

[54] **METHOD AND APPARATUS FOR DETERMINING POSITION AND ORIENTATION OF A MOVEABLE OBJECT USING ACCELEROMETERS**

[75] Inventors: **Mike A. Horton**, Berkeley; **A. Richard Newton**, Woodside, both of Calif.

[73] Assignee: **Crossbow Technology, Inc.**, San Jose, Calif.

[21] Appl. No.: **184,583**

[22] Filed: **Jan. 21, 1994**

[51] **Int. Cl.⁶** **G09G 3/02**

[52] **U.S. Cl.** **364/516; 364/517; 364/578; 364/410; 364/449.1; 340/988; 351/209**

[58] **Field of Search** **364/410, 449, 364/453, 516, 517, 578; 351/210, 209; 340/988, 989, 990**

[56] **References Cited**

U.S. PATENT DOCUMENTS

3,983,474	9/1976	Kuipers	324/43 R
4,017,858	4/1977	Kuipers	343/100 R
4,849,692	7/1989	Blood	324/208
4,852,988	8/1989	Velez et al.	351/210 R
4,945,305	7/1990	Blood	324/207
4,988,981	6/1991	Zimmermann et al.	340/709
5,072,218	12/1991	Spero et al.	340/980
5,245,537	9/1993	Barber	364/453 X
5,280,265	1/1994	Kramer et al.	338/210
5,290,964	3/1994	Hiyoshi et al.	84/600
5,307,072	4/1994	Jones, Jr.	342/147
5,373,857	12/1994	Travers et al.	128/782
5,422,653	6/1995	Maguire et al.	345/9

OTHER PUBLICATIONS

GDMulti-Receivers/Transmitters Tracking Device, A Flock of Birds™ Product Specification by Asension Tech. Corp. ACT Nov. 1992.

3 Space Fastrak Product specifications by PDLHEM US; Jul. 1992.

Friedmann, Martin, Staner, Thad and Pentland, Alex, "Synchronization in Virtual Realities," 1992 PRESENCE vol. 1, No. 1, pp. 139 - 144.

J. A. Adam, "Virtual Reality is for Real", IEEE Spectrum Oct. 1993, pp. 22-29.

T. A. DeFanti et al., "A 'Room' with a 'View'", IEEE Spectrum Oct. 1993, pp. 30-33.

Analog Devices product specification for Model ADXL50*, "Monolithic Accelerometer with Signal Conditioning", pp. 1-16 Jun. 1993.

R. A. Quinell, "Software Simplifies Virtual-World Design", EDN-Technology Update, Nov. 25, 1993, pp. 47-54.

North Atlantic Treaty Organization, Agard Lecture Series No. 133 "Advances in Strapdown Intertial Systems", pp. 3-1 through 3-29; May 1994.

(List continued on next page.)

Primary Examiner—James P. Trammell

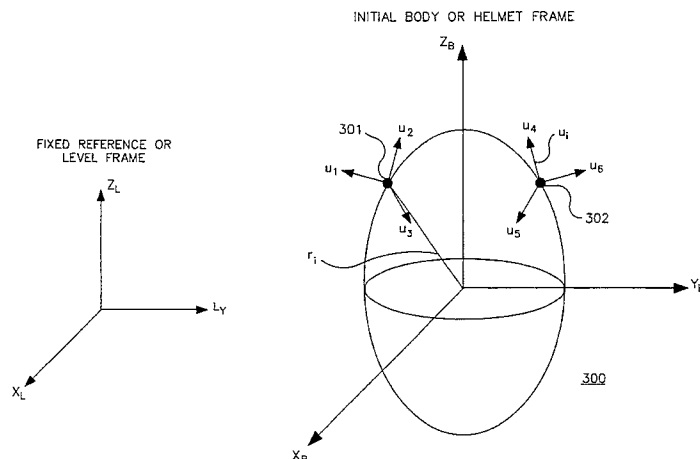
Assistant Examiner—Kamini Shah

Attorney, Agent, or Firm—Albert C. Smith

[57] **ABSTRACT**

A three-dimensional position and orientation tracking system uses accelerometers to measure acceleration of a moveable object (e.g., a head-mounted display unit or a data glove). A tracking processor generates both position and orientation information on the object relative to a simulation environment as a function of the acceleration data. In one embodiment, a simplified radar-based tracking system is disposed relative to the object and periodically provides additional tracking data on the object to the tracking processor. The tracking processor uses the additional data to correct the position and orientation information using a feedback filter process. The position and orientation information signals generated can be used, for example, in a simulation or virtual reality application. Position and orientation information is received by a simulation processor relative to the object. The simulation processor modifies a simulation environment as a function of the position and orientation information received. Modified simulation environment information (e.g., video and/or audio information) is then presented to a user.

