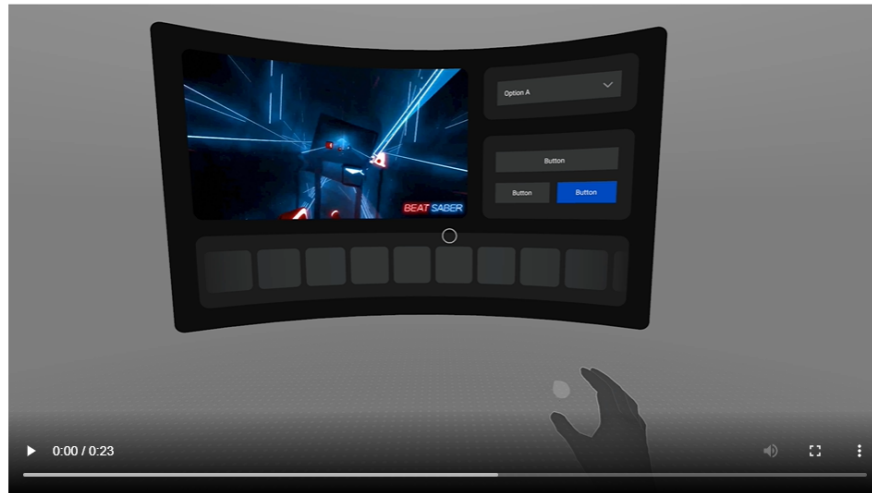
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See also Designing for Hands.
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There are other complications, too. The infrared LEDs in the two hand controllers drastically change appearance when they move closer or farther away from the headset as you swing a virtual sword or maneuver a virtual spaceship. Oculus Insight also uses other sensors, drawing acceleration and velocity data from the inertial measurement units (IMUs) located in the headset and controllers. The system must process all of these data points in real time and, in the case of Quest, on a mobile chipset.

See also id.

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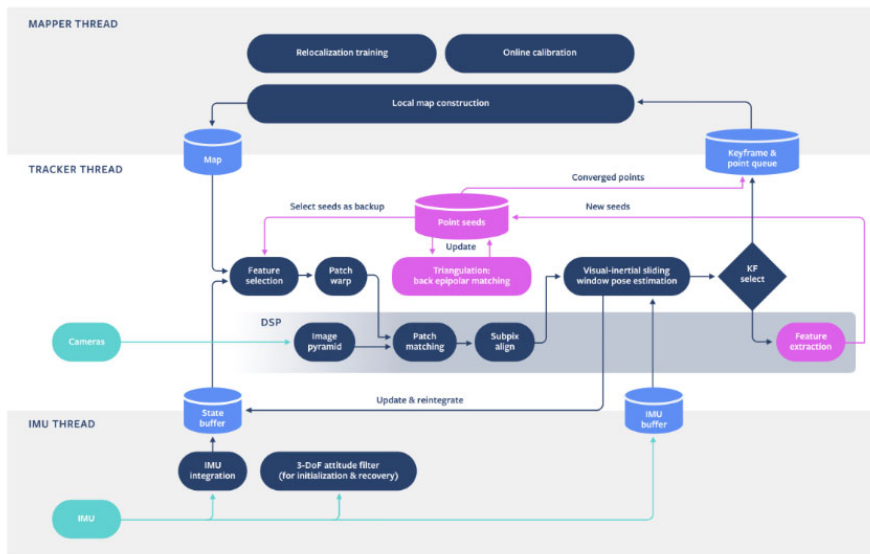
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Facebook's VR controllers are tracked via infrared LEDs under the plastic

Claim 58

(58) The method of claim 54 wherein implementing the distributed Kalman filter includes implementing a Federated Kalman Filter.

See supra claims 47, 51, 52, 54. Facebook encourages, directs, or promotes users to use the Accused Products to perform the method of claim 54 in which implementing the distributed Kalman filter includes implementing a Federated Kalman Filter, and Facebook performs such step itself. For example, on information and belief and subject to discovery which has not yet occurred, the Oculus Insight tracking system in the Accused Products implements a Federated Kalman filter to update the estimated positions and orientations of objects (e.g., the user's head, the user's hand(s), and/or the Oculus controller(s)). The Accused Products are especially adapted to carry out this method, which is a material part of the claimed invention, and have no substantial noninfringing uses. Further, Facebook conditions a user's use of the Accused Products, and therefore the user's receipt of the benefits of the Accused Products, upon this method and establishes the manner or timing of that use.

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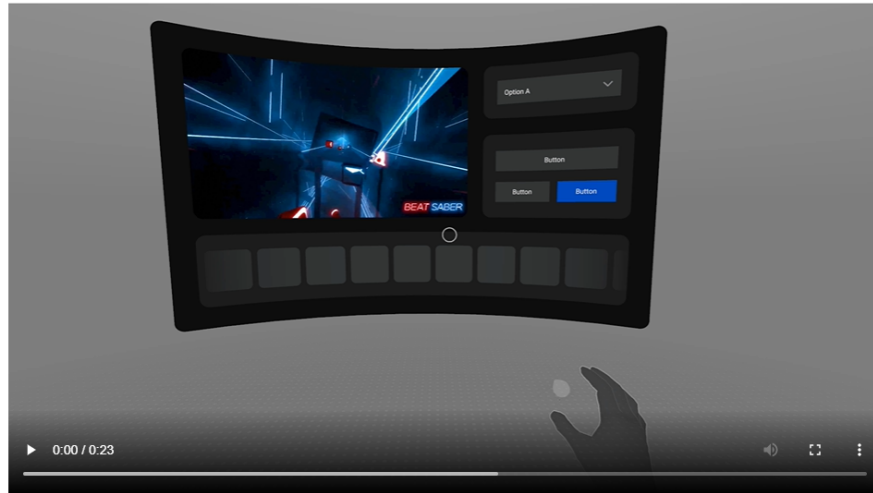
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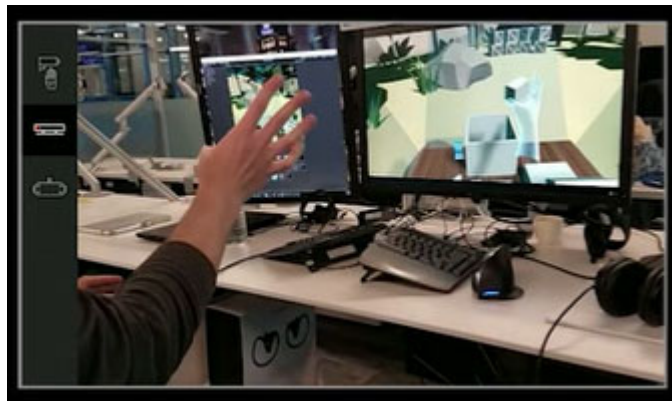
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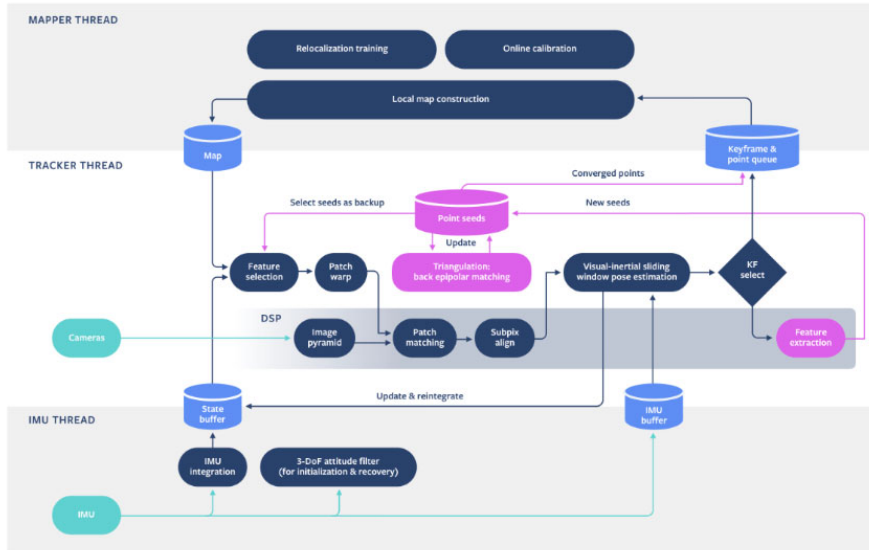
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Facebook's VR controllers are tracked via infrared LEDs under the plastic

Claim 59

(59) The method of claim 47 wherein providing configuration information from the sensor modules includes providing information characterizing a type of a sensor associated with a sensor module.

See supra claim 47. Facebook encourages, directs, or promotes users to use the Accused Products to perform the method of claim 47 in which providing configuration information from the sensor modules includes providing information characterizing a type of a sensor associated with a sensor module, and Facebook performs such step itself. For example, in the Accused Products, information regarding the type and characteristics of the available sensors associated with the sensor modules corresponding to different sensors, including optical sensors (e.g., cameras) and inertial sensors (e.g., IMUs), is provided by the sensor modules to the Oculus Insight tracking system. As a further example, the Accused Products can operate using both controllers, a single controller, or no controller at all, and this configuration information regarding the characteristics of the sensors is provided from each of the software components associated with the sensors to the Oculus Insight tracking system. The Oculus Insight tracking system in the Accused Products is then configured to use different sets of sensor modules coupled to it, corresponding to the sensors available at a given time. The configuration information characterizes the types of sensors associated with the software components. The Accused Products are especially adapted to carry out this method, which is a material part of the claimed invention, and have no substantial noninfringing uses. Further, Facebook conditions a user's use of the Accused Products, and therefore the user's receipt of the benefits of the Accused Products, upon this method and establishes the manner or timing of that use.

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See also Designing for Hands.
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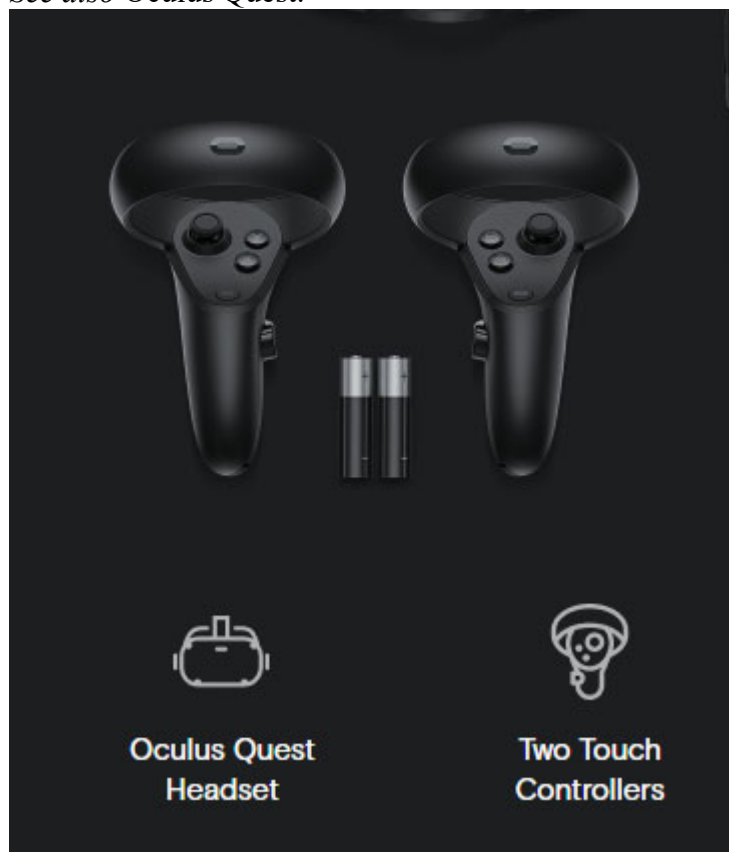
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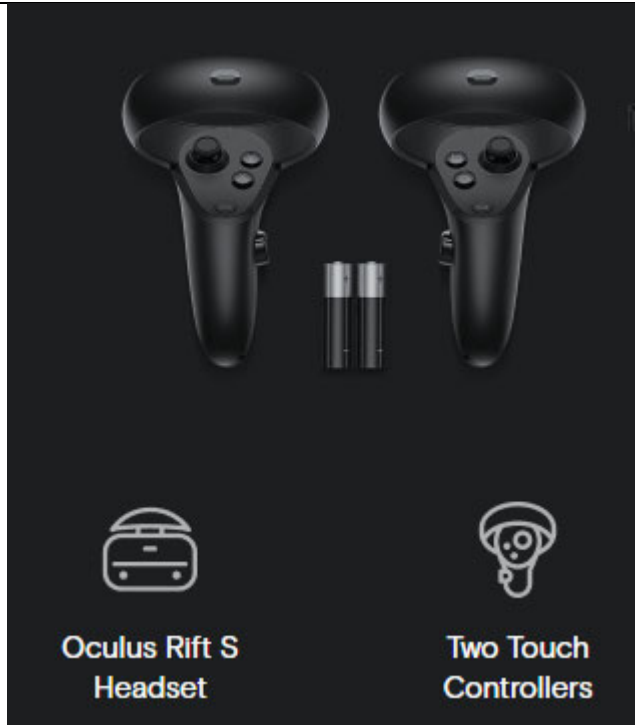
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See also Oculus Quest.



See also Oculus Rift S.



Oculus Rift S
Headset

Two Touch
Controllers

See also From the Lab.

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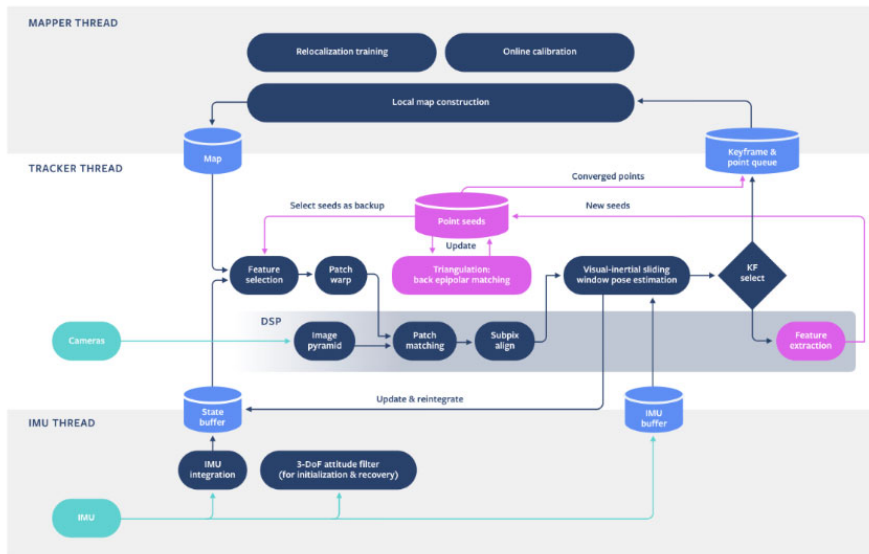
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See also id.

Headset tracking compute architecture



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Claim 60

(60) The method of claim 47 wherein providing configuration information from the sensor modules includes providing information characterizing a position or an orientation of a sensor associated with a sensor module.

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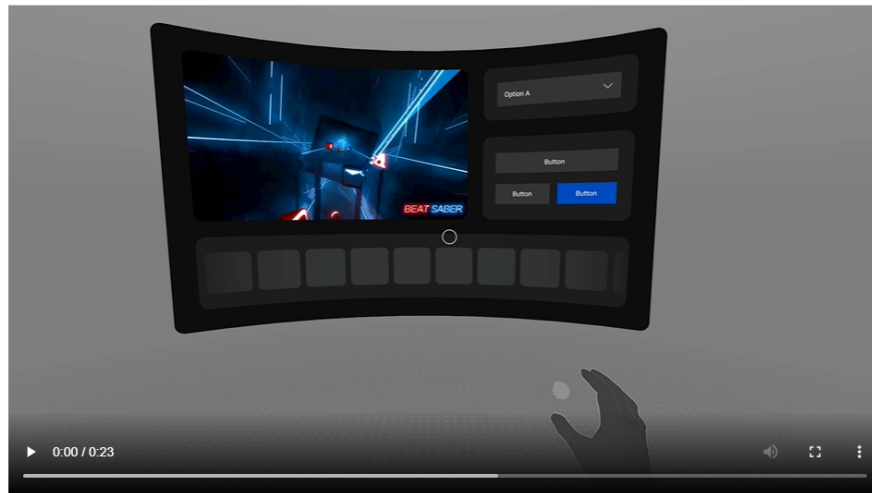
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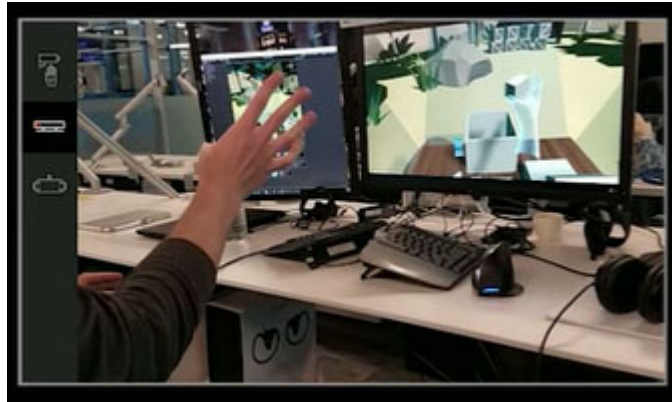
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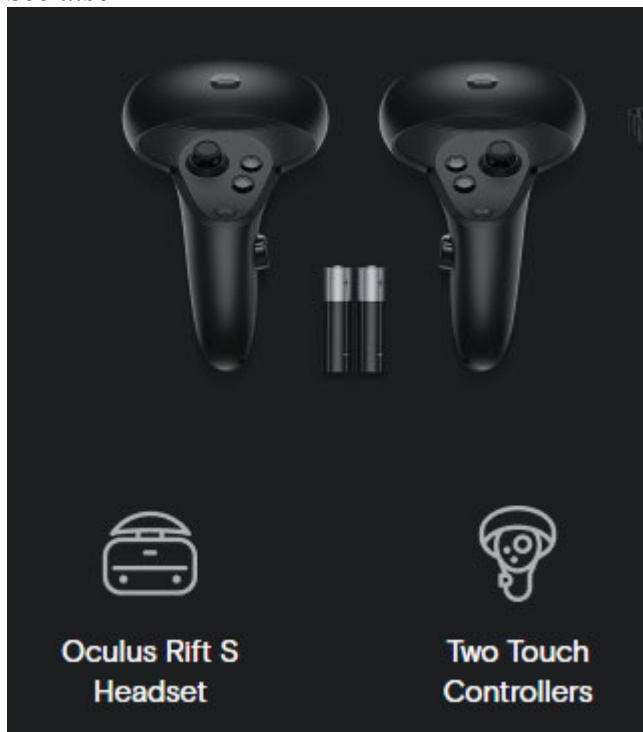
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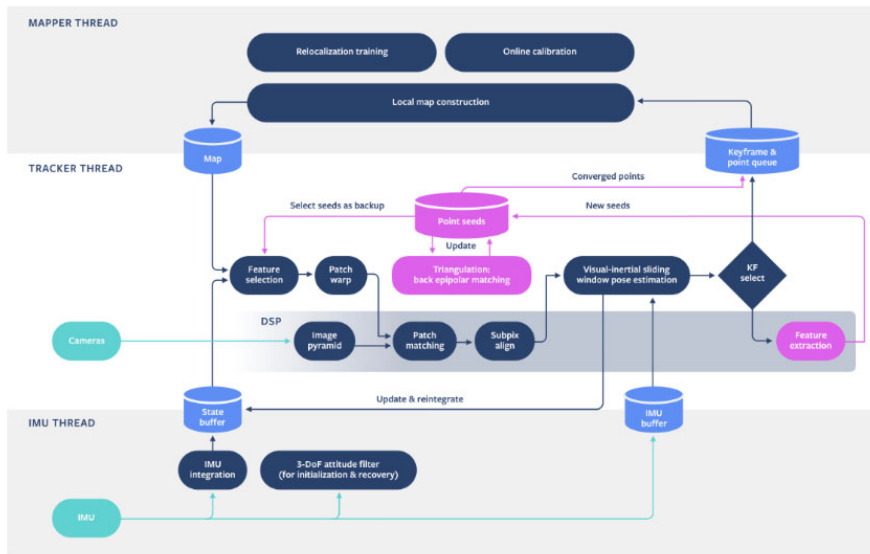
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Claim 61

(61) The method of claim 47 wherein providing configuration information from the sensor modules includes providing information characterizing one or more calibration parameters of a sensor associated with a sensor module.

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See also Designing for Hands.

