



(12) **United States Patent**
DiGioia, III et al.

(10) **Patent No.:** **US 6,205,411 B1**
(45) **Date of Patent:** ***Mar. 20, 2001**

(54) **COMPUTER-ASSISTED SURGERY PLANNER AND INTRA-OPERATIVE GUIDANCE SYSTEM**

(75) Inventors: **Anthony M. DiGioia, III**, Pittsburgh, PA (US); **David A. Simon**, Boulder, CO (US); **Branislav Jaramaz**; **Michael K. Blackwell**, both of Pittsburgh, PA (US); **Frederick M. Morgan**, Quincy; **Robert V. O'Toole**, Brookline, both of MA (US); **Takeo Kanade**, Pittsburgh, PA (US)

(73) Assignee: **Carnegie Mellon University**, Pittsburgh, PA (US)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.

This patent is subject to a terminal disclaimer.

(21) Appl. No.: **09/189,914**

(22) Filed: **Nov. 12, 1998**

Related U.S. Application Data

(63) Continuation-in-part of application No. 08/803,993, filed on Feb. 21, 1997, now Pat. No. 5,880,976.

(51) **Int. Cl.**⁷ **A61F 2/32**; A61F 2/34; A61F 2/36

(52) **U.S. Cl.** **703/11**; 703/7; 623/19; 623/20; 623/21; 623/22

(58) **Field of Search** 703/11, 7; 606/86, 606/89, 90, 91; 623/11, 16, 18, 19, 20, 21, 22, 23, 914

(56) **References Cited**

U.S. PATENT DOCUMENTS

4,341,220 7/1982 Perry 606/130
4,905,148 2/1990 Crawford 382/131

5,007,936	4/1991	Woolson	128/898
5,086,401	2/1992	Glassman et al.	700/259
5,141,512	8/1992	Farmer et al.	606/87
5,242,455	9/1993	Skeens et al.	606/130
5,251,127	10/1993	Raab	606/130
5,299,288	3/1994	Glassman et al.	700/245
5,305,203	4/1994	Raab	606/1
5,360,446	11/1994	Kennedy	128/898
5,383,454	1/1995	Bucholz	600/429

(List continued on next page.)

OTHER PUBLICATIONS

A. M. DiGioia, M.D., D. A. Simon, B. Jaramaz, M. Blackwell, F. Morgan, R. V. O'Toole, B. Colgan, E. Kischell, HipNav: Pre-operative Planning and Intra-operative Navigational Guidance for Acetabular Implant Placement in Total Hip Replacement Surgery, Proceeding of Computer Assisted Orthopedic Surgery, Bern, Switzerland (1996).

Robert J. Krushell, M.D., Denis W. Burke, M.D. and William H. Harris, M.D., Range of Motion in Contemporary Total Hip Arthroplasty, pp. 97-101, The Journal of Arthroplasty, vol. 6, No. 2, Jun. 1991.

Robert J. Krushell, M.D., Dennis W. Burke, M.D. and William H. Harris, M.D., Elevated-rim Acetabular Components, pp. 1-6, The Journal of Arthroplasty, vol. 6, Oct., 1991.

(List continued on next page.)

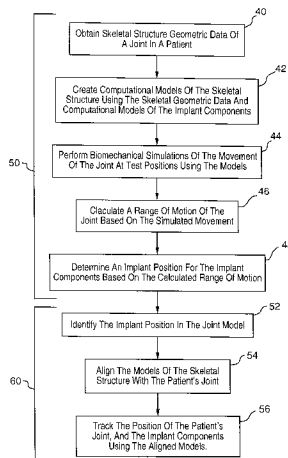
Primary Examiner—Kevin J. Teska
Assistant Examiner—Russell W. Frejz

(74) *Attorney, Agent, or Firm*—Kirkpatrick & Lockhart LLP

(57) **ABSTRACT**

An apparatus for facilitating the implantation of an artificial component in one of a hip joint, a knee joint, a hand and wrist joint, an elbow joint, a shoulder joint, and a foot and ankle joint. The apparatus includes a pre-operative geometric planner and a pre-operative kinematic biomechanical simulator in communication with the pre-operative geometric planner.