21 Claims, 9 Drawing Sheets



OTHER PUBLICATIONS

North Atlantic Treaty Organization, Agard Lecture Series No. 82 "Practical Aspects of Kalman Filtering Implementation", pp. 2-1 through 2-11; 1976.

A. Gelb et al., "Applied Optimal Estimation", The M.I.T. Press, pp. 50-143 1974.

Shetty et al., Image-sensor-based target maneuver detection; Optical Engineering vol. 32, No. 11, pp. 2735-2740 Nov. 1993.

Guedry et al., The dynamic of spatial orientation during complex and changing linear and angular acceleration, Journal of Vestibular Research:Equilibrium and Orientation, vol. 2, No. 4, pp. 259-283 Nov. 1992.

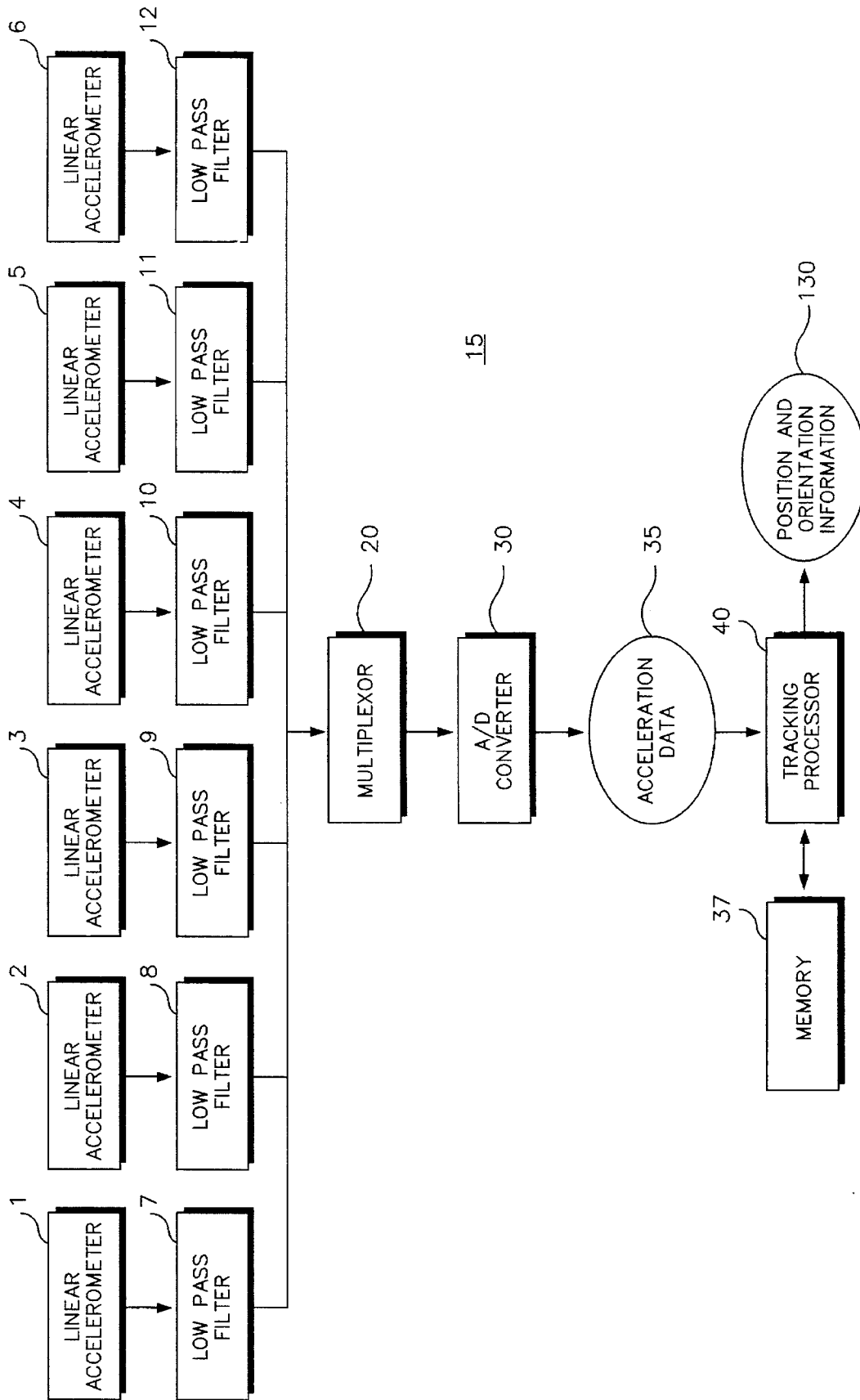


FIGURE 1

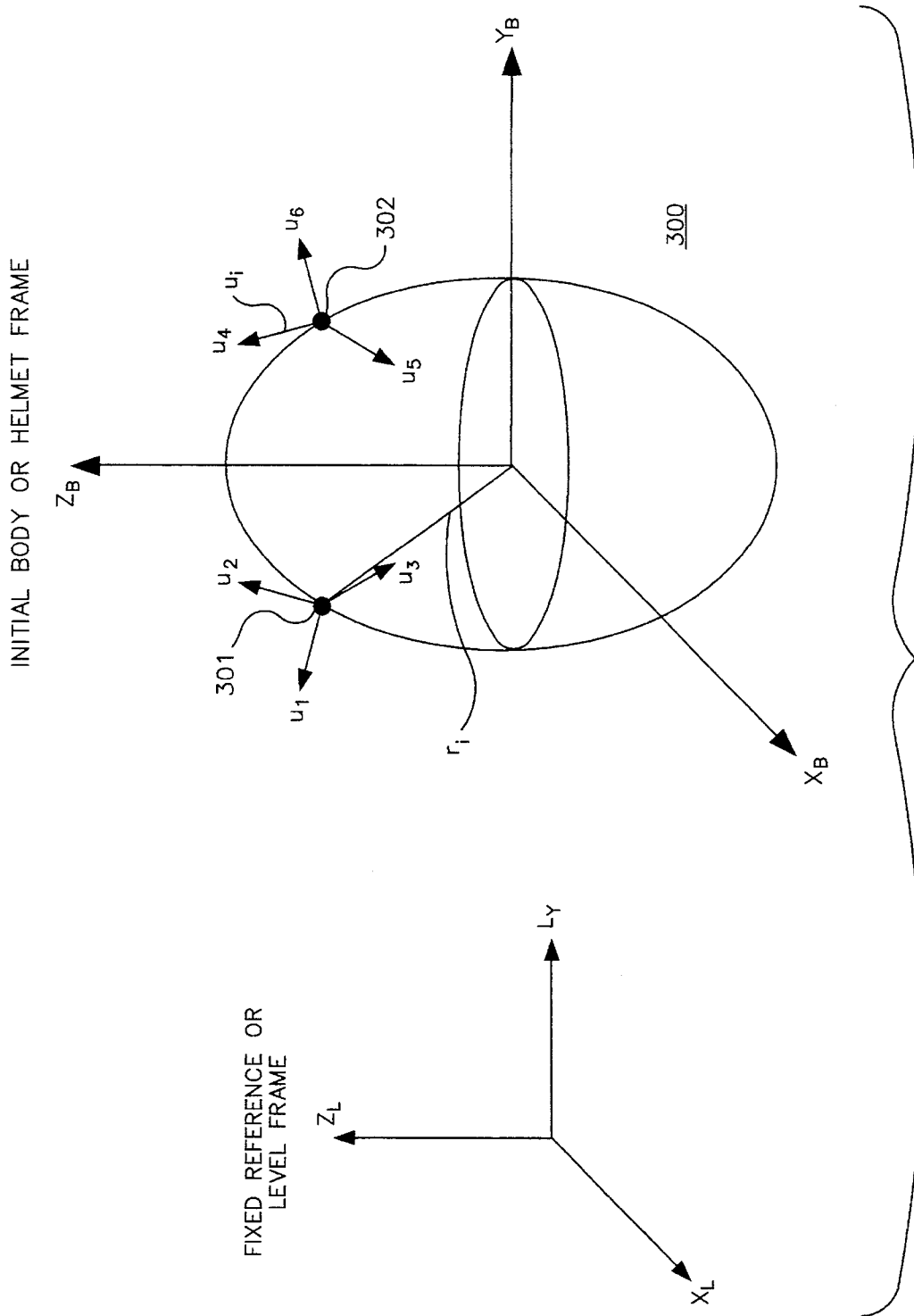


FIGURE 2

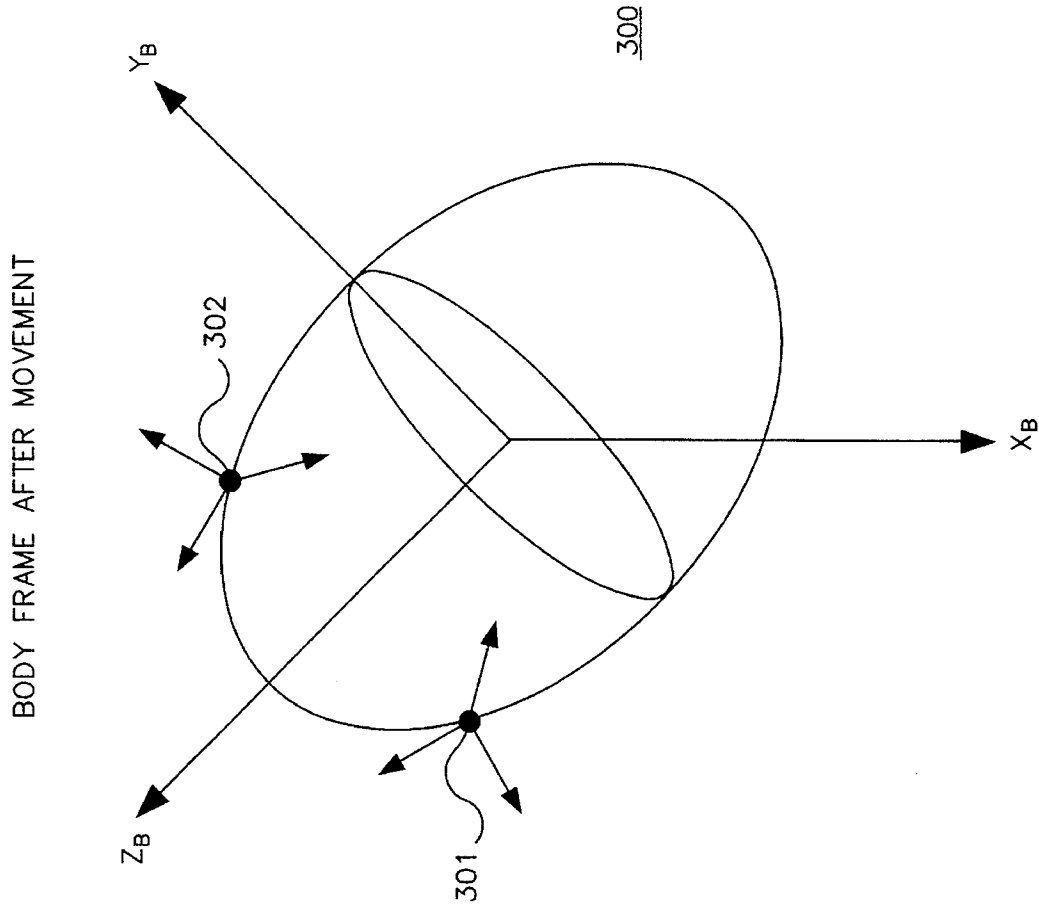


FIGURE 2A

Explore Litigation Insights