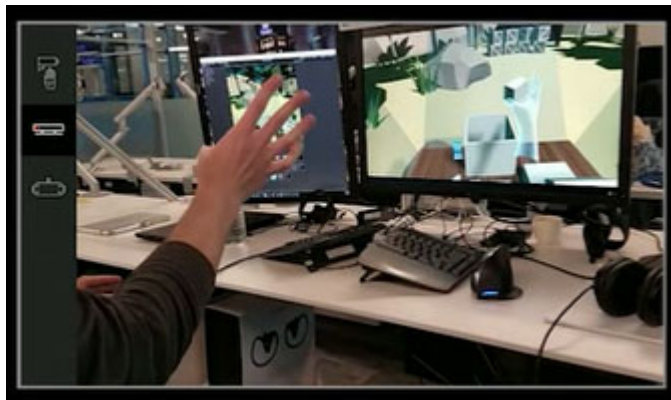
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See also Hand Tracking Deep Dive.



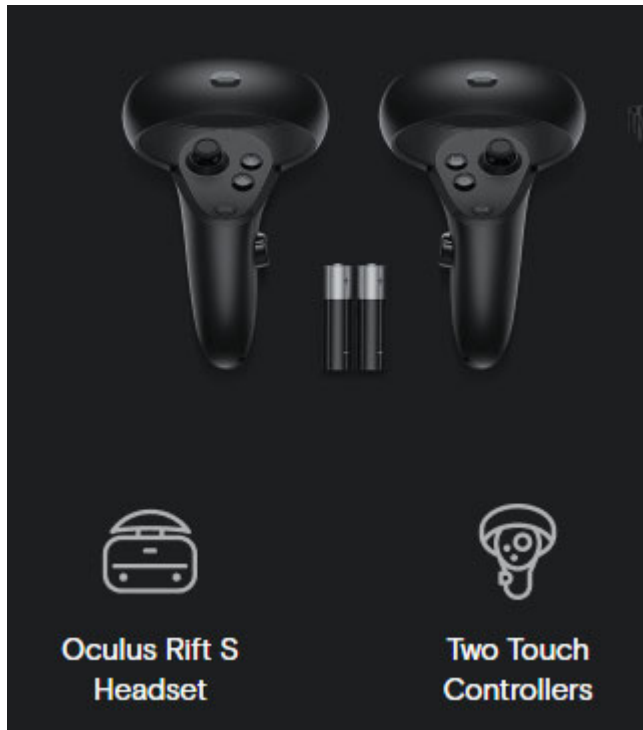
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See also Oculus Quest.



See also Oculus Rift S.



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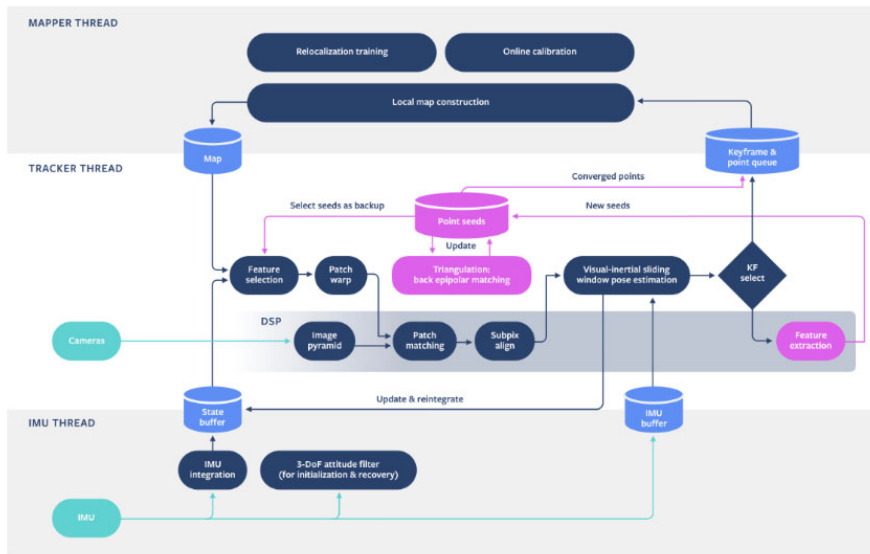
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Claim 66

(66a) A method comprising: receiving sensor configuration information indicating a set of sensing elements available to a tracking or navigation system;

Facebook encourages, directs, or promotes users to use the Accused Products to carry out the claimed method, and Facebook performs the claimed method. For example, the Oculus Insight tracking system in the Accused Products is configured using the configuration information of the sensors available at a given time. The Accused Products are especially adapted to carry out this method, which is a material part of the claimed invention, and have no substantial noninfringing uses. Further, on information and belief, Facebook conditions a user's use of the Accused Products, and therefore the user's receipt of the benefits of the Accused Products, upon this method and establishes the manner or timing of that use (e.g., through its software and/or user instructions, which have not been provided at this stage of the litigation).

See, e.g., Hand Tracking.

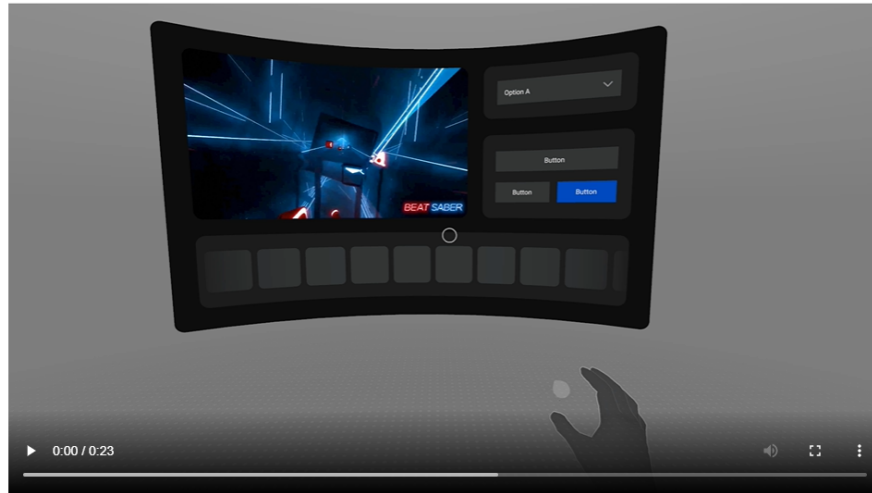
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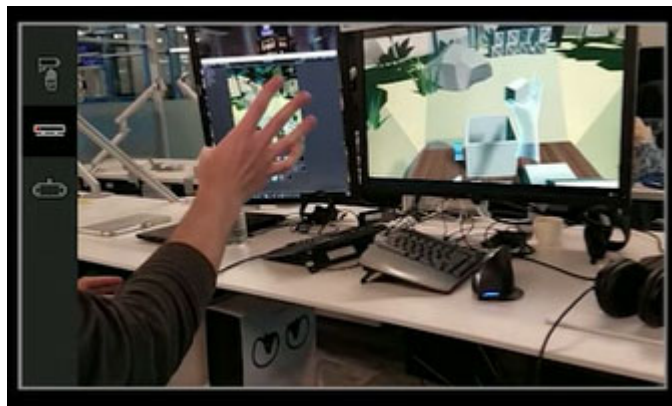
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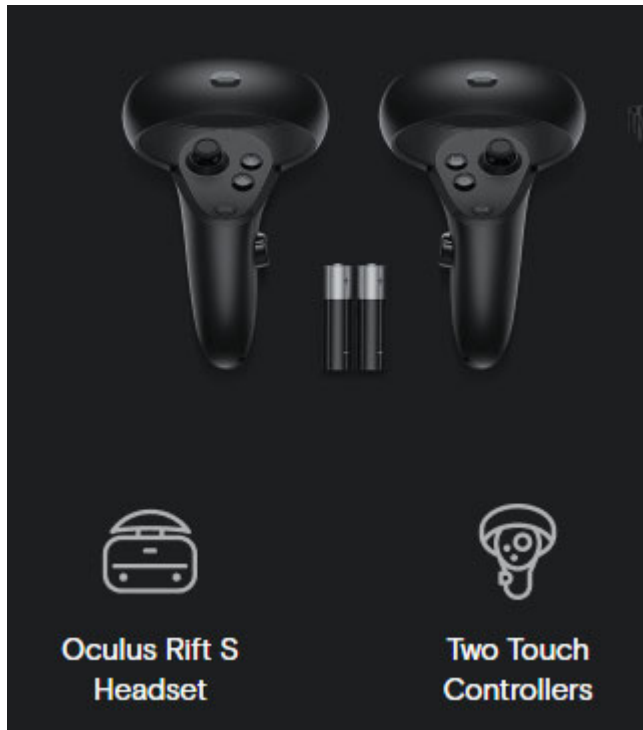
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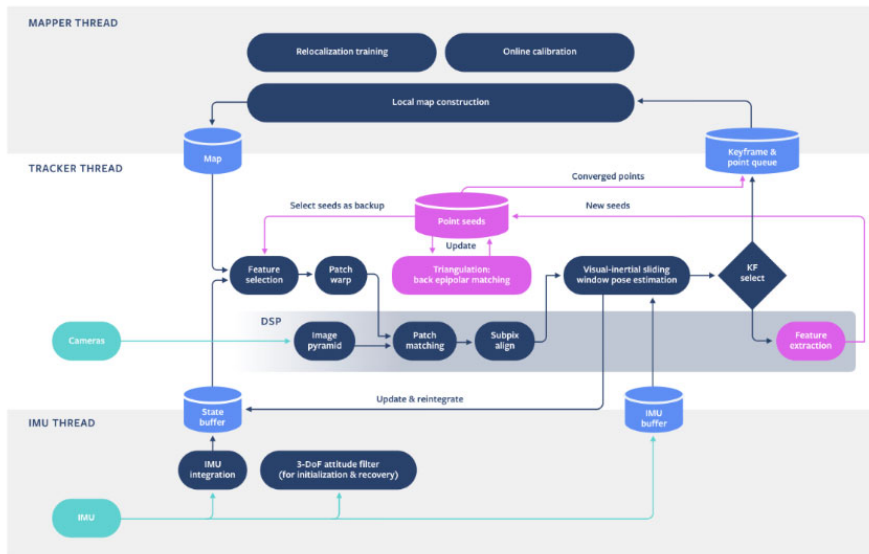
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My stepdad sent his old Oculus Go, it is a lot better than I expected! My good friend who is in the picture absolutely loves the Go. I make sure I bring it every time we hang out since I got it recently. He is able to play some of the games because there is only one controller. He would not be able to operate a controller with his other hand. We are looking at getting him one so we can play together, or both of us upgrading to the Quest. I was wondering if you guys have seen many games you can play with only one controller on the quest, or if we should stick to the Go. My friend would be doing a lot of video but I know he did like the ability to play some of the games. This has been the only video game system he has every really been able to play. I hope the quest will work out for us. Let me know what you guys think, thanks for the help.

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SORT BY BEST

maltakan0 6 points · 1 year ago

Virtual virtual reality can be played with one controller

MRHBK 5 points · 1 year ago

Quest is a bit heavier too if that is a factor

↑ stigzcousin 1 point · 1 year ago

↓ This is something I did not think about. Good to know. Thank you

jebwillnotdivideus 5 points · 1 year ago

Beatsaber and sportsscramble can be played with 1 controller. Other games im not sure.

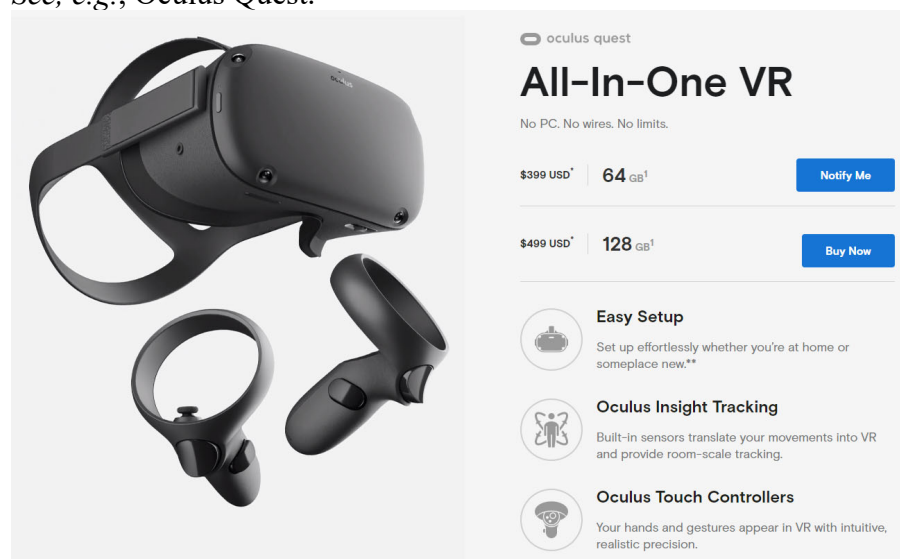
See also Expert Mode at 2:36.



(66b) configuring a data processing module of the tracking or navigation system based on the sensor configuration information to selectively perform one of (a) receiving data from at least one inside-out bearing sensor, and updating an estimated pose of an object based on data received from the inside-out bearing sensor, (b) receiving data from at least one outside-in bearing sensor, and updating an estimated pose of an object based on data received from the outside-in bearing sensor, and (c) receiving data from at least one inside-out bearing sensor and at least one outside-in bearing sensor, and updating an estimated pose of an object based on data received from the outside-in bearing sensor and the inside-out bearing sensor.

Facebook encourages, directs, or promotes users to use the Accused Products to perform this step, and Facebook performs such step itself. For example, the Accused Products configure a data processing module of the Oculus Insight tracking system based on the configuration of the sensors to receive data from the cameras and/or IMUs in the headset and/or the IMUs in the Oculus controllers, which are inside-out bearing sensors. The Accused Products update an estimated pose of an object, such as the user's head, the user's hand(s), and/or the Oculus controller(s), based on the sensor data received. The Accused Products are especially adapted to carry out this method, which is a material part of the claimed invention, and have no substantial noninfringing uses. Further, Facebook conditions a user's use of the Accused Products, and therefore the user's receipt of the benefits of the Accused Products, upon this method and establishes the manner or timing of that use.

See, e.g., Oculus Quest.



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- Oculus Touch Controllers**
Your hands and gestures appear in VR with intuitive, realistic precision.

See also Oculus Quest Features.



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Make your move.

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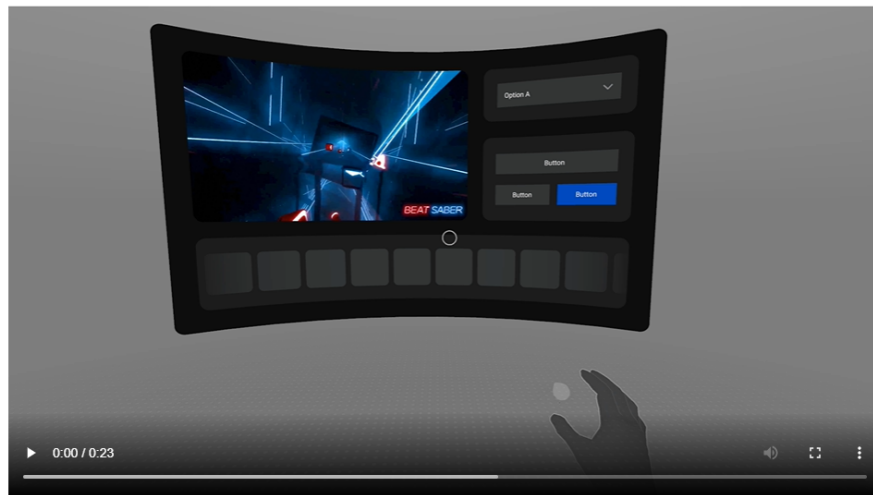
See, e.g., Hand Tracking.

The hand tracking feature enables the use of hands as an input method for the Oculus Quest device. It delivers a new sense of presence, enhances social engagement, and delivers more natural interactions with fully tracked hands and articulated fingers. Integrated hands can perform object interactions by using simple hand gestures such as pinch, unpinch, and pinch and hold.

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See also Designing for Hands.
Designing for Hands



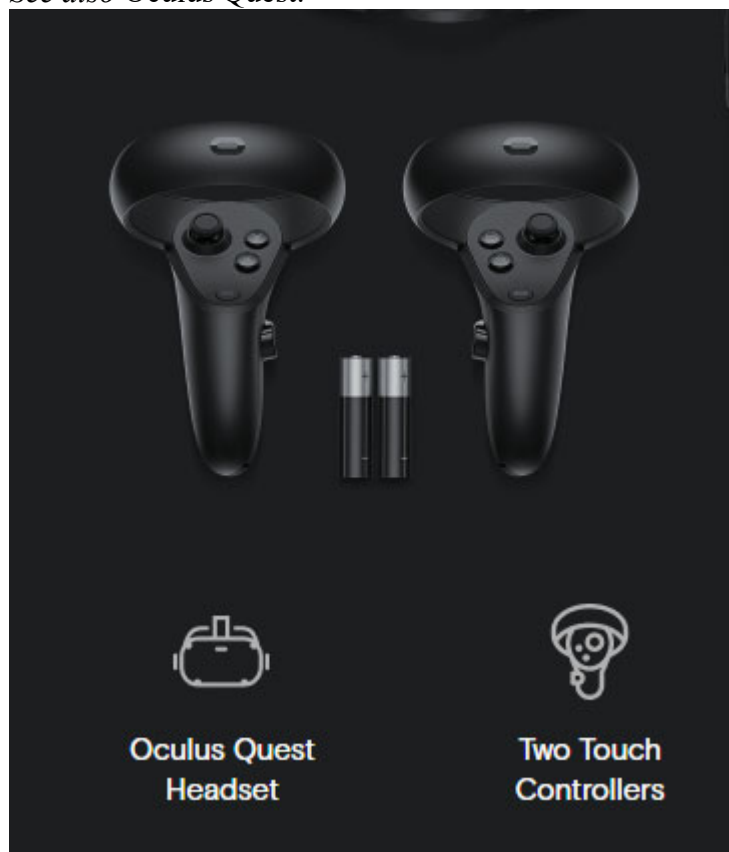
See also Hand Tracking Deep Dive at 4:00–10:00.



See also id. at 4:00–10:00.



See also Oculus Quest.



See also Oculus Rift S.



See also From the Lab.

There are other complications, too. The infrared LEDs in the two hand controllers drastically change appearance when they move closer or farther away from the headset as you swing a virtual sword or maneuver a virtual spaceship. Oculus Insight also uses other sensors, drawing acceleration and velocity data from the inertial measurement units (IMUs) located in the headset and controllers. The system must process all of these data points in real time and, in the case of Quest, on a mobile chipset.

See also From the Lab.

Taking SLAM technology ...

The foundation of Oculus Insight's inside-out tracking is [simultaneous localization and mapping, or SLAM](#), which uses computer vision CV algorithms to essentially fuse incoming data from multiple sensors in order to fix the position of an object within a constantly updated digital map. SLAM has been used in robotics and in [AR camera effects](#) on smartphones and was demoed in the Oculus [Santa Cruz VR headset prototype](#) in 2016. But Oculus Insight required an unprecedented level of precision and efficiency, and that meant adapting the latest research on tracking and computer vision.

"A lot of these technologies really start in academia — inside the lab," Kozminski notes. It's no coincidence, then, that she's part of Facebook's Zurich-based team of engineers, many of whom came from [Zurich Eye](#) — a joint program from the prestigious [ETH University](#) and [University of Zurich](#) that researched self-navigating systems.

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visually anchored to real objects in the world. Oculus Insight is the second generation of this library, and it incorporates significantly more information from a combination of multiple IMUs and ultra-wide-angle cameras, as well as infrared LEDs to jointly track the 6DoF position of a VR headset and controllers.