17 Claims, 14 Drawing Sheets



U.S. PATENT DOCUMENTS

5,389,101	2/1995	Heilbrun et al.	606/130
5,408,409	4/1995	Glassman et al.	600/407
5,517,990	5/1996	Kalfas et al.	600/414
5,682,886	11/1997	Delp et al.	600/407
5,733,338	3/1998	Kampner	128/898
5,880,976 *	3/1999	DiGioia, III et al.	703/7
5,995,738 *	11/1999	DiGioia, III et al.	703/11
6,002,859 *	12/1999	DiGioia, III et al.	703/11

OTHER PUBLICATIONS

George E. Lewinnek, M.D., Jack L. Lewis, Ph.D., Richard Tarr, M.S., Clinton L. Compere, M.D. and Jerald R. Zimmerman, B.S., Dislocations After Total Hip-Replacement Arthroplasties, pp. 217-220, vol. 60-A, No. 2, Mar., 1978, The Journal of Bone and Joint Surgery, Incorporated.

Harlan C. Amstutz, M.D., R. M. Ludwig, D. J. Schurman, M.D. and A. G. Hodgson, Range of Motion Studies for Total Hip Replacements, pp. 124-130, Clinical Orthopaedics and Related Research, #111, Sep., 1975.

T. K. Cobb, M.D., B. F. Morrey, M.D. and D. M. Ilstrup, M.S., The Elevated-Rim Acetabular Liner in Total Hip Arthroplasty: Relationship to Postoperative Dislocation, pp. 80-86, The Journal of Bone and Joint Surgery, 1996.

D. A. Simon, R. V. O'Toole, M. Blackwell, F. Morgan, A. M. DiGioia and T. Kanade, Accuracy Validation in Image-Guided Orthopaedic Surgery, 2nd Annual Symposium on Medical Robotics and Computer Assisted Surgery, Baltimore, MD, Nov. 4-7th, 1995.

David A. Simon, Martial Hebert and Takeo Kanade, Techniques for Fast and Accurate Intraoperative Registration, Journal of Image Guided Surgery, 1:17-29 (1995).

Donald E. McCollum, M.D. and William J. Gray, M.D., Dislocation After Total Hip Arthroplasty, pp. 159-170, Clinical Orthopaedics and Related Research, No. 261, Dec., 1990.

David A. Simon, Martial Hebert and Takeo Kanade, Real-time 3-D Pose Estimation Using a High-Speed Range Sensor, pp. 1-14, Carnegie Mellon University, Robotics Institute, Technical Report, CMU-RI-TR-93-24, Nov., 1993.

T. A. Maxian, T. D. Brown, D. R. Pedersen, J. J. Callaghan, Femoral Head Containment in Total Hip Arthroplasty: Standard vs. Extended Lip Liners, p. 420, 42nd Annual Meeting, Orthopaedic Research Society, Feb. 19-22, Atlanta, Georgia.

T. A. Maxian, T. D. Brown, D. R. Pederson and J. J. Callaghan, Finite Element Modeling of Dislocation Propensity in Total Hip Arthroplasty, p. 259-44, 42nd Annual Meeting, Orthopaedic Research Society, Feb. 19-22, 1996, Atlanta, Georgia.

Vincent Dessenne, Stephane Lavallee, Remi Julliard, Rachel Orti, Sandra Martelli, Philippe Cinquin, , Computer-Assisted Knee Anterior Cruciate Ligament Reconstruction: First Clinical Tests, Journal of Image Guided Surgery 1:59-64 (1995).

Ali Hamadeh, Stephane Lavallee, Richard Szeliski, Philippe Cinquin, Olivier Peria, Anatomy-based Registration for Computer-integrated Surgery, pp. 212-218, Program of 1st International Conference on Computer Version Virtual Reality "Robotics in Medicine" 1995, Nice, France.

K. Rademacher, H. W. Staudte, G. Rau, Computer Assisted Orthopedic Surgery by Means of Individual Templates Aspects and Analysis of Potential Applications, pp. 42-48.

Lutz-P. Nolte, Lucia J. Zamorano, Zhaowei Jiang, Qinghai Wang, Frank Langlotz, Erich Arm, Heiko Visarius, A Novel Approach to Computer Assisted Spine Surgery, pp. 323-328.

Robert Rohling, Patrice Munger, John M. Hollerbach, Terry Peters, Comparison of Relative Accuracy Between a Mechanical and an Optical Position Tracker for Image-Guided Neurosurgery, Journal of Image Guided Surgery, 1:30-34 (1995).

E. Grimson, T. Lozano-Perez, W. Wells, G. Ettinger, S. White, R. Kikinis, Automated Registration for Enhanced Reality Visualization in Surgery, pp. 26-29.