Docket Alarm provides insights to develop a more informed litigation strategy and the peace of mind of knowing you're on top of things.

Real-Time Litigation Alerts



Keep your litigation team up-to-date with **real-time alerts** and advanced team management tools built for the enterprise, all while greatly reducing PACER spend.

Our comprehensive service means we can handle Federal, State, and Administrative courts across the country.

Advanced Docket Research



With over 230 million records, Docket Alarm's cloud-native docket research platform finds what other services can't. Coverage includes Federal, State, plus PTAB, TTAB, ITC and NLRB decisions, all in one place.

Identify arguments that have been successful in the past with full text, pinpoint searching. Link to case law cited within any court document via Fastcase.

Analytics At Your Fingertips



Learn what happened the last time a particular judge, opposing counsel or company faced cases similar to yours.

Advanced out-of-the-box PTAB and TTAB analytics are always at your fingertips.

API

Docket Alarm offers a powerful API (application programming interface) to developers that want to integrate case filings into their apps.

LAW FIRMS

Build custom dashboards for your attorneys and clients with live data direct from the court.

Automate many repetitive legal tasks like conflict checks, document management, and marketing.

FINANCIAL INSTITUTIONS

Litigation and bankruptcy checks for companies and debtors.

E-DISCOVERY AND LEGAL VENDORS

Sync your system to PACER to automate legal marketing.