See also Powered by AI.

headset and controllers with respect to a 3D map that is generated and constantly updated by Insight. The data used for this process comes from three types of sensors built into the Quest and Rift S hardware:

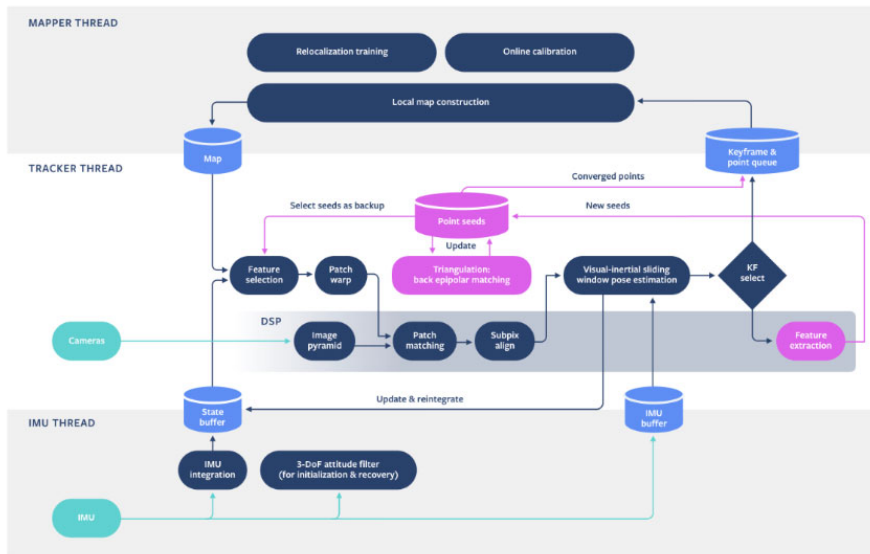
1. Linear acceleration and rotational velocity data from IMUs in the headset and controllers are integrated to track the orientation and position of each with low latency.
2. Image data from cameras in the headset helps generate a 3D map of the room, pinpointing landmarks like the corners of furniture or the patterns on your floor. These landmarks are observed repeatedly, which enables Insight to compensate for drift (a common challenge with IMUs, where even tiny measurement discrepancies build up over time, resulting in inaccurate location tracking).
3. Infrared LEDs in the controllers are detected by the headset cameras, letting the system bound the controller position drift caused by integrating multiple IMUs.

See also Powered by AI.

Another major factor to avoid in delivering immersive experiences is latency — any lag between physical movements and their VR equivalents can disorient the user and degrade the sense of realism. By using low-latency IMU data and a kinematic model that predicts a user's motion into the future, Insight is able to effectively eliminate the apparent latency. We'll go into more detail in the next section about the sensor fusion process that incorporates SLAM data, but reducing both jitter and latency is central to Insight's ability to deliver a new level of realism within VR.

See also id.

Headset tracking compute architecture



Oculus Insight processes multiple threads of data at once, in real-time — the mapper thread modifies the map, sending updated copies to the tracker thread, which uses camera frames to estimate poses in the mapper-provided frames, while the IMU thread uses measurements from the IMUs to update the latest SLAM state.

See also *From the Lab*, Sensor Placement at 0:23.



See also *From the Lab*, Sensor Placement at 0:30.



See also Heaney.

More Precise Tracking

A function for infrared LED calibration exists, suggesting this controller is optically tracked in the same way as the current Touch— cameras on the headset follow the movement of the LED constellation, and this is fused with the accelerometer readings to achieve sub-mm precision.



Facebook's VR controllers are tracked via infrared LEDs under the plastic

See also id.

The driver also reveals the series model number of the controller's inertial measurement unit (IMU)- the chip within all VR controllers which contains the accelerometer.

Teardowns and the [FCC filings](#) for the current Touch showed it uses TDK's ICM-20601 IMU from late 2015.



The IMU in the current Touch controllers for Rift S and Quest

See also ICM-20601 Specification.

Claim 67

(67) The method of claim 66 further comprising configuring the data processing module to selectively perform one of


(d) receiving data from at least one range sensor, and updating an estimated pose of an object based on data received from the range sensor,

(e) receiving data from at least one range sensor and at least one inside-out bearing sensor, and updating an estimated

See supra claim 66. Facebook encourages, directs, or promotes users to use the Accused Products to perform the method of claim 66, further comprising this step, and Facebook performs such step itself. For example, on information and belief and subject to discovery which has not yet occurred, the Accused Products configure a data processing module of the Oculus Insight tracking system to selectively receive data from at least one range sensor in the headset and the cameras and/or IMUs in the headset and/or the IMUs in the Oculus controllers, which are inside-out bearing sensors. The Accused Products combine or “fus[e]” all the sensor data received and update an estimated pose of an object, such as the user’s head, the user’s hand(s), and/or the Oculus controller(s). The Accused Products are especially adapted to carry out this method, which is a material part of the claimed invention, and have no substantial noninfringing uses. Further, Facebook conditions a user’s use of the Accused Products, and therefore the user’s receipt of the benefits of the Accused Products, upon this method and establishes the manner or timing of that use.

See, e.g., Oculus Quest.

pose of an object based on data received from the range sensor and the inside-out bearing sensor, (f) receiving data from at least one range sensor and at least one outside-in bearing sensor, and updating an estimated pose of an object based on data received from the range sensor and the outside-in bearing sensor, and (g) receiving data from at least one range sensor, at least one outside-in bearing sensor, and at least one inside-out bearing sensor, and updating an estimated pose of an object based on data received from the range sensor, the inside-out bearing sensor, and the outside-in bearing sensor.



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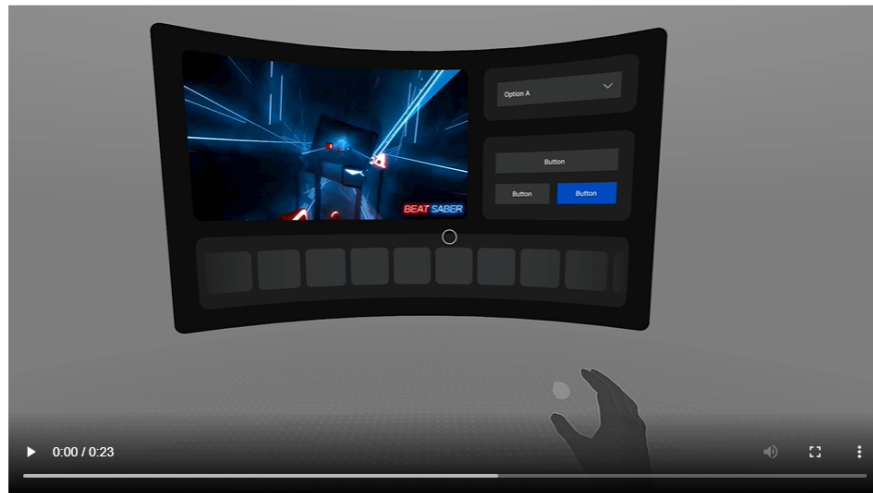
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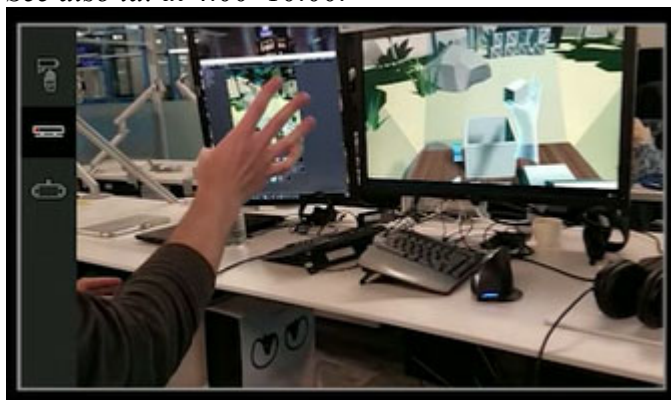
Designing for Hands



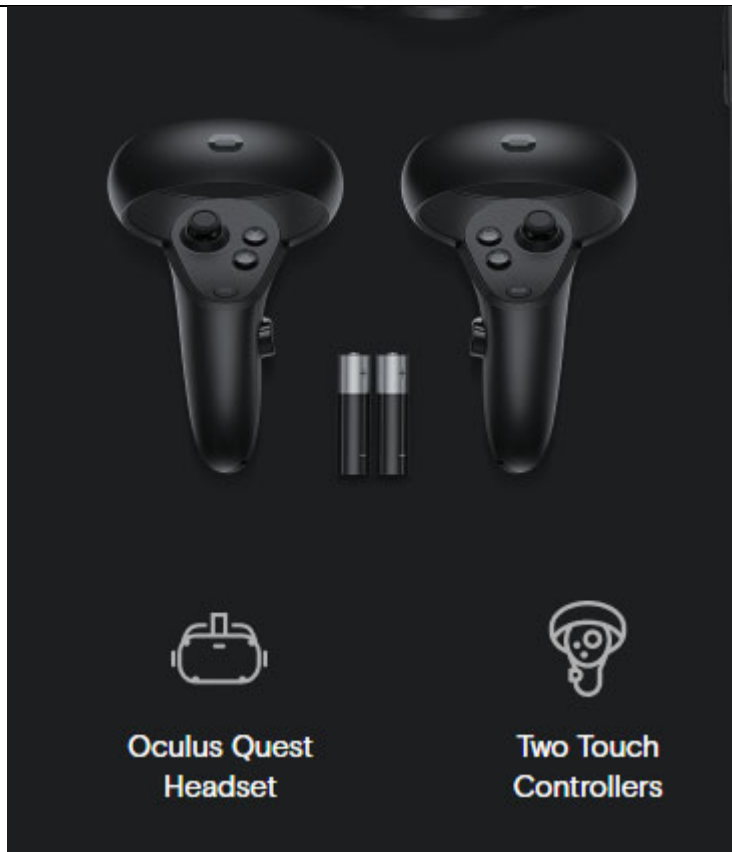
See also Hand Tracking Deep Dive at 4:00–10:00.



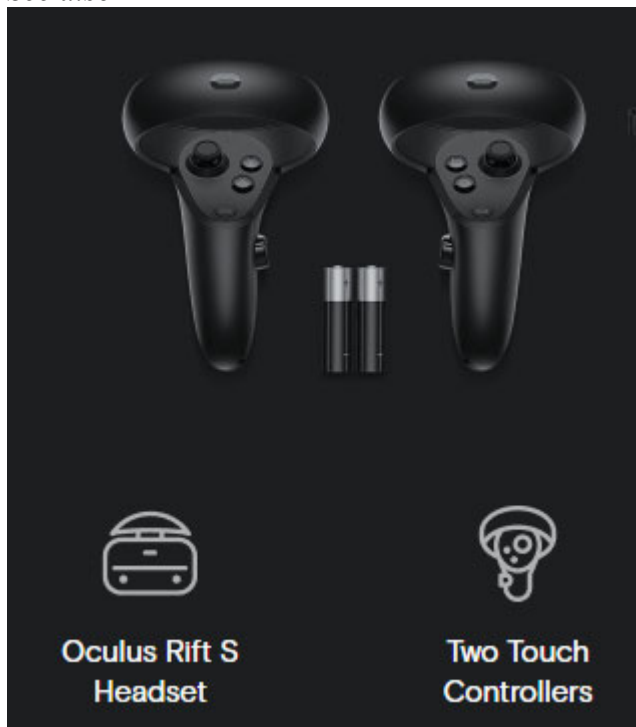
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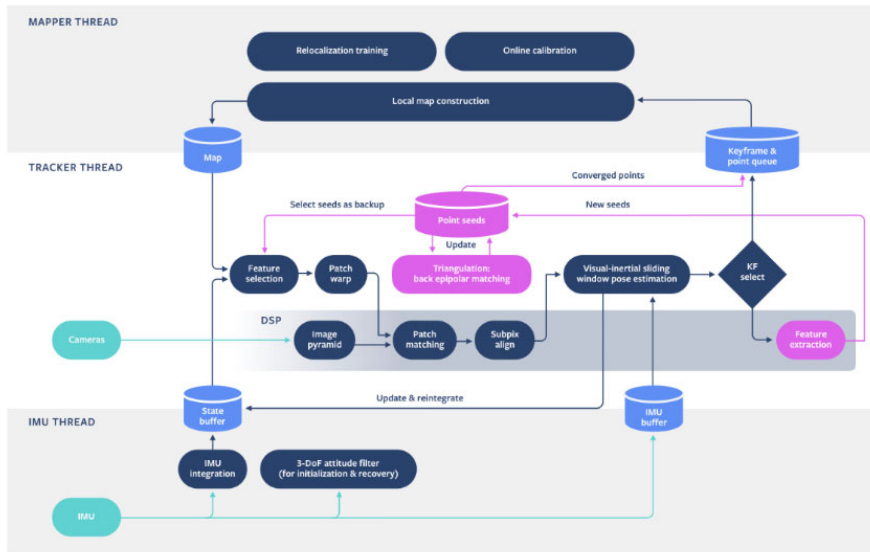
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2. Image data from cameras in the headset helps generate a 3D map of the room, pinpointing landmarks like the corners of furniture or the patterns on your floor. These landmarks are observed repeatedly, which enables Insight to compensate for drift (a common challenge with IMUs, where even tiny measurement discrepancies build up over time, resulting in inaccurate location tracking).
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Another major factor to avoid in delivering immersive experiences is latency — any lag between physical movements and their VR equivalents can disorient the user and degrade the sense of realism. By using low-latency IMU data and a kinematic model that predicts a user's motion into the future, Insight is able to effectively eliminate the apparent latency. We'll go into more detail in the next section about the sensor fusion process that incorporates SLAM data, but reducing both jitter and latency is central to Insight's ability to deliver a new level of realism within VR.

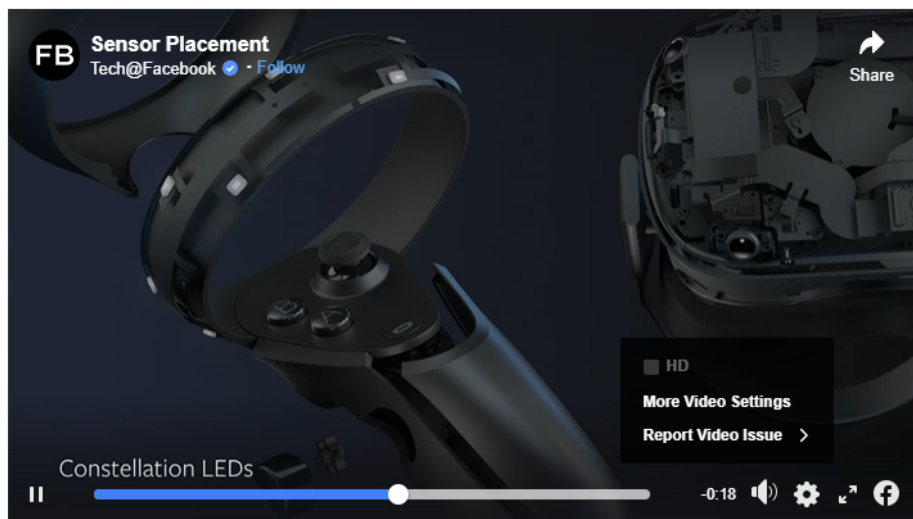
See also *id.*

Headset tracking compute architecture



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A function for infrared LED calibration exists, suggesting this controller is optically tracked in the same way as the current Touch— cameras on the headset follow the movement of the LED constellation, and this is fused with the accelerometer readings to achieve sub-mm precision.



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The IMU in the current Touch controllers for Rift S and Quest

See also ICM-20601 Specification.

Claim 68

(68) An apparatus comprising:
an estimation module to estimate a pose of an object based on measurement data from sensing elements, the estimation module configured to enable selective performance of (a) receiving data from at least one inside-out bearing sensor, and updating an estimated pose of an object based on the data received from the inside-out bearing sensor, (b) receiving data from at least one

Facebook makes, uses, sells, and/or offers for sale in the United States, and/or imports into the United States, the Accused Products, which comprise the claimed estimation module. In particular, the Accused Products comprise the Oculus Insight tracking system, which estimates a pose of an object (e.g., the user's head, the user's hand(s), and/or the Oculus controller(s)) based on measurement data from sensing elements (e.g., cameras and/or IMUs within the HMD, the IMUs within the Oculus controller(s), and/or the Oculus controller(s)). The Oculus Insight tracking system is configured to receive data from the aforementioned sensing elements, which comprise at least one inside-out bearing sensor, and update an estimated pose of the object based on the data received.

Facebook encourages, directs, or promotes users to use the estimation module within the Accused Products (e.g., through its software and/or user instructions, which have not been provided at this stage of the litigation), and its users use the estimation module within the Accused Products. Facebook further provides or sells the Accused Products to third parties (e.g., distributors and retailers) and directs them to sell and/or offer for sale in the United States, or import the Accused Products into the United States. Facebook also makes, uses, sells, and/or offers for sale in the United States, and/or imports into the United States, components (e.g., Oculus controllers) that are especially made and adapted to be used with the Accused Products, are a material part of the claimed invention, and have no substantial noninfringing uses.

outside-in bearing sensor, and updating an estimated pose of an object based on the data received from the outside-in bearing sensor, and (c) receiving data from at least one inside-out bearing sensor and at least one outside-in bearing sensor, and updating an estimated pose of an object based on the data received from the outside-in bearing sensor and the inside-out bearing sensor.

See, e.g., From the Lab.

There are other complications, too. The infrared LEDs in the two hand controllers drastically change appearance when they move closer or farther away from the headset as you swing a virtual sword or maneuver a virtual spaceship. Oculus Insight also uses other sensors, drawing acceleration and velocity data from the inertial measurement units (IMUs) located in the headset and controllers. The system must process all of these data points in real time and, in the case of Quest, on a mobile chipset.

See also Oculus Rift S.

Is your PC VR Ready?

Your PC is the engine that powers Oculus Rift S. Show off the true potential of high-performance VR gameplay with our recommended level of hardware.

See also Hand Tracking.

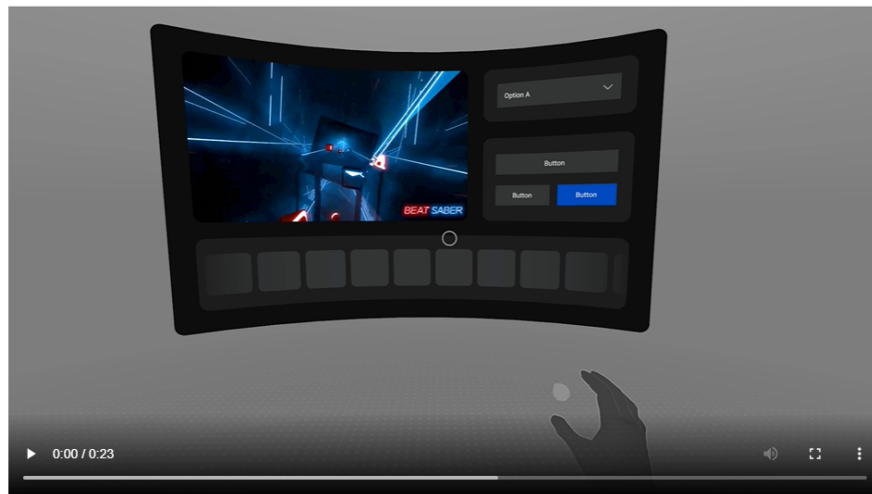
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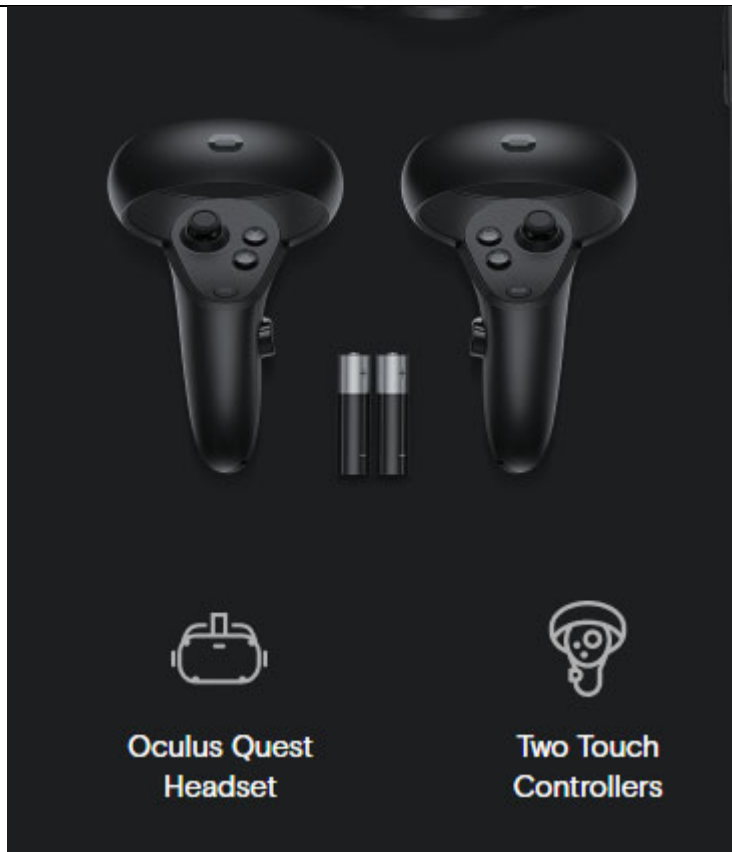
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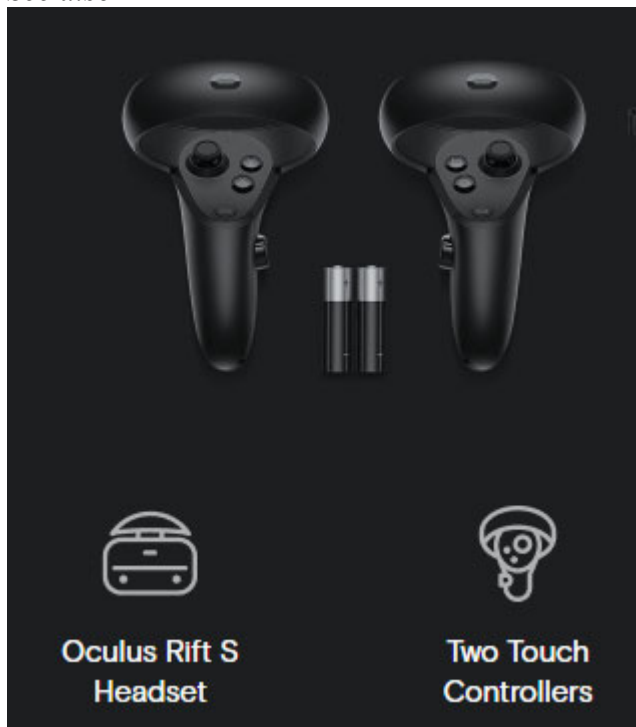
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See also Oculus Quest.



See also Oculus Rift S.



See also Powered by AI.

Academic research has been done on SLAM techniques for several decades, but the technology has only recently become mature enough for consumer applications, such as driverless cars and mobile AR apps. Facebook previously released a version of [SLAM for AR on mobile devices](#) which uses a single camera and inertial measurement unit (IMU) to track a phone's position and enable world-locked content — content that's visually anchored to real objects in the world. Oculus Insight is the second generation of this library, and it incorporates significantly more information from a combination of multiple IMUs and ultra-wide-angle cameras, as well as infrared LEDs to jointly track the 6DoF position of a VR headset and controllers.

The Oculus Insight system uses a custom hardware architecture and advanced computer vision algorithms — including visual-inertial mapping, place recognition, and geometry reconstruction — to establish the location of objects in relation to other objects within a given space. This novel algorithm stack enables a VR device to pinpoint its location, identify aspects of room geometry (such as floor location), and track the positions of the headset and controllers with respect to a 3D map that is generated and constantly updated by Insight. The data used for this process comes from three types of sensors built into the Quest and Rift S hardware:

See also id.

At last year's Oculus Connect event we shared some details about [Oculus Insight](#), the cutting-edge technology that powers both Quest and Rift S. Now that both of those products are available, we're providing a deeper look at the AI systems and techniques that power this VR technology. Oculus Insight marks the first time that fully untethered six-degree-of-freedom (6DoF) headset and controller tracking has shipped in a consumer AR/VR device. Built from the ground up, the Insight stack leverages state-of-the-art computer vision (CV) systems and visual-inertial simultaneous localization and mapping, or SLAM.

See also From the Lab.

"We wanted to create a system that lets you move and explore a VR world just as naturally and easily as you would in real life," says Kozminski.

Kozminski joined a team whose mission was to create the first full-featured "inside-out" tracking system for a consumer VR device. The technology would have to track the full range of a person's movements (known as six degrees of freedom) and be able to pinpoint the location of the two handheld controllers as well as the headset.

Previously, VR devices relied on external sensors to track these movements. These cameras attach to a PC, and while they work well, they make VR less portable and more complicated to set up.

"With inside-out tracking in the headset, VR becomes as easy as putting on headphones to listen to music," says Kozminski.

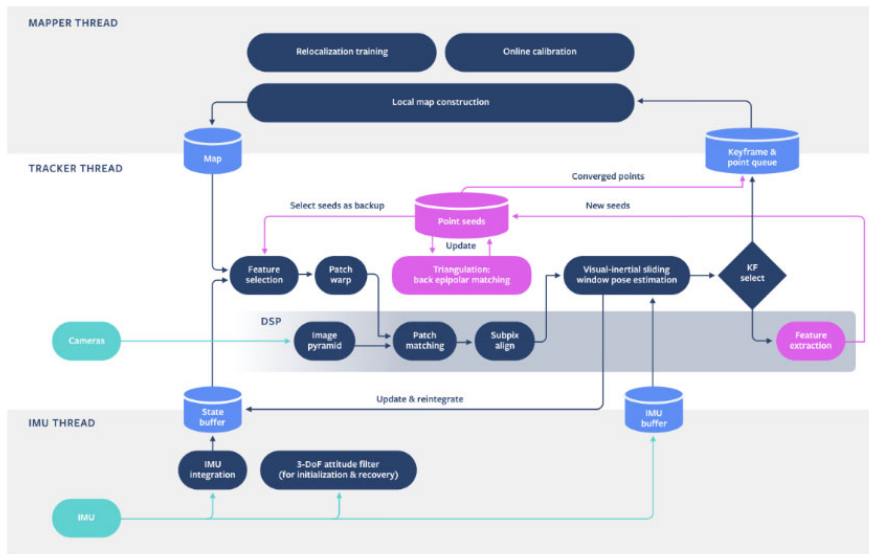
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The IMU in the current Touch controllers for Rift S and Quest

See also ICM-20601 Specification.

FEATURES

- 3-Axis Gyroscope with Programmable FSR of $\pm 500\text{dps}$, $\pm 100\text{dps}$, $\pm 2000\text{dps}$ and $\pm 4000\text{dps}$
- 3-Axis Accelerometer with Programmable FSR of $\pm 4g$, $\pm 8g$, $\pm 16g$, and $\pm 32g$
- User-programmable interrupts
- Wake-on-motion interrupt for low power operation of applications processor
- 512 byte FIFO buffer enables the applications processor to read the data in bursts
- On-Chip 16-bit ADCs and Programmable Filters
- Host interface: 8 MHz SPI or 400k Hz Fast Mode I²C
- Digital-output temperature sensor
- VDD operating range of 1.71 to 3.45V
- MEMS structure hermetically sealed and bonded at wafer level
- RoHS and Green compliant

See also Reddit Single Controller Discussion.

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<https://imgur.com/a/1dLoatG>

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maltakan0 6 points · 1 year ago

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MRHBK 5 points · 1 year ago

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↑ stigzcousin 1 point · 1 year ago

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jebwillnotdivideus 5 points · 1 year ago

Beatsaber and sportsscramble can be played with 1 controller. Other games im not sure.

See also Expert Mode at 2:36.



Claim 69

(69) An apparatus comprising:
an estimation module to estimate a pose of an object based on measurement data from sensing elements, the estimation module configured to enable selective performance of one of:
(a) updating an estimate of the position or orientation of the object relative to an environment,
(b) updating an estimate of the position or orientation, relative to the object, of at least one sensing element fixed to the object, and
(c) updating an estimate of the position or orientation, relative to the environment, of at least one sensing element fixed in the environment.

Facebook makes, uses, sells, and/or offers for sale in the United States, and/or imports into the United States, the Accused Products, which comprise the claimed estimation module. In particular, the Accused Products comprise the Oculus Insight tracking system, which estimates a pose of an object (e.g., the user’s head, the user’s hand(s), and/or the Oculus controller(s)) based on measurement data from sensing elements (e.g., cameras and/or IMUs within the HMD, the IMUs within the Oculus controller(s), and/or the Oculus controller(s)). The Oculus Insight tracking system is configured to receive data from the aforementioned sensing elements, which comprise at least one inside-out bearing sensor, and update the estimated position and orientation of the object relative to the user’s environment based on the data received. The Oculus Insight tracking system further uses the measurement data to update an estimated position and/or orientation, relative to the object, of sensing elements fixed to the object (e.g., the IMUs within the Oculus controller(s)). The Oculus Insight tracking system further uses the measurement data to update an estimated position and/or orientation, relative to the environment, of sensing elements fixed in the environment (e.g., landmarks like the corners of furniture or the patterns on the floor).

Facebook encourages, directs, or promotes users to use the estimation module within the Accused Products (e.g., through its software and/or user instructions, which have not been provided at this stage of the litigation), and its users use the estimation module within the Accused Products. Facebook further provides or sells the Accused Products to third parties (e.g., distributors and retailers) and directs them to sell and/or offer for sale in the United States, or import the Accused Products into the United States. Facebook also makes, uses, sells, and/or offers for sale in the United States, and/or imports into the United States, components (e.g., Oculus controllers) that are especially made and adapted to be used with the Accused Products, are a material part of the claimed invention, and have no substantial noninfringing uses.

See, e.g., From the Lab.

There are other complications, too. The infrared LEDs in the two hand controllers drastically change appearance when they move closer or farther away from the headset as you swing a virtual sword or maneuver a virtual spaceship. Oculus Insight also uses other sensors, drawing acceleration and velocity data from the inertial measurement units (IMUs) located in the headset and controllers. The system must process all of these data points in real time and, in the case of Quest, on a mobile chipset.

See also Oculus Rift S.



Is your PC VR Ready?
Your PC is the engine that powers Oculus Rift S. Show off the true potential of high-performance VR gameplay with our recommended level of hardware.

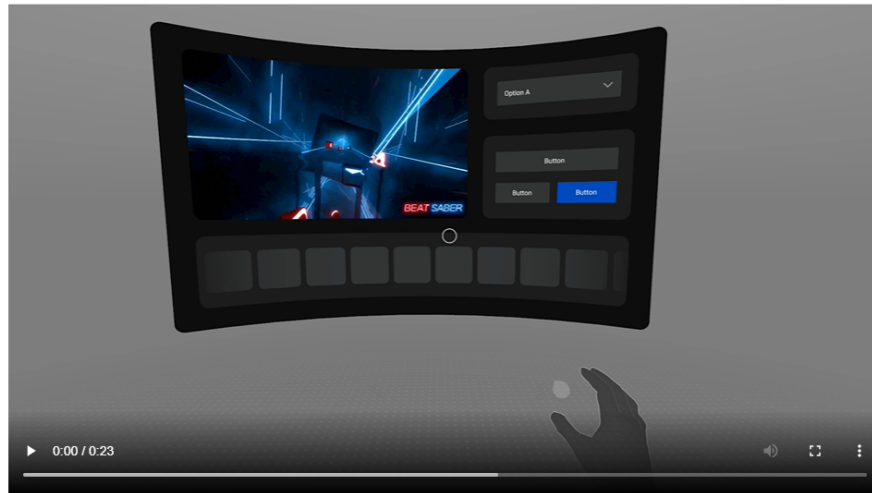
See also Hand Tracking.

The hand tracking feature enables the use of hands as an input method for the Oculus Quest device. It delivers a new sense of presence, enhances social engagement, and delivers more natural interactions with fully tracked hands and articulated fingers. Integrated hands can perform object interactions by using simple hand gestures such as pinch, unpinch, and pinch and hold.

The hand tracking feature lets you operate with hands and controllers interchangeably. When you opt to use hands, the hand's pose drives a laser cursor-pointer that behaves like the standard controller cursor. You can use the cursor-pointer to highlight, select, click, or write your own app-level event logic.

Hand tracking complements the Touch controllers and is not intended to replace controllers in all scenarios, especially with games or creative tools that require a high degree of precision. By opting-in to hand support, your app also needs to satisfy additional technical requirements specific to hand tracking in order to be accepted on Oculus Store. To submit an app to Oculus Store, the app must support controllers along with hand tracking.

See also Designing for Hands.
Designing for Hands



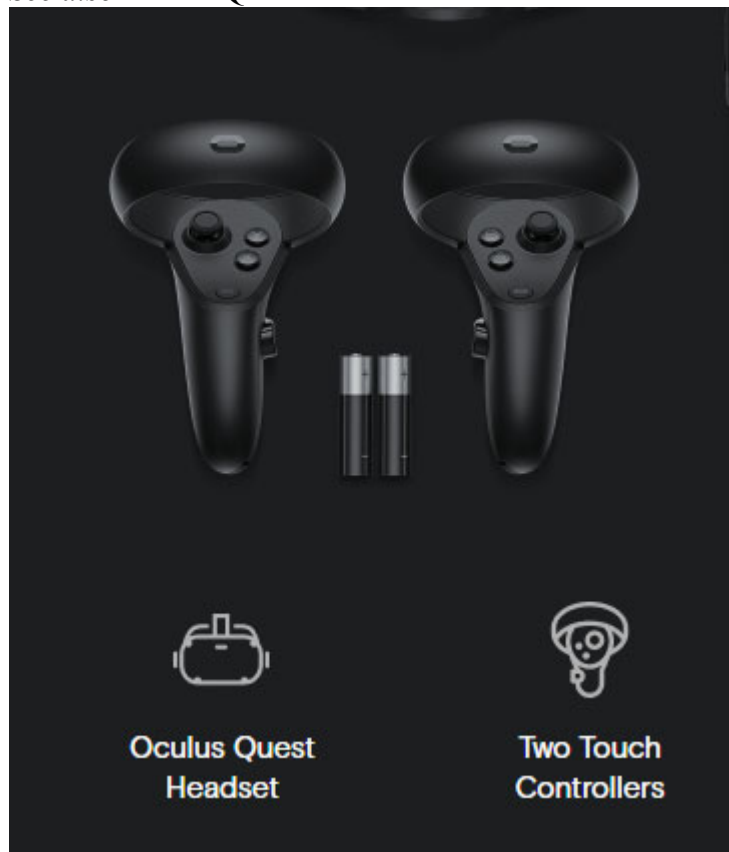
See also Hand Tracking Deep Dive at 4:00–10:00.



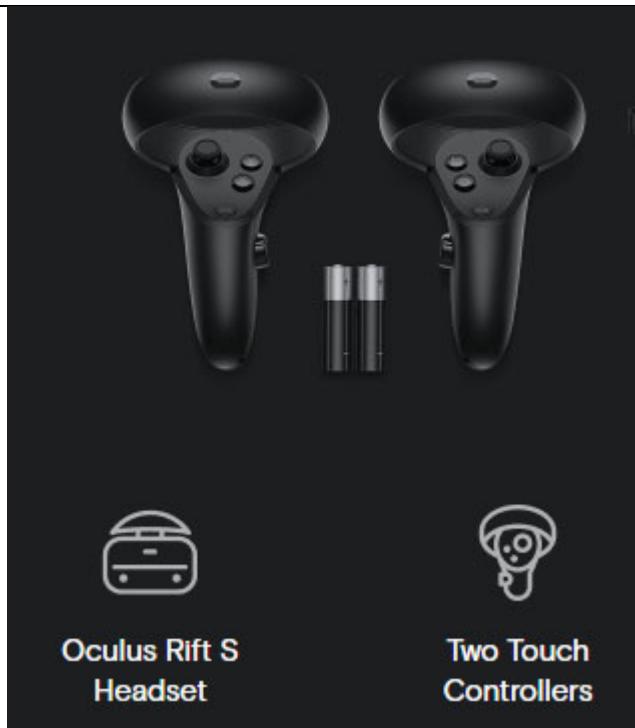
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See also Oculus Quest.



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The Oculus Insight system uses a custom hardware architecture and advanced computer vision algorithms — including visual-inertial mapping, place recognition, and geometry reconstruction — to establish the location of objects in relation to other objects within a given space. This novel algorithm stack enables a VR device to pinpoint its location, identify aspects of room geometry (such as floor location), and track the positions of the headset and controllers with respect to a 3D map that is generated and constantly updated by Insight. The data used for this process comes from three types of sensors built into the Quest and Rift S hardware:

See also id.

At last year's Oculus Connect event we shared some details about [Oculus Insight](#), the cutting-edge technology that powers both Quest and Rift S. Now that both of those products are available, we're providing a deeper look at the AI systems and techniques that power this VR technology. Oculus Insight marks the first time that fully untethered six-degree-of-freedom (6DoF) headset and controller tracking has shipped in a consumer AR/VR device. Built from the ground up, the Insight stack leverages state-of-the-art computer vision (CV) systems and visual-inertial simultaneous localization and mapping, or SLAM.

See also From the Lab.

"We wanted to create a system that lets you move and explore a VR world just as naturally and easily as you would in real life," says Kozminski.

Kozminski joined a team whose mission was to create the first full-featured "inside-out" tracking system for a consumer VR device. The technology would have to track the full range of a person's movements (known as six degrees of freedom) and be able to pinpoint the location of the two handheld controllers as well as the headset.

Previously, VR devices relied on external sensors to track these movements. These cameras attach to a PC, and while they work well, they make VR less portable and more complicated to set up.

"With inside-out tracking in the headset, VR becomes as easy as putting on headphones to listen to music," says Kozminski.

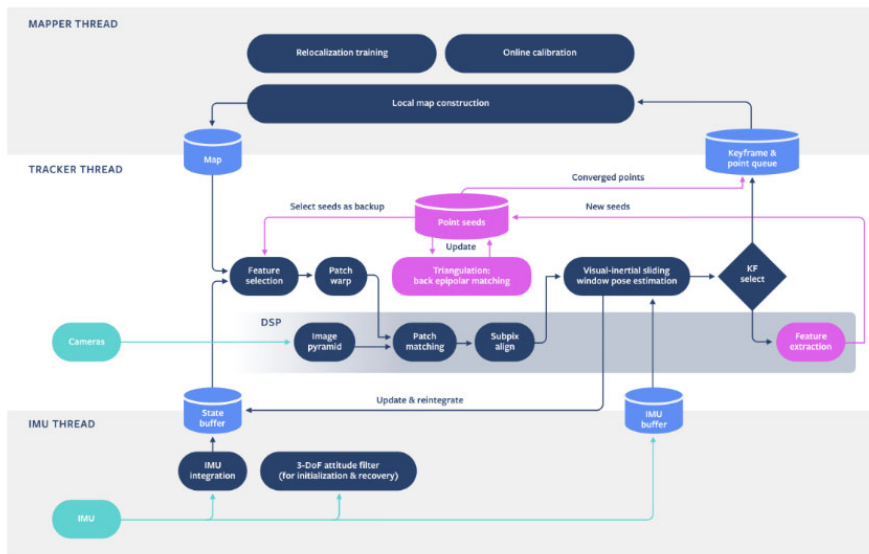
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See also id.

Headset tracking compute architecture

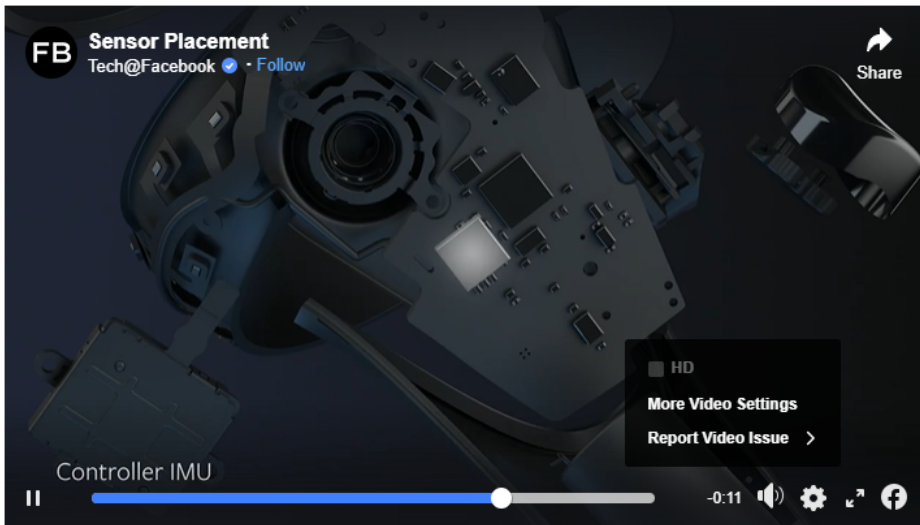


Oculus Insight processes multiple threads of data at once, in real-time — the mapper thread modifies the map, sending updated copies to the tracker thread, which uses camera frames to estimate poses in the mapper-provided frames, while the IMU thread uses measurements from the IMUs to update the latest SLAM state.

See also From the Lab, Sensor Placement at 0:23.



See also From the Lab, Sensor Placement at 0:30.



See also Heaney.

More Precise Tracking

A function for infrared LED calibration exists, suggesting this controller is optically tracked in the same way as the current Touch— cameras on the headset follow the movement of the LED constellation, and this is fused with the accelerometer readings to achieve sub-mm precision.



Facebook's VR controllers are tracked via infrared LEDs under the plastic

See also id.

The driver also reveals the series model number of the controller's inertial measurement unit (IMU)- the chip within all VR controllers which contains the accelerometer.

Teardowns and the FCC filings for the current Touch showed it uses TDK's ICM-20601 IMU from late 2015.



The IMU in the current Touch controllers for Rift S and Quest

See also ICM-20601 Specification.

FEATURES

- 3-Axis Gyroscope with Programmable FSR of $\pm 500\text{dps}$, $\pm 100\text{dps}$, $\pm 2000\text{dps}$ and $\pm 4000\text{dps}$
- 3-Axis Accelerometer with Programmable FSR of $\pm 4g$, $\pm 8g$, $\pm 16g$, and $\pm 32g$
- User-programmable interrupts
- Wake-on-motion interrupt for low power operation of applications processor
- 512 byte FIFO buffer enables the applications processor to read the data in bursts
- On-Chip 16-bit ADCs and Programmable Filters
- Host interface: 8 MHz SPI or 400k Hz Fast Mode I²C
- Digital-output temperature sensor
- VDD operating range of 1.71 to 3.45V
- MEMS structure hermetically sealed and bonded at wafer level
- RoHS and Green compliant

See also [Reddit Single Controller Discussion](#).

Does the Quest have a single controller mode for any games?

<https://imgur.com/a/1dLoatG>

My stepdad sent his old Oculus Go, it is a lot better than I expected! My good friend who is in the picture absolutely loves the Go. I make sure I bring it every time we hang out since I got it recently. He is able to play some of the games because there is only one controller. He would not be able to operate a controller with his other hand. We are looking at getting him one so we can play together, or both of us upgrading to the Quest. I was wondering if you guys have seen many games you can play with only one controller on the quest, or if we should stick to the Go. My friend would be doing a lot of video but I know he did like the ability to play some of the games. This has been the only video game system he has every really been able to play. I hope the quest will work out for us. Let me know what you guys think, thanks for the help.

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Beatsaber and sportsscramble can be played with 1 controller. Other games im not sure.

See also Expert Mode at 2:36.



Exhibit 5

Gentex Corporation and Indigo Technologies, LLC (collectively, “Gentex”) presently contend that Facebook, Inc. and Facebook Technologies, LLC (collectively, “Facebook”) infringe claims 1-4 and 6-9 (the “Asserted Claims”) of U.S. Patent No. 7,725,253, directly and/or indirectly, either literally or under the doctrine of equivalents. This chart sets forth Gentex’s preliminary infringement contentions relating to the Asserted Claims and the accused products, i.e., the Oculus Rift S, Oculus Quest, and Oculus Quest 2 (collectively, the “Accused Products”). In the event Facebook releases new products or services that infringe the ’253 patent, or further investigation reveals that other products or services infringe the ’253 patent, Gentex reserves the right to update these contentions as appropriate under the Order Governing Proceedings.

These contentions articulate the structure and acts that constitute direct and/or indirect infringement of the ’253 patent and identify specifically where each element of each asserted claim is found within each Accused Product. Exemplary references to publicly available information concerning the Accused Products is provided where appropriate. Exemplary references to specific Accused Products are not intended and should not be read to exclude Accused Products not exemplified. On information and belief, the Accused Products are materially the same with respect to the claims of the ’253 patent discussed below, except the contentions below regarding hand tracking, which is performed by the Oculus Quest and Oculus Quest 2, but based on present information, is not performed by the Oculus Rift S. This disclosure is not intended to describe all acts of direct, induced, or contributory infringement Facebook has and continues to commit by making, using, selling, providing, developing, installing, testing, deploying, and/or directing the use of the Accused Products by customers and end users. The parties have not engaged in any discovery. The parties also have not discussed proposed constructions for, and the Court has not yet construed, any of the claims of the ’253 patent. As a result, and consistent with the Order Governing Proceedings, Gentex reserves the right to modify, amend, or otherwise supplement these initial infringement contentions as discovery and the pre-trial phase of the litigation proceed and as additional information comes to light, including with respect to which claims Gentex is asserting, the infringement analysis for one or more of the claims, and whether and how limitations of one or more claims are met literally or under the doctrine of equivalents.

U.S. Patent 7,725,253

Claim 1	
Claim Limitation	Accused Products
(1pre) A tracking system comprising:	<p>Facebook makes, uses, sells, and/or offers for sale in the United States, and/or imports into the United States, the Accused Products, which comprise a tracking system. For example, the Accused Products comprise a tracking system comprising a headset and zero or more controllers. The tracking system estimates the position and orientation of the head-mounted display (“HMD”), one or more Oculus controllers, and/or the user’s head and hands based on measurement data from sensing elements, such as the HMD cameras and the inertial measurement units (“IMUs”) of the HMD and controllers.</p> <p>Facebook encourages, directs, or promotes users to use the tracking system within the Accused Products (e.g., through its software and/or user instructions, which have not been provided at this stage of the litigation), and its users use the tracking system within the Accused Products. Facebook further provides or sells the Accused Products to third</p>

parties (e.g., distributors and retailers) and directs them to sell and/or offer for sale in the United States, or import the Accused Products into the United States. Facebook also makes, uses, sells, and/or offers for sale in the United States, and/or imports into the United States, components (e.g., Oculus controllers) that are especially made and adapted to be used with the Accused Products, are a material part of the claimed invention, and have no substantial noninfringing uses.

See, e.g., Compare Headsets,
<https://www.oculus.com/compare/?products=quest%2Cquest-2>.



Oculus Quest
All-In-One VR Gaming

TRACKING

Six Degrees of Freedom

With 6DOF, the headset tracks the movement of both your head and body, then translates them into VR with realistic precision. No external sensors required.



Oculus Quest 2
Advanced All-In-One VR Gaming

Starting At \$299 USD*

BUY NOW

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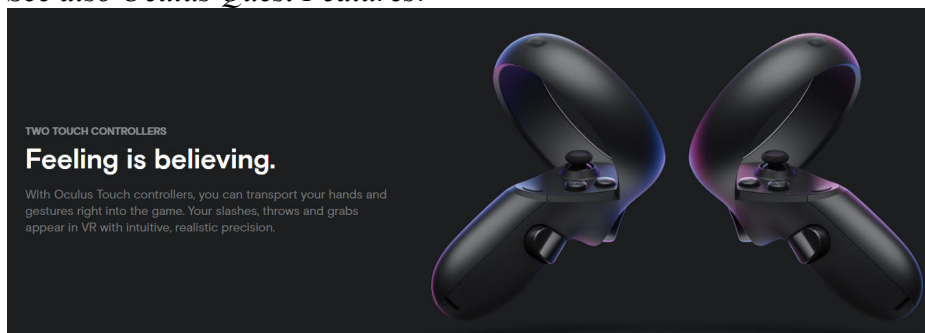
Oculus Rift S
PC-Powered VR Gaming

TRACKING

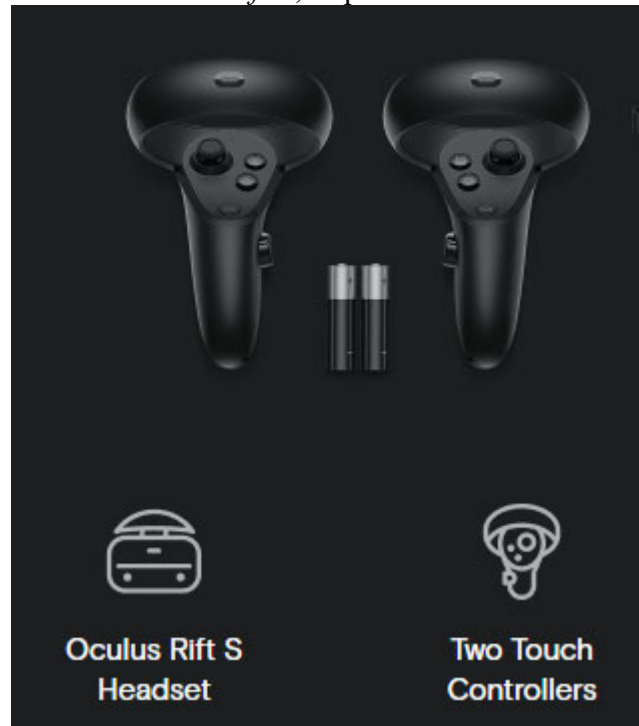
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See also Oculus Quest Features.



See also *Oculus Rift S*, <https://www.oculus.com/rift-s/>.



See also Tech@facebook, *From the Lab to the living room: The story behind Facebook's Oculus Insight technology and a new era of consumer VR* (Aug. 22, 2019), <https://tech.fb.com/the-story-behind-oculus-insight-technology/>, Sensor Placement at 0:15 (hereinafter "*From the Lab*").

Taking SLAM technology ...

The foundation of Oculus Insight's inside-out tracking is simultaneous localization and mapping, or SLAM, which uses computer vision CV algorithms to essentially fuse incoming data from multiple sensors in order to fix the position of an object within a constantly updated digital map. SLAM has been used in robotics and in AR camera effects on smartphones and was demoed in the Oculus Santa Cruz VR headset prototype in 2016. But Oculus Insight required an unprecedented level of precision and efficiency, and that meant adapting the latest research on tracking and computer vision.

"A lot of these technologies really start in academia — inside the lab," Kozminski notes. It's no coincidence, then, that she's part of Facebook's Zurich-based team of engineers, many of whom came from Zurich Eye — a joint program from the prestigious ETH University and University of Zurich that researched self-navigating systems.

See also *id.*

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See also Oculus Blog, *Powered by AI* (Aug. 22, 2019), <https://ai.facebook.com/blog/powered-by-ai-oculus-insight/> (hereinafter “*Powered by AI*”).

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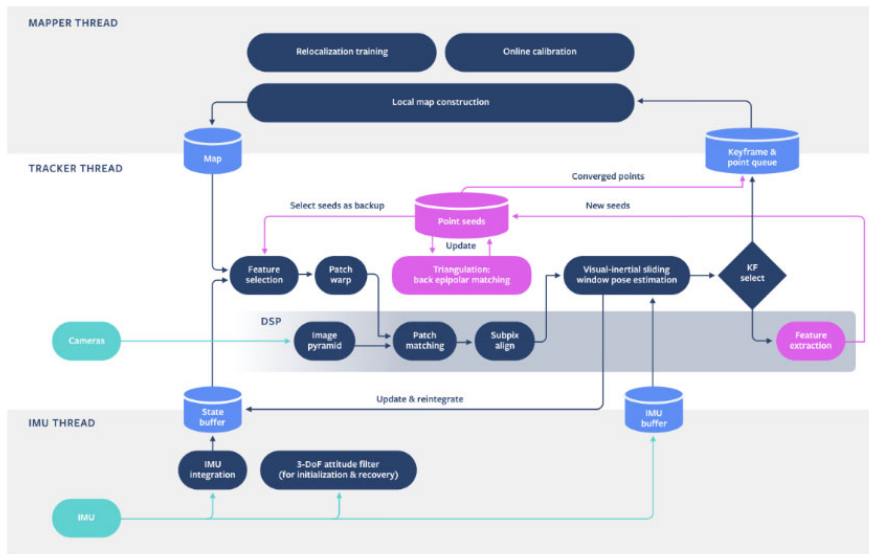
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See also Ben Lang, *Quest Teardown Shows How Oculus Crammed Cooling & Cameras Inside* (July 17, 2019), <https://www.roadtovr.com/oculus-quest-teardown-disassembly/> (hereinafter “Lang”).



Image courtesy BadVR, Jad Meouchy

Around the mainboard we can also see the headset’s four cameras mounted at very purposeful angles at the corners. The cameras are essential to enabling 6DOF tracking on both the headset and the controllers; their views are also merged together to allow a pass-through vision mode on the headset which is used to trace the boundary of your playspace.

See also David Heaney, Oculus Firmware Reveals New Touch Controllers, Referencing Improvements to Tracking, Finger Sensing, Haptics (Apr. 16, 2020), <https://uploadvr.com/oculus-jedi-controller-driver-found/> (hereinafter “Heaney”).

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A function for infrared LED calibration exists, suggesting this controller is optically tracked in the same way as the current Touch— cameras on the headset follow the movement of the LED constellation, and this is fused with the accelerometer readings to achieve sub-mm precision.



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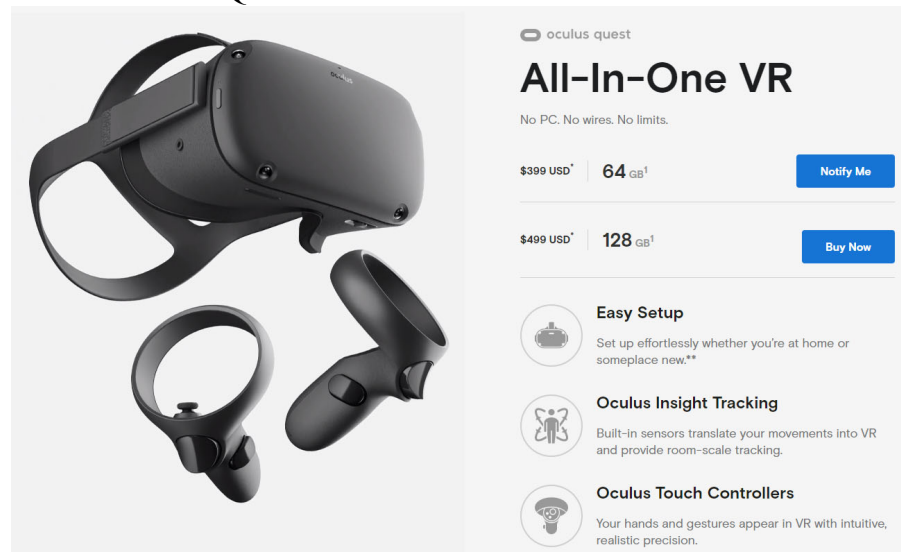
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See also Powered by AI.


To unlock the full potential of virtual reality (VR) and augmented reality (AR) experiences, the technology needs to work anywhere, adapting to the spaces where people live and how they move within those real-world environments. When we developed [Oculus Quest](#), the first all-in-one, completely wire-free VR gaming system, we knew we needed positional tracking that was precise, accurate, and available in real time — within the confines of a standalone headset, meaning it had to be compact and energy efficient.

See also Oculus Quest.



The screenshot displays the Oculus Quest product page. On the left, there is a high-quality image of the Oculus Quest VR headset and its two touch controllers. On the right, the product title "All-In-One VR" is prominently displayed, followed by the tagline "No PC. No wires. No limits." Below this, two pricing options are listed: "\$399 USD* 64 GB¹" with a "Notify Me" button, and "\$499 USD* 128 GB¹" with a "Buy Now" button. Three key features are highlighted with icons and text: "Easy Setup" (Set up effortlessly whether you're at home or someplace new**), "Oculus Insight Tracking" (Built-in sensors translate your movements into VR and provide room-scale tracking), and "Oculus Touch Controllers" (Your hands and gestures appear in VR with intuitive, realistic precision).

See also Oculus Rift S.






oculus rift s

PC-Powered VR Gaming

Step into our best VR games.

[Buy Now](#) \$399 USD* | [View PC requirements](#)

- 
Improved Optics
 Improved optics deliver bright, vivid colors and reduced "screen-door" effect.
- 
Ergonomic Design
 The halo headband is redesigned with speed and comfort in mind.
- 
Oculus Touch Controllers
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See also Lang.



Image courtesy BadVR, Jad Meouchy

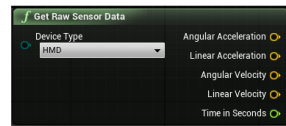
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See also [Get Raw Sensor Data, Oculus Documentation, https://developer.oculus.com/documentation/unreal/unreal-blueprints-get-raw-sensor-data/?locale=en_US.](https://developer.oculus.com/documentation/unreal/unreal-blueprints-get-raw-sensor-data/?locale=en_US)

Overview

This blueprint reports raw sensor data from the headset, such as its angular acceleration or linear velocity. If the headset does not support a sensor data reading, then that result will return as zero.

Blueprint



See also Powered by AI.

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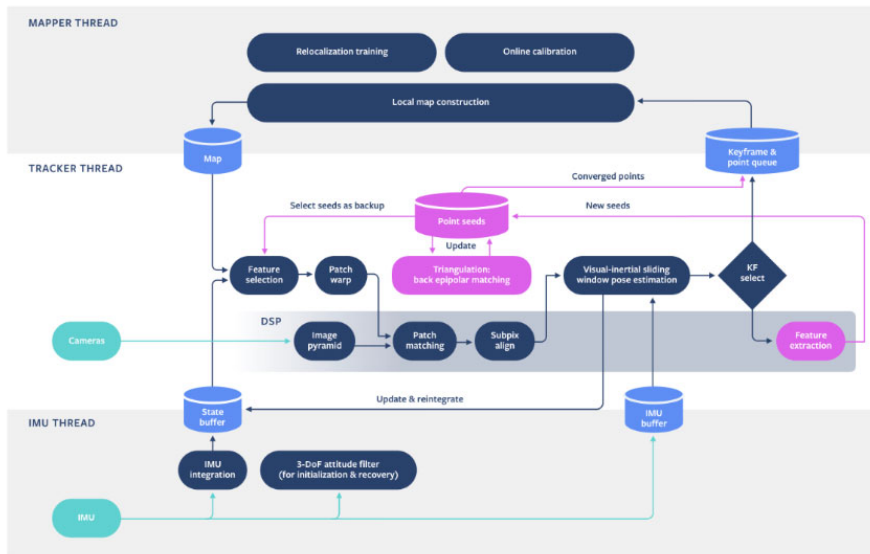
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The driver also reveals the series model number of the controller's inertial measurement unit (IMU)- the chip within all VR controllers which contains the accelerometer.

Teardowns and the [FCC filings](#) for the current Touch showed it uses TDK's ICM-20601 IMU from late 2015.



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(1b) a sensor subsystem coupled to the estimation subsystem and configured to provide configuration data to the estimation subsystem and to provide measurement information to the estimation subsystem for localizing an object;

The Accused Products further comprise a sensor subsystem coupled to the estimation subsystem and configured to provide configuration data to the estimation subsystem and to provide measurement information to the estimation subsystem for localizing an object. For example, the Accused Products include a sensor subsystem (e.g., the cameras and inertial measurement units (“IMUs”), such as accelerometers and gyroscopes, within the HMD, and the IMUs within the Oculus controllers, along with the software components associated with these sensors) that is coupled to the estimation subsystem (e.g., the Oculus Insight tracking system). The sensor subsystem is configured to provide data about the configuration of the sensors to the estimation subsystem for localizing an object (e.g., the HMD, one or more Oculus controllers, and/or the user’s head and hands). For example, the Accused Products can operate using both controllers, a single controller, or no controller at all, and the estimation subsystem in the Accused Products is configured to provide data about the sensors in use at a given time to the estimation subsystem for localizing the controllers.

See, e.g., From the Lab.

There are other complications, too. The infrared LEDs in the two hand controllers drastically change appearance when they move closer or farther away from the headset as you swing a virtual sword or maneuver a virtual spaceship. Oculus Insight also uses other sensors, drawing acceleration and velocity data from the inertial measurement units (IMUs) located in the headset and controllers. The system must process all of these data points in real time and, in the case of Quest, on a mobile chipset.

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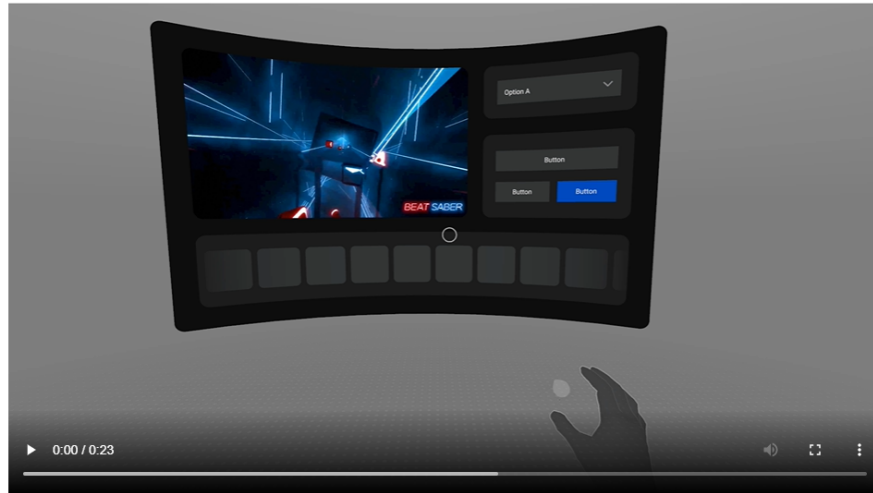
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See also Designing for Hands.

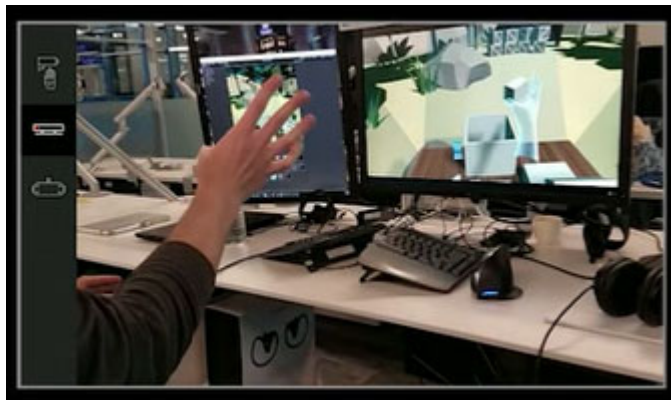
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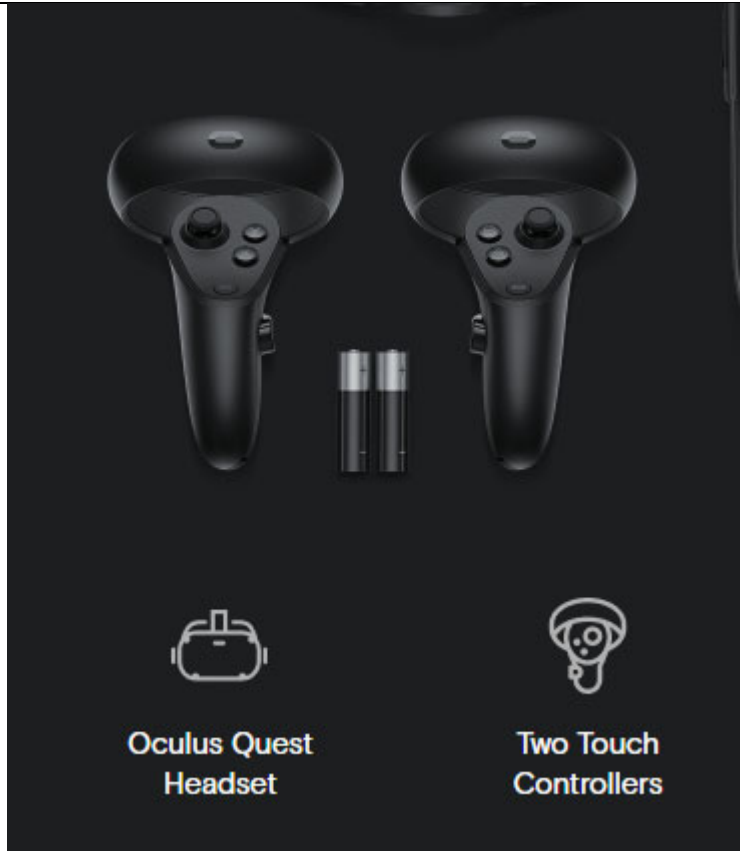
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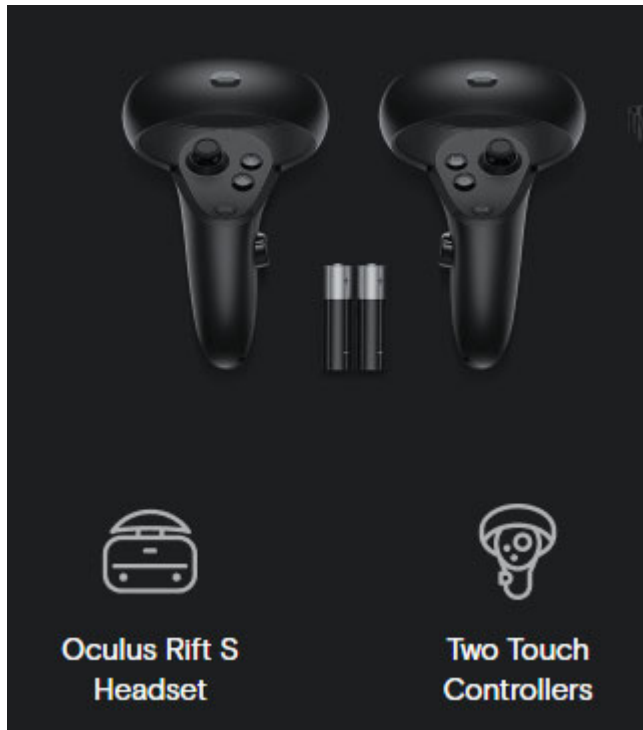
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See also Does the Quest have a single controller mode for any games?, Reddit, https://www.reddit.com/r/OculusQuest/comments/c1rwr1/does_the_quest_have_a_single_controller_mode_for/ (hereinafter "Reddit Single Controller Discussion").

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maltakan0 6 points · 1 year ago

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MRHBK 5 points · 1 year ago

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See also EXPERT MODE on Beat Saber [ft Oculus Quest!] at 2:36, <https://www.youtube.com/watch?v=bPtrX70O2rA> (hereinafter “Expert Mode”).



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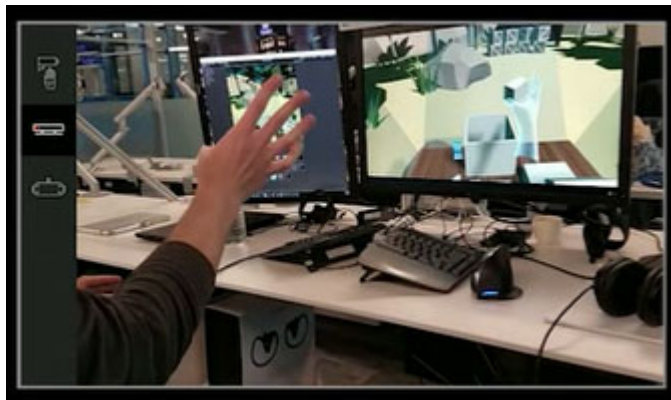
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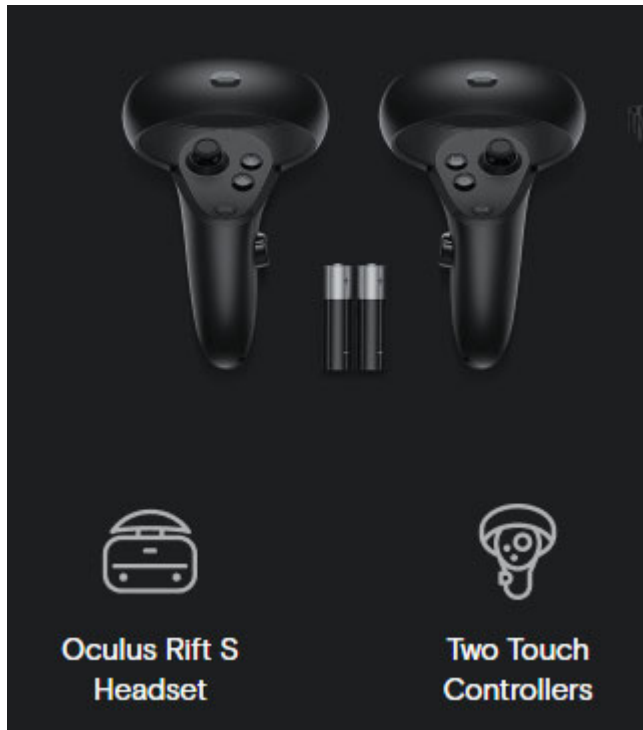
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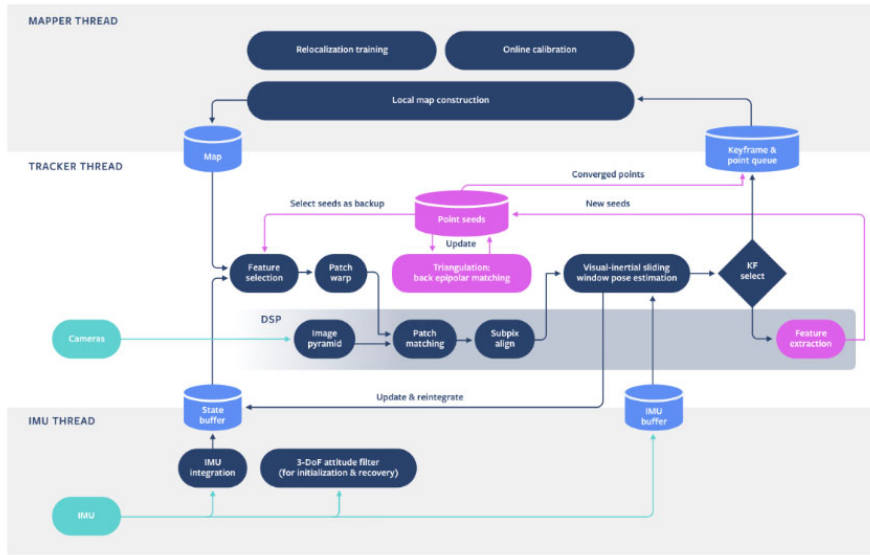
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Claim 2

(2) The system of claim 1 wherein the sensor subsystem includes one or more sensor modules, each providing an interface for interacting with a corresponding set of one or more sensing elements.

See supra claim 1. Facebook makes, uses, sells, and/or offers for sale in the United States, and/or imports into the United States, the Accused Products, comprising a sensor subsystem that includes one or more sensor modules, each providing an interface for interacting with a corresponding set of one or more sensing elements. For example, the sensor subsystem in the Accused Products (e.g., the cameras and IMUs, such as accelerometers and gyroscopes, within the HMD, and the IMUs within the Oculus controllers, along with the software components associated with these sensors) comprises one or more sensor modules (e.g., software components, such as the IMU thread), each of which provides an interface for interacting with a corresponding set of sensing elements (e.g., cameras and/or IMUs within the HMD, and/or the IMUs within the Oculus controllers).

Facebook encourages, directs, or promotes users to use the tracking system within the Accused Products (e.g., through its software and/or user instructions, which have not been provided at this stage of the litigation), and its users use the tracking system within the Accused Products. Facebook further provides or sells the Accused Products to third parties (e.g., distributors and retailers) and directs them to sell and/or offer for sale in the United States, or import the Accused Products into the United States. Facebook also makes, uses, sells, and/or offers for sale in the United States, and/or imports into the United States, components (e.g., Oculus controllers) that are especially made and adapted to be used with the Accused Products, are a material part of the claimed invention, and have no substantial noninfringing uses.

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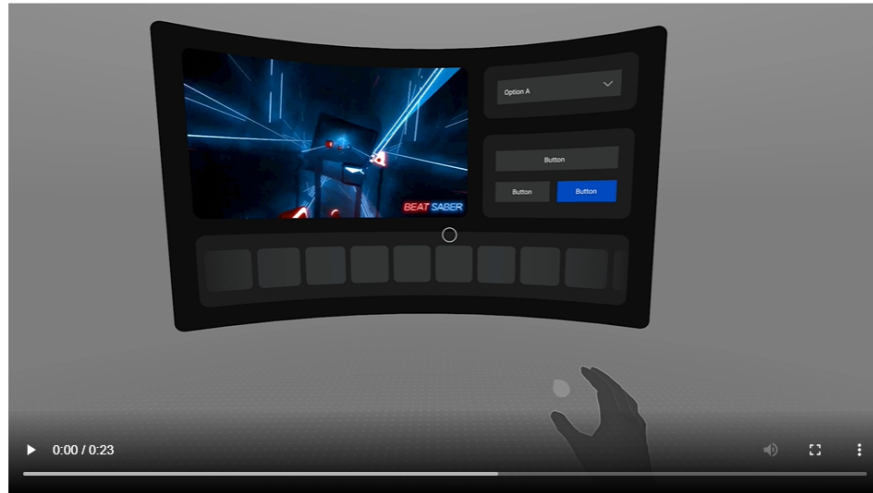
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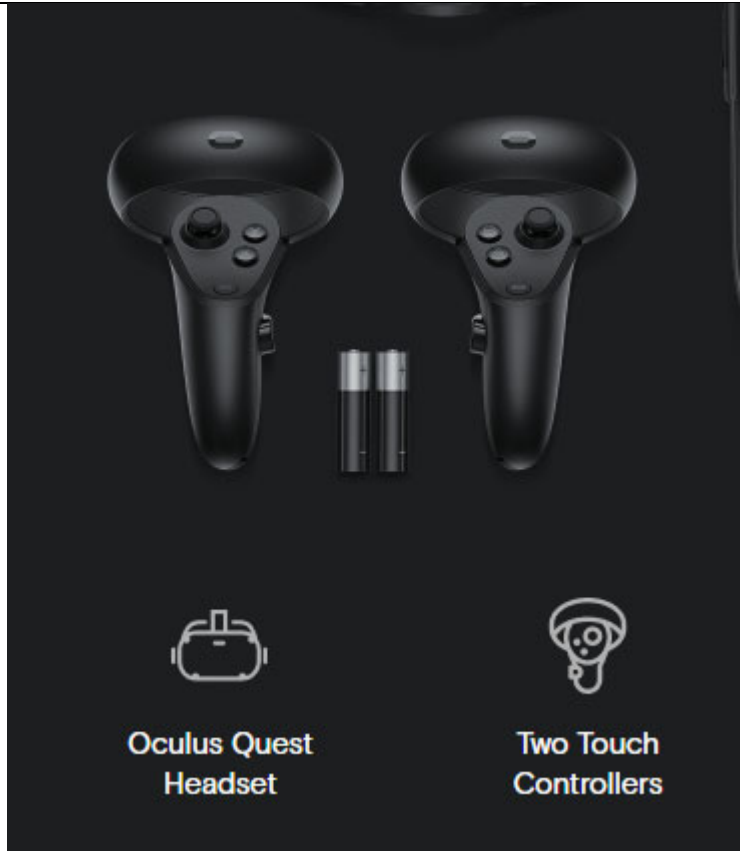
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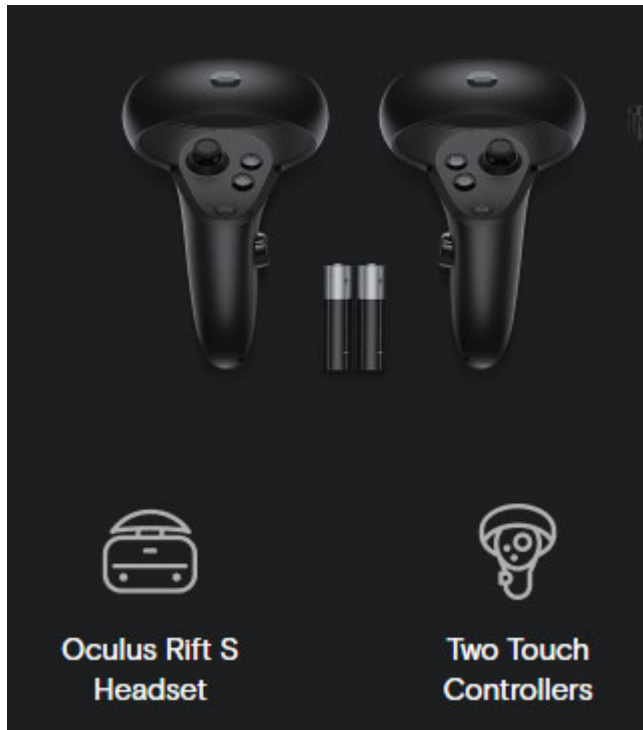
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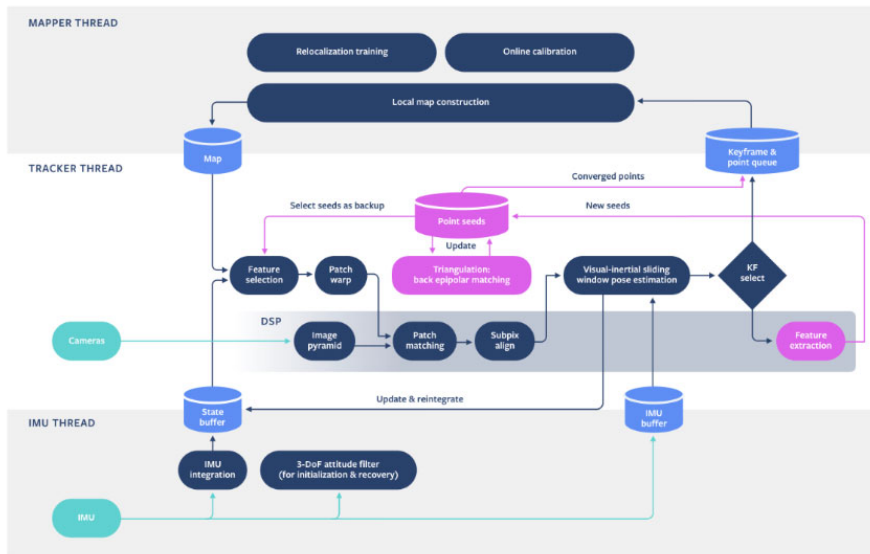
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Claim 3

(3) The system of claim 2 wherein the interface enables the sensor module to perform computations independently of an implementation of the estimation subsystem.

See supra claims 1, 2. Facebook makes, uses, sells, and/or offers for sale in the United States, and/or imports into the United States, the Accused Products, in which the interface for each sensor module included in the sensor subsystem to interact with a corresponding set of one or more sensing elements enables the sensor module to perform computations independently of an implementation of the estimation subsystem. For example, in the Accused Products, the interfaces between each sensor module (e.g., software components, such as the IMU thread) and a corresponding set of one or more sensing elements (e.g., the cameras and IMUs, such as accelerometers and gyroscopes, within the HMD, and the IMUs within the Oculus controllers) enable the sensor module to perform computations (e.g., processing data received from the cameras and IMUs) independently of the implementation of the estimation subsystem (e.g., the Oculus Insight tracking system).

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There are other complications, too. The infrared LEDs in the two hand controllers drastically change appearance when they move closer or farther away from the headset as you swing a virtual sword or maneuver a virtual spaceship. Oculus Insight also uses other sensors, drawing acceleration and velocity data from the inertial measurement units (IMUs) located in the headset and controllers. The system must process all of these data points in real time and, in the case of Quest, on a mobile chipset.

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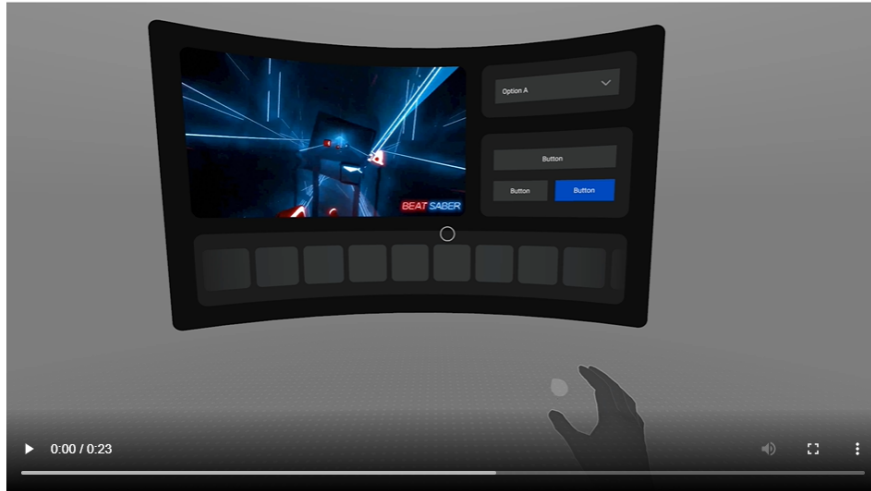
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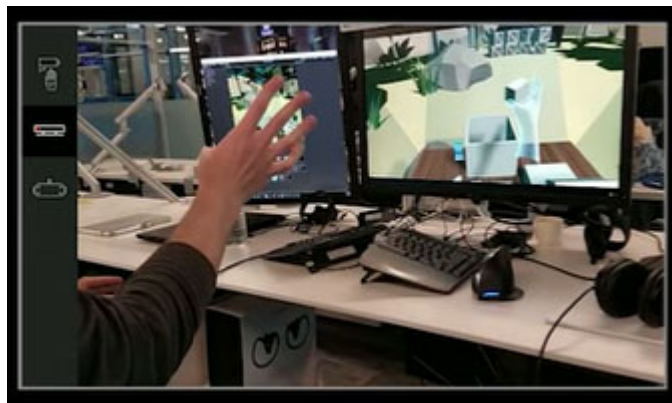
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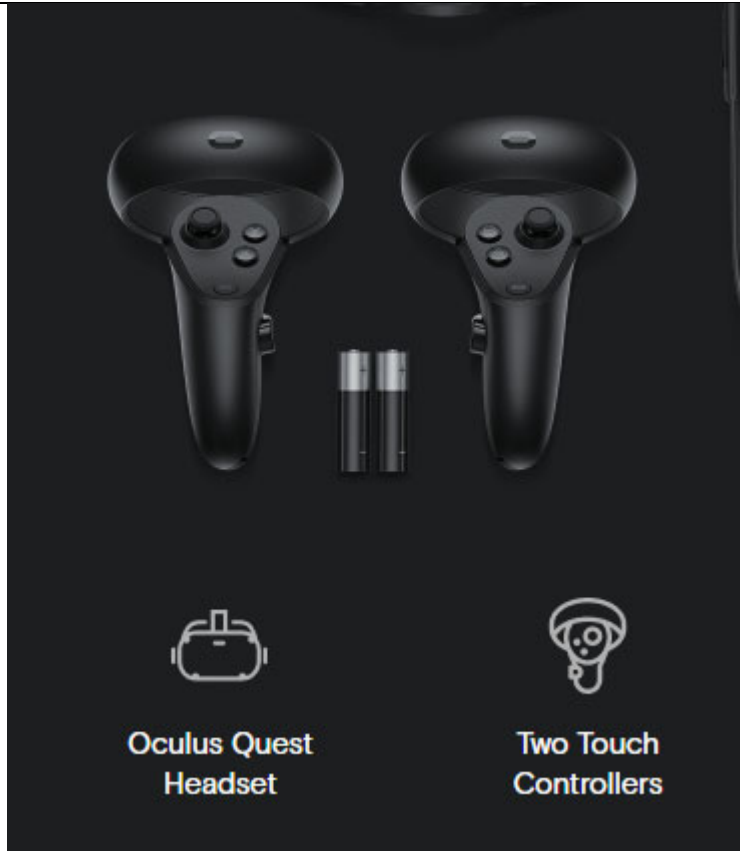
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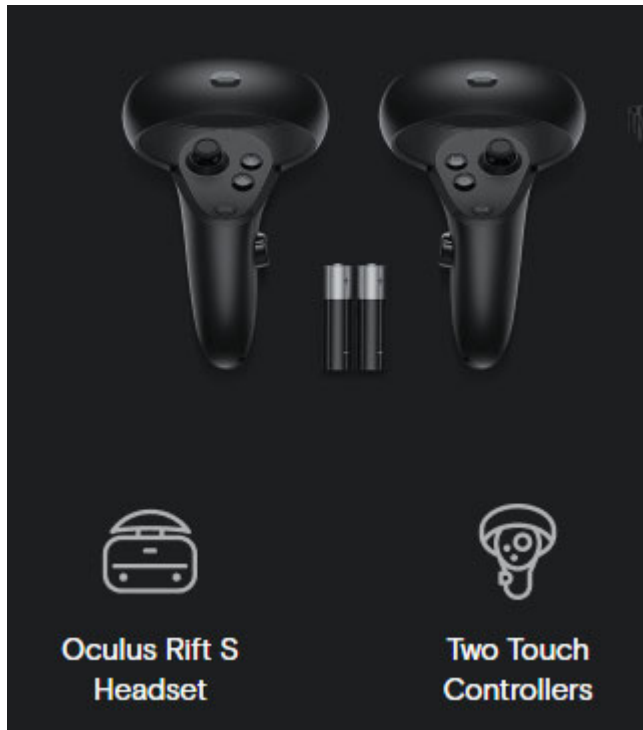
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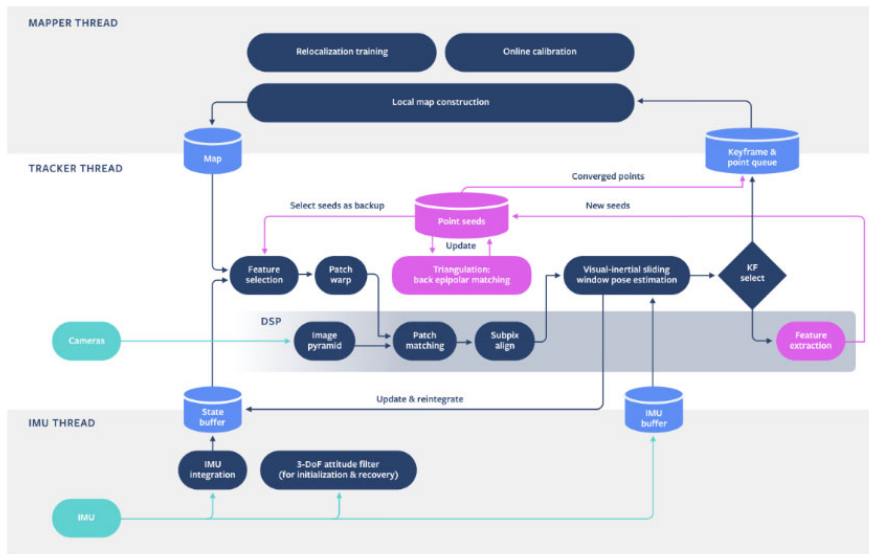
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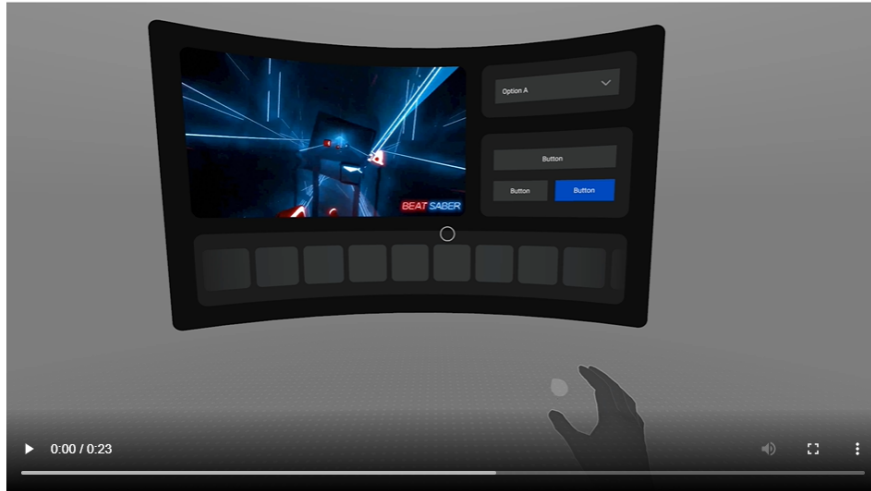
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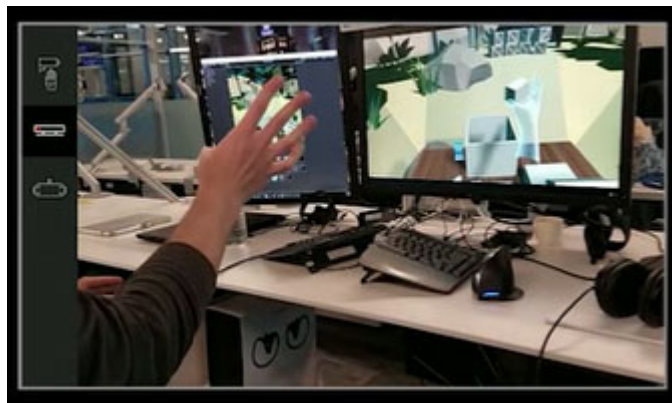
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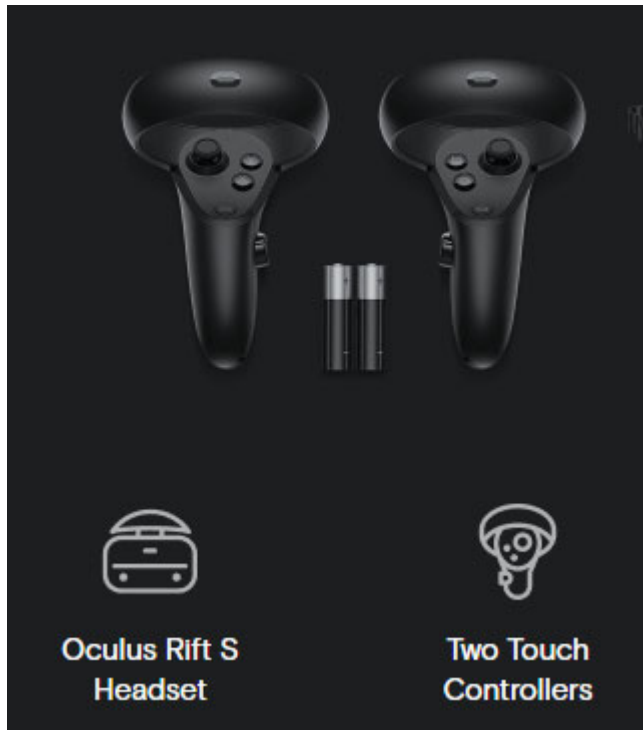
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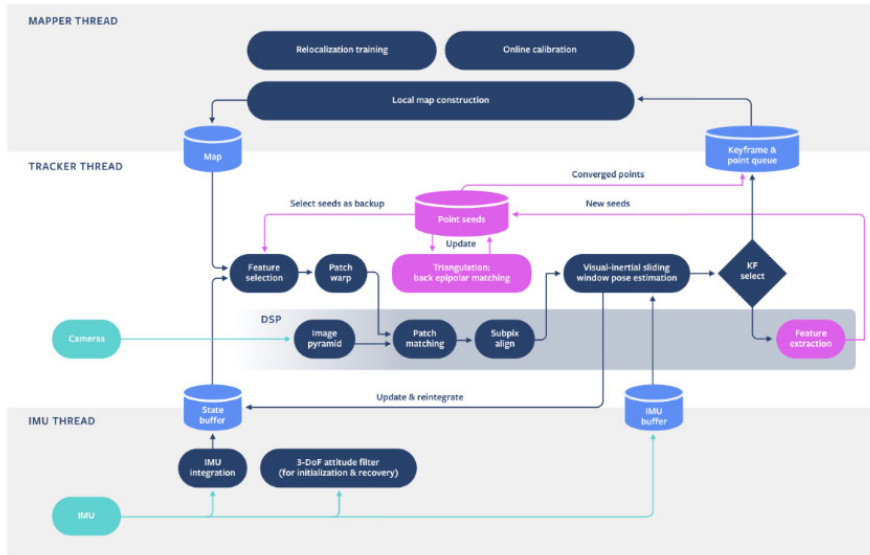
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Claim 6

(6pre) A method comprising:

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See, e.g., Compare Headsets.



Oculus Quest
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With 6DOF, the headset tracks the movement of both your head and body, then translates them into VR with realistic precision. No external sensors required.



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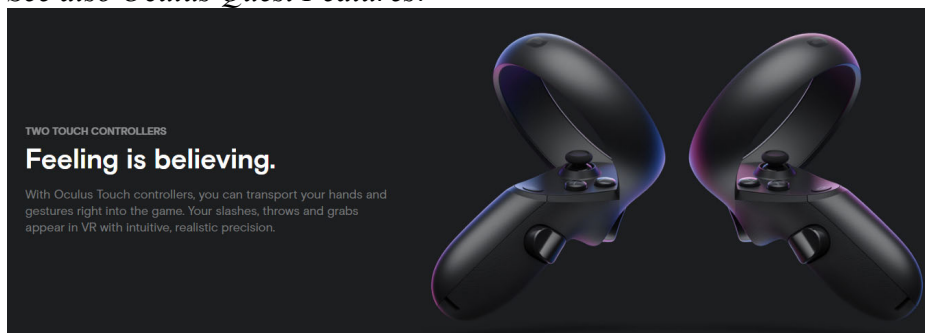
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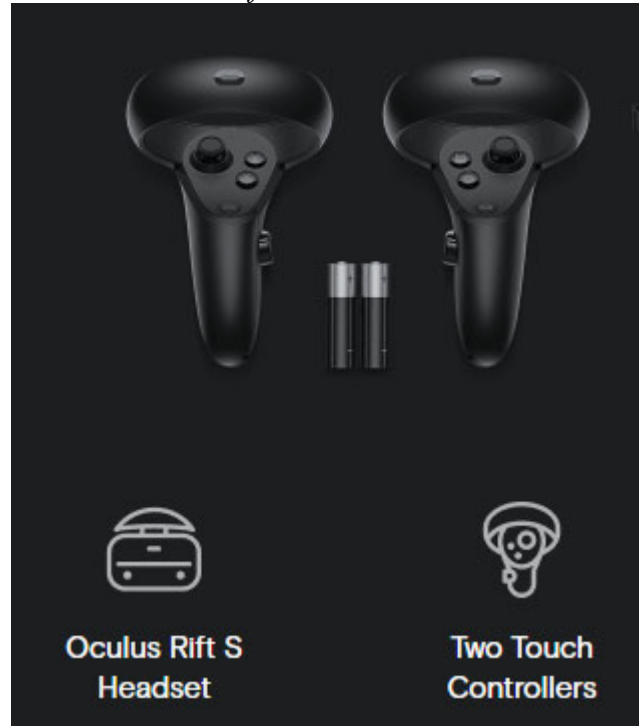
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See also Oculus Quest Features.



See also Oculus Rift S.



(6a) enumerating sensing elements available to a tracking system that includes an estimation subsystem that estimates a position or orientation of an object; and

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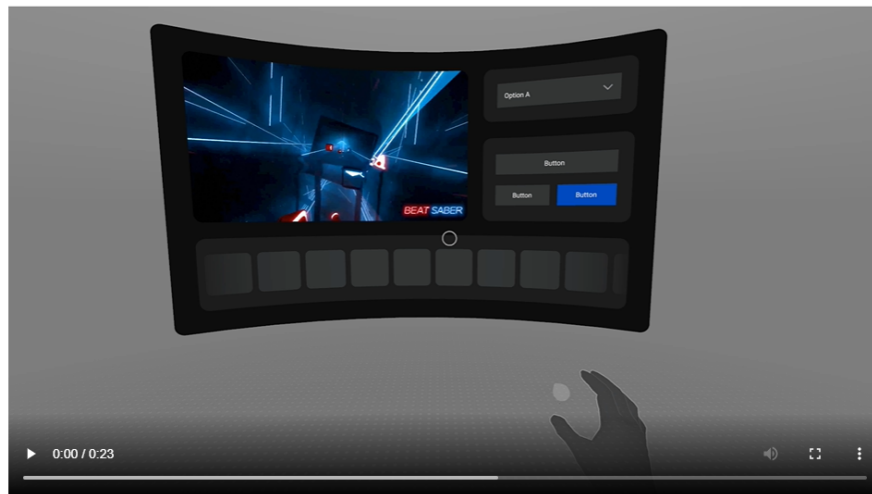
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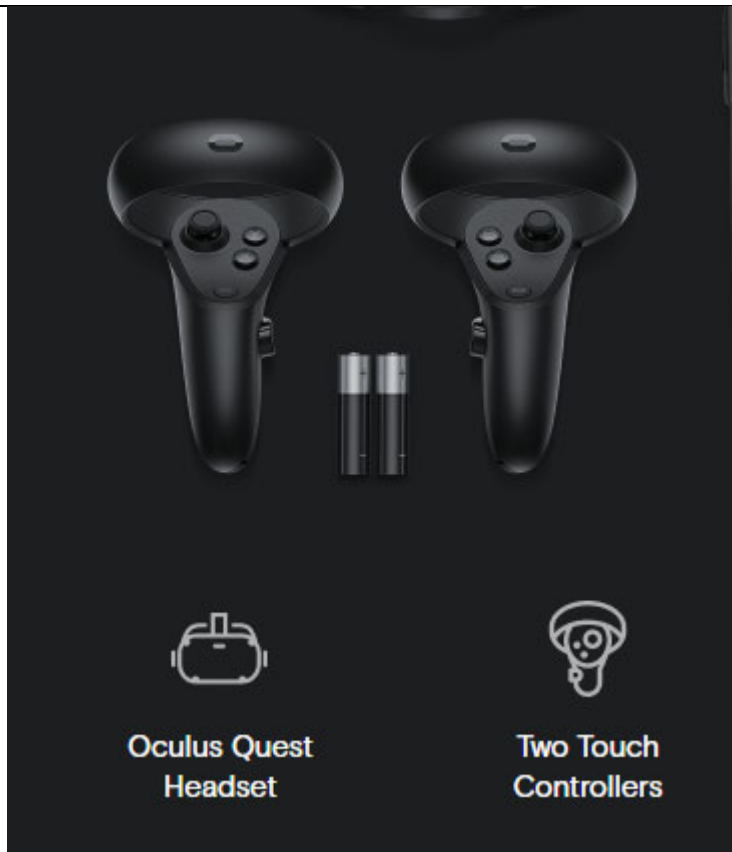
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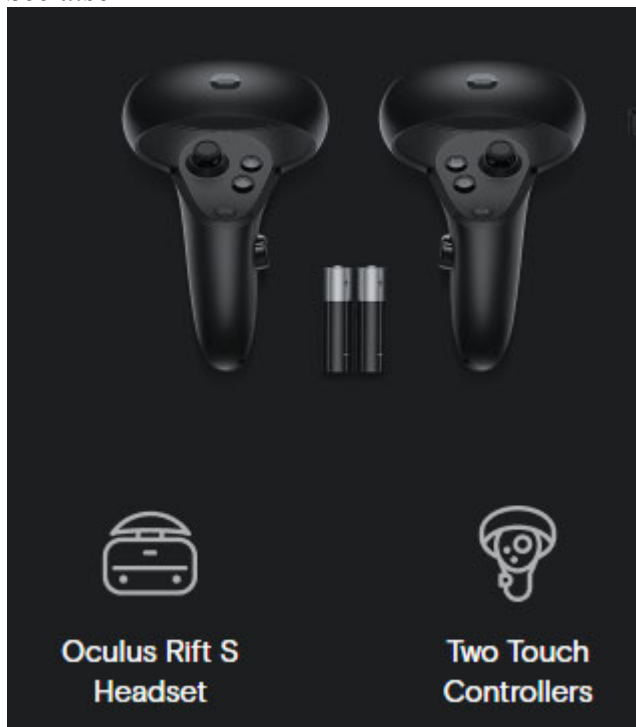
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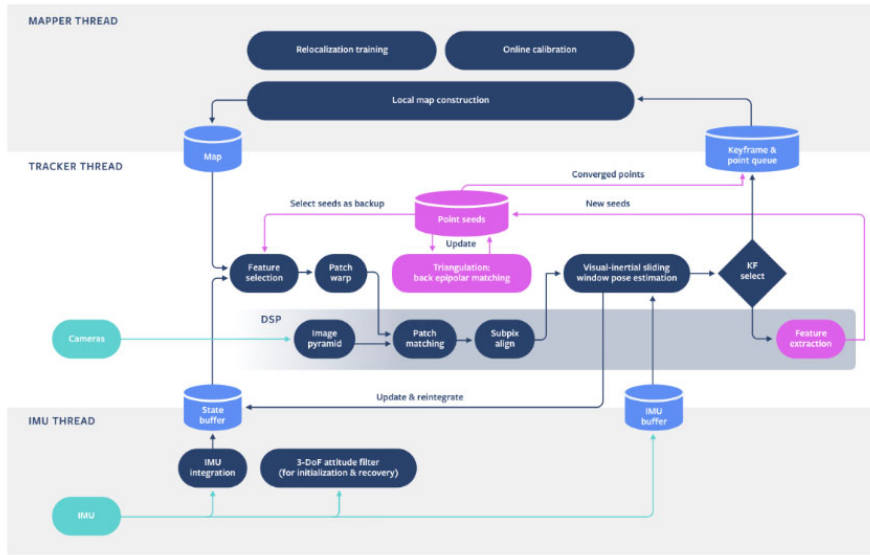
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(6b) providing parameters specific to the enumerated sensing elements to the tracking system to enable the estimation subsystem to be configured based on the parameters specific to the enumerated sensing elements to enable the estimation subsystem to estimate the position or orientation of the object.

Facebook encourages, directs, or promotes users to use the Accused Products to provide parameters specific to the enumerated sensing elements (e.g., the characteristics of the sensing elements and/or the number of controllers in use at a particular time) to the tracking system to enable the estimation subsystem to be configured based on the parameters specific to the enumerated sensing elements to enable the estimation subsystem (e.g., the Oculus Insight tracking system) to estimate the position or orientation of the object (e.g., the user's hand(s) and/or the Oculus controller(s)), and Facebook performs such step itself. For example, when the Accused Products are in the no controller configuration, only the HMD cameras are enumerated to track the user's hand location based on features on the hands. If one or both controllers are used, then the HMD cameras detect the infrared LEDs on the controllers held by the user and the HMD receives inertial signals from the controller IMUs to determine the location of the user's hand(s) and/or the Oculus controller(s). As a further example, in the Accused Products, parameters specific to the sensing elements enumerated, including optical sensors (e.g., cameras) and inertial sensors (e.g., IMUs), are provided to the tracking system so that the Oculus Insight tracking system can be configured based on parameters specific to the sensing elements enumerated. Configuring the Oculus Insight tracking system based on these parameters enables it to estimate the position or orientation of the user's hand(s) and/or the Oculus controller(s).

The Accused Products are especially adapted to carry out this method, which is a material part of the claimed invention, and have no substantial noninfringing uses. Further, on information and belief, Facebook conditions a user's use of the Accused Products, and therefore the user's receipt of the benefits of the Accused Products, upon this method and establishes the manner or timing of that use (e.g., through its software and/or user instructions, which have not been provided at this stage of the litigation).

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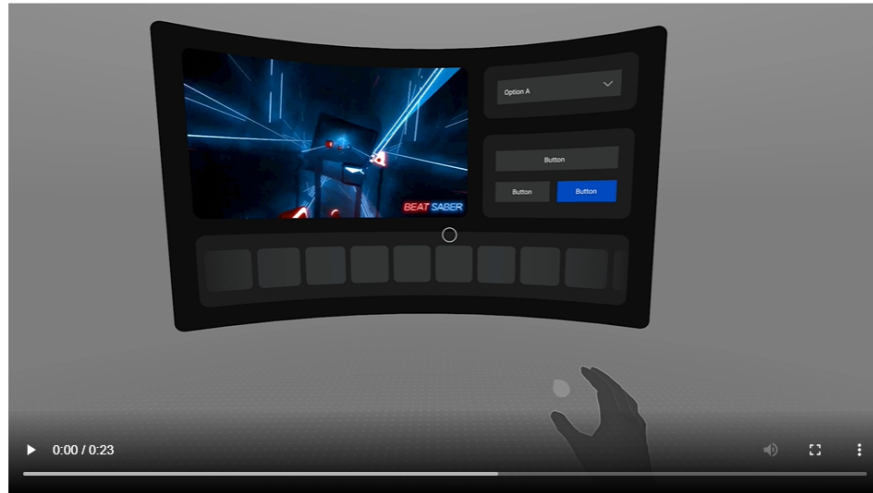
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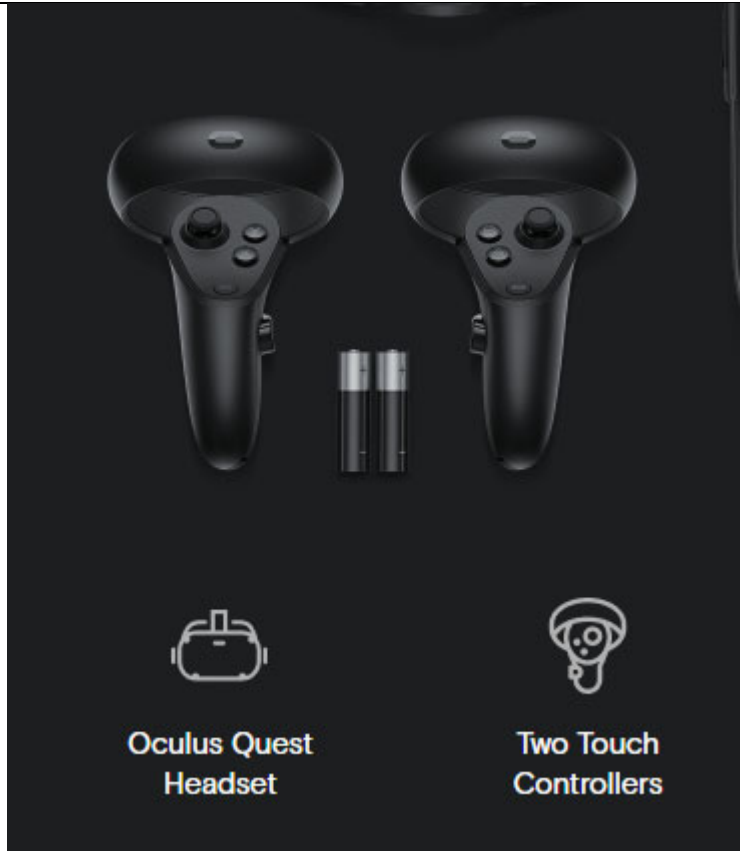
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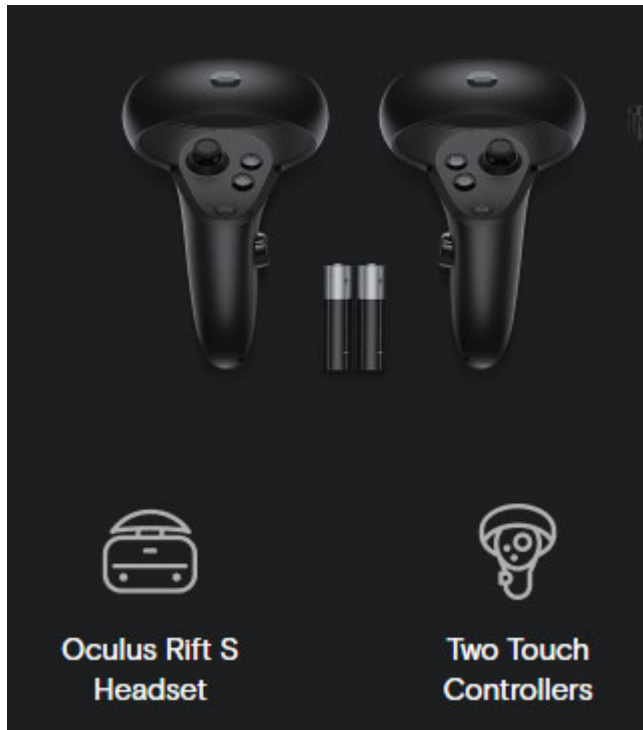
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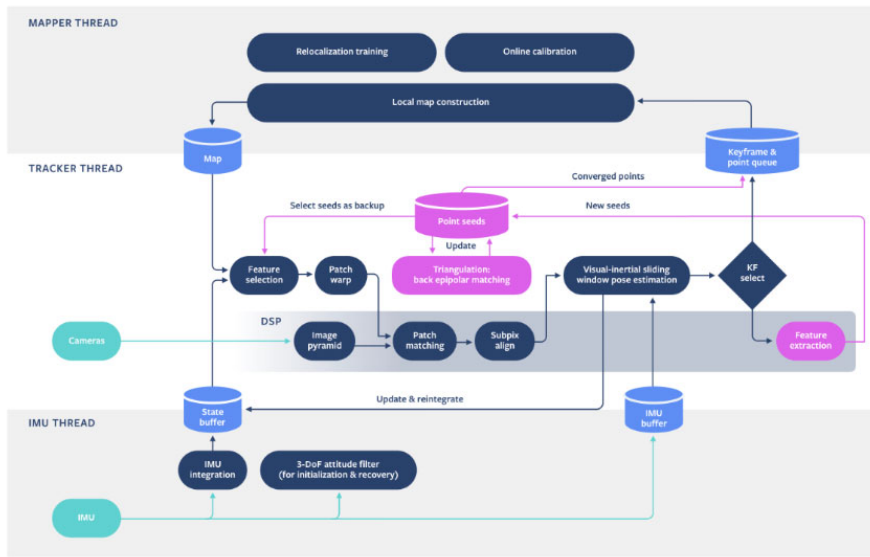
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Claim 7

(7) The method of claim 6, further comprising selecting a pair of sensing elements from a sequence of candidates of pairs of sensing elements, the selected pair of sensing elements being ready to make a measurement at the time of selection of the pair or at a predefined time after the time of selection of the pair, the selected pair having a highest expected utility of a measurement among the sequence of candidates.

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See, e.g., From the Lab.

There are other complications, too. The infrared LEDs in the two hand controllers drastically change appearance when they move closer or farther away from the headset as you swing a virtual sword or maneuver a virtual spaceship. Oculus Insight also uses other sensors, drawing acceleration and velocity data from the inertial measurement units (IMUs) located in the headset and controllers. The system must process all of these data points in real time and, in the case of Quest, on a mobile chipset.

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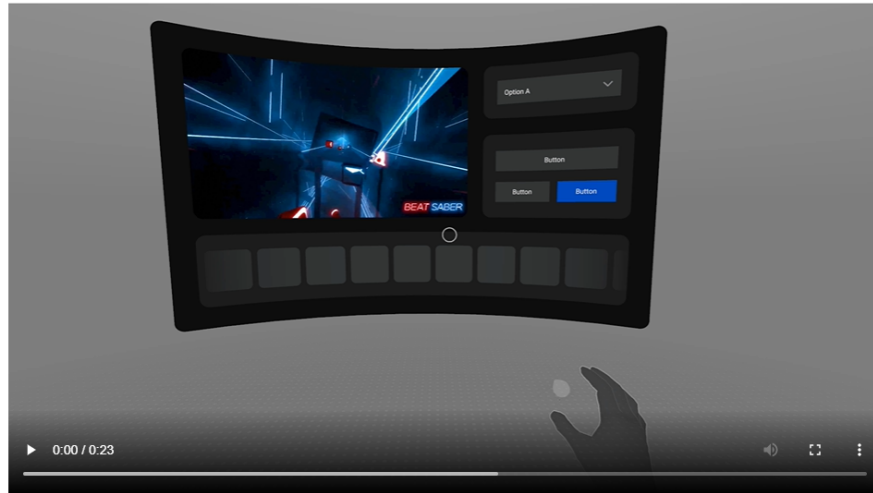
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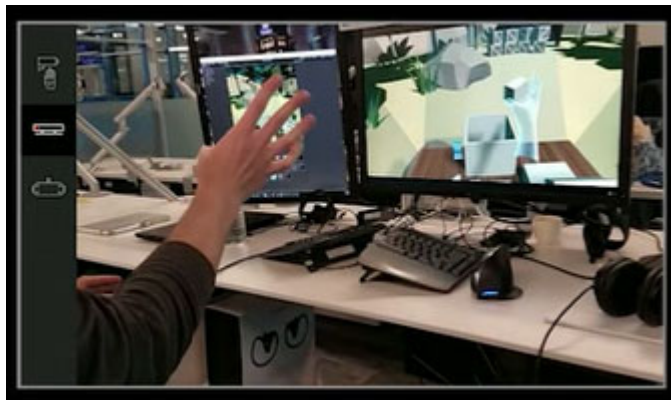
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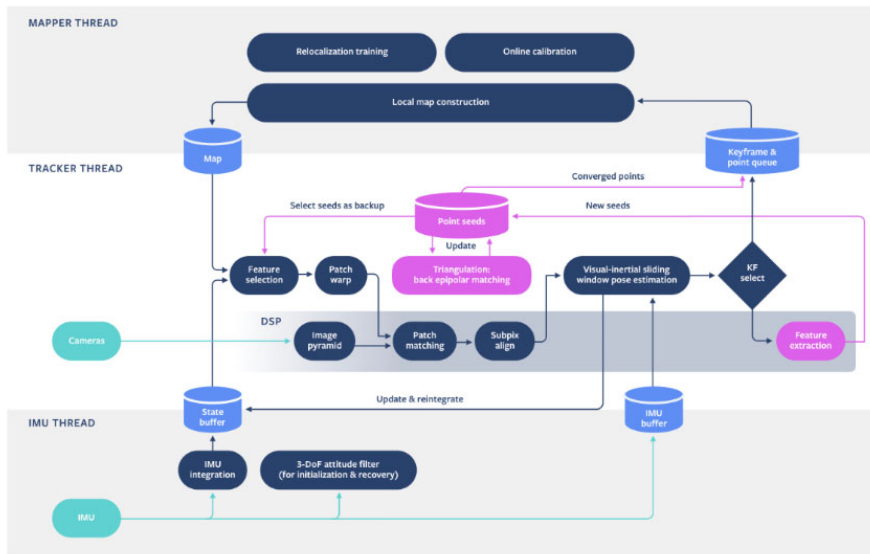
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Claim 8

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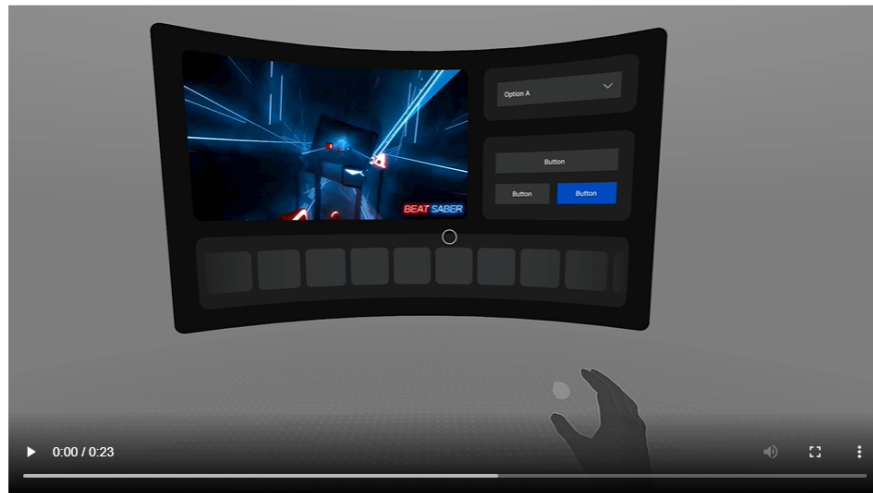
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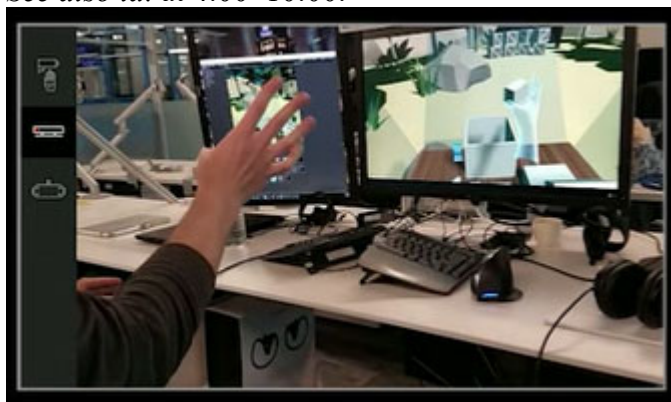
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The Oculus Insight system uses a custom hardware architecture and advanced computer vision algorithms — including visual-inertial mapping, place recognition, and geometry reconstruction — to establish the location of objects in relation to other objects within a given space. This novel algorithm stack enables a VR device to pinpoint its location, identify aspects of room geometry (such as floor location), and track the positions of the headset and controllers with respect to a 3D map that is generated and constantly updated by Insight. The data used for this process comes from three types of sensors built into the Quest and Rift S hardware:

See also id.

At last year's Oculus Connect event we shared some details about [Oculus Insight](#), the cutting-edge technology that powers both Quest and Rift S. Now that both of those products are available, we're providing a deeper look at the AI systems and techniques that power this VR technology. Oculus Insight marks the first time that fully untethered six-degree-of-freedom (6DoF) headset and controller tracking has shipped in a consumer AR/VR device. Built from the ground up, the Insight stack leverages state-of-the-art computer vision (CV) systems and visual-inertial simultaneous localization and mapping, or SLAM.

See also From the Lab.

"We wanted to create a system that lets you move and explore a VR world just as naturally and easily as you would in real life," says Kozminski.

Kozminski joined a team whose mission was to create the first full-featured "inside-out" tracking system for a consumer VR device. The technology would have to track the full range of a person's movements (known as six degrees of freedom) and be able to pinpoint the location of the two handheld controllers as well as the headset.

Previously, VR devices relied on external sensors to track these movements. These cameras attach to a PC, and while they work well, they make VR less portable and more complicated to set up.

"With inside-out tracking in the headset, VR becomes as easy as putting on headphones to listen to music," says Kozminski.

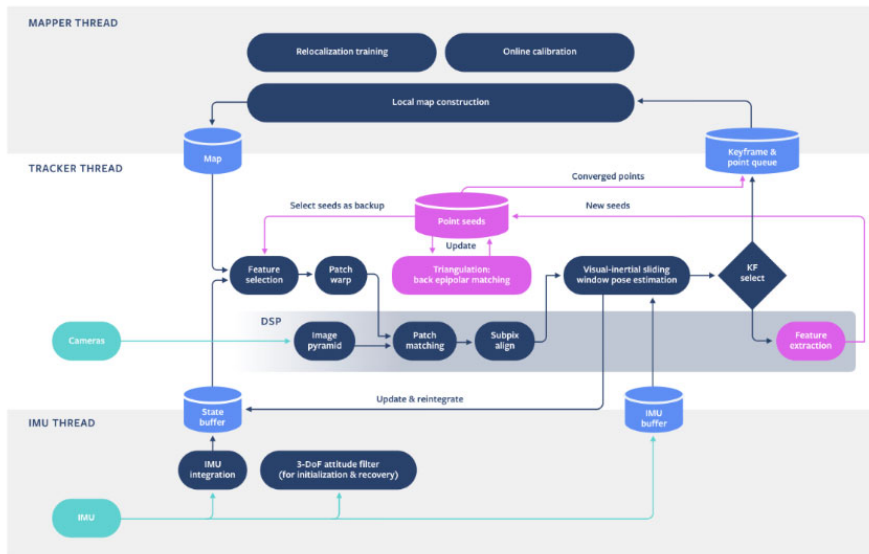
See also Powered by AI.

headset and controllers with respect to a 3D map that is generated and constantly updated by Insight. The data used for this process comes from three types of sensors built into the Quest and Rift S hardware:

1. Linear acceleration and rotational velocity data from IMUs in the headset and controllers are integrated to track the orientation and position of each with low latency.
2. Image data from cameras in the headset helps generate a 3D map of the room, pinpointing landmarks like the corners of furniture or the patterns on your floor. These landmarks are observed repeatedly, which enables Insight to compensate for drift (a common challenge with IMUs, where even tiny measurement discrepancies build up over time, resulting in inaccurate location tracking).
3. Infrared LEDs in the controllers are detected by the headset cameras, letting the system bound the controller position drift caused by integrating multiple IMUs.

See also id.

Headset tracking compute architecture



Oculus Insight processes multiple threads of data at once, in real-time — the mapper thread modifies the map, sending updated copies to the tracker thread, which uses camera frames to estimate poses in the mapper-provided frames, while the IMU thread uses measurements from the IMUs to update the latest SLAM state.

See also *From the Lab*, Sensor Placement at 0:23.



See also *From the Lab*, Sensor Placement at 0:30.



See also Heaney.

More Precise Tracking

A function for infrared LED calibration exists, suggesting this controller is optically tracked in the same way as the current Touch— cameras on the headset follow the movement of the LED constellation, and this is fused with the accelerometer readings to achieve sub-mm precision.



Facebook's VR controllers are tracked via infrared LEDs under the plastic

See also id.

The driver also reveals the series model number of the controller's inertial measurement unit (IMU)- the chip within all VR controllers which contains the accelerometer.

Teardowns and the [FCC filings](#) for the current Touch showed it uses TDK's ICM-20601 IMU from late 2015.



The IMU in the current Touch controllers for Rift S and Quest

See also ICM-20601 Specification.

FEATURES

- 3-Axis Gyroscope with Programmable FSR of $\pm 500\text{dps}$, $\pm 100\text{dps}$, $\pm 2000\text{dps}$ and $\pm 4000\text{dps}$
- 3-Axis Accelerometer with Programmable FSR of $\pm 4g$, $\pm 8g$, $\pm 16g$, and $\pm 32g$
- User-programmable interrupts
- Wake-on-motion interrupt for low power operation of applications processor
- 512 byte FIFO buffer enables the applications processor to read the data in bursts
- On-Chip 16-bit ADCs and Programmable Filters
- Host interface: 8 MHz SPI or 400k Hz Fast Mode I²C
- Digital-output temperature sensor
- VDD operating range of 1.71 to 3.45V
- MEMS structure hermetically sealed and bonded at wafer level
- RoHS and Green compliant

Claim 9

(9) The method of claim 8 wherein the target comprises a natural feature in an environment.

See supra claims 6, 8. Facebook encourages, directs, or promotes users to perform the method of claim 8 in which the target comprises a natural feature in an environment (e.g., landmarks like the corners of furniture or the patterns on the floor), and Facebook performs such step itself. The Accused Products are especially adapted to carry out this method, which is a material part of the claimed invention, and have no substantial noninfringing uses. Further, Facebook conditions a user's use of the Accused Products upon this method and establishes the manner or timing of that use.

See, e.g., From the Lab.

There are other complications, too. The infrared LEDs in the two hand controllers drastically change appearance when they move closer or farther away from the headset as you swing a virtual sword or maneuver a virtual spaceship. Oculus Insight also uses other sensors, drawing acceleration and velocity data from the inertial measurement units (IMUs) located in the headset and controllers. The system must process all of these data points in real time and, in the case of Quest, on a mobile chipset.

See also Powered by AI.

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