S. Lavalle, P. Sautot, J. Troccaz, P. Cinquin, P. Merloz, Computer-Assisted Spine Surgery: A Technique for Accurate Transpedicular Screw Fixation Using CT Data and a 3-D Optical Localizer, Journal of Image Guided Surgery 1:65-73 (1995).

Russell H. Taylor, Brent D. Mittelstadt, Howard A. Paul, William Hanson, Peter Kazanzides, Joel F. Zuhars, Bill Williamson, Bela L. Musits, Edward Glassman, William L. Bargar, An Image-Directed Robotic System for Precise Orthopaedic Surgery, IEEE Transactions on Robotics and Automation, vol. 10, No. 3, Jun., 1994.

* cited by examiner

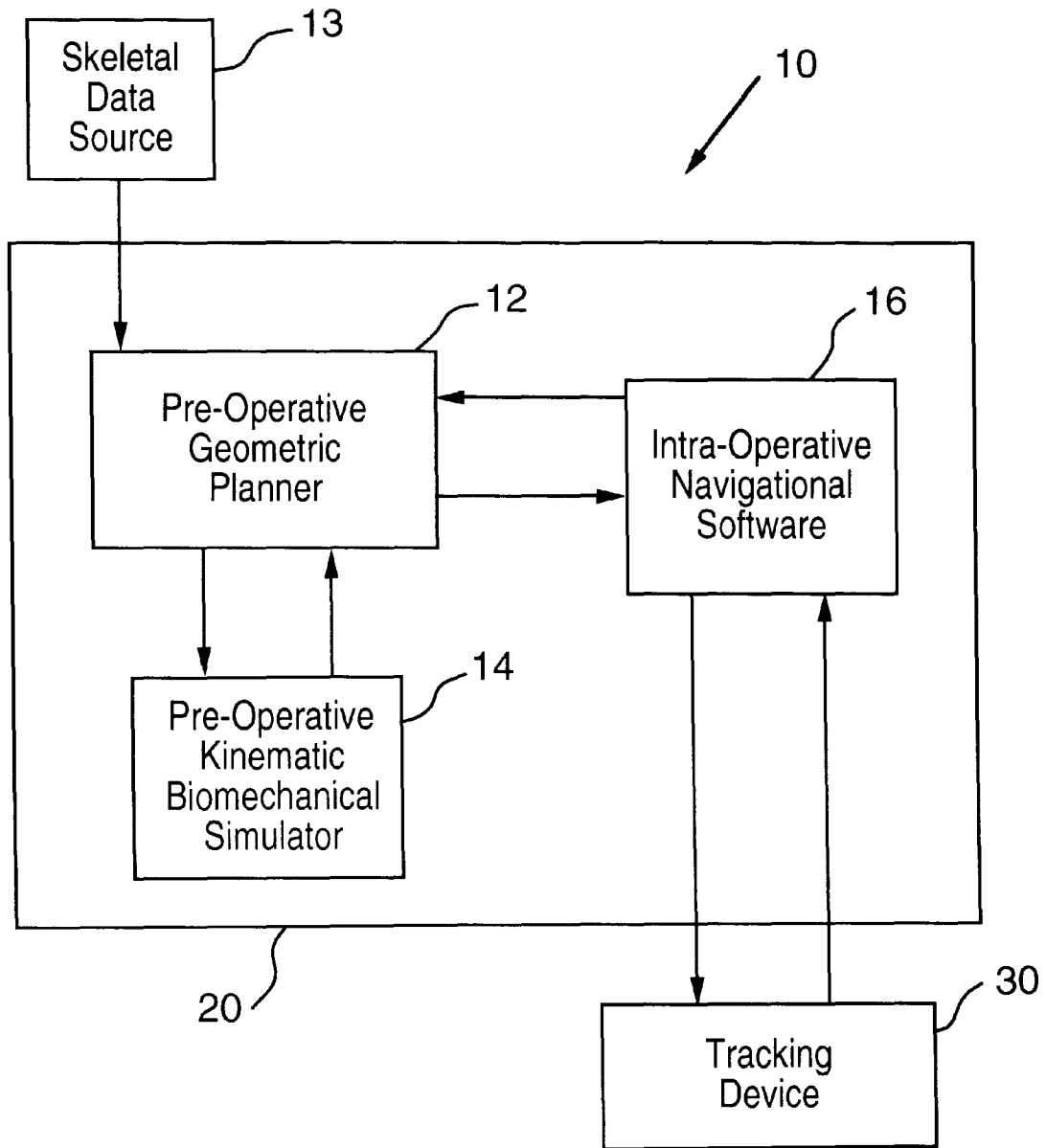


FIG. 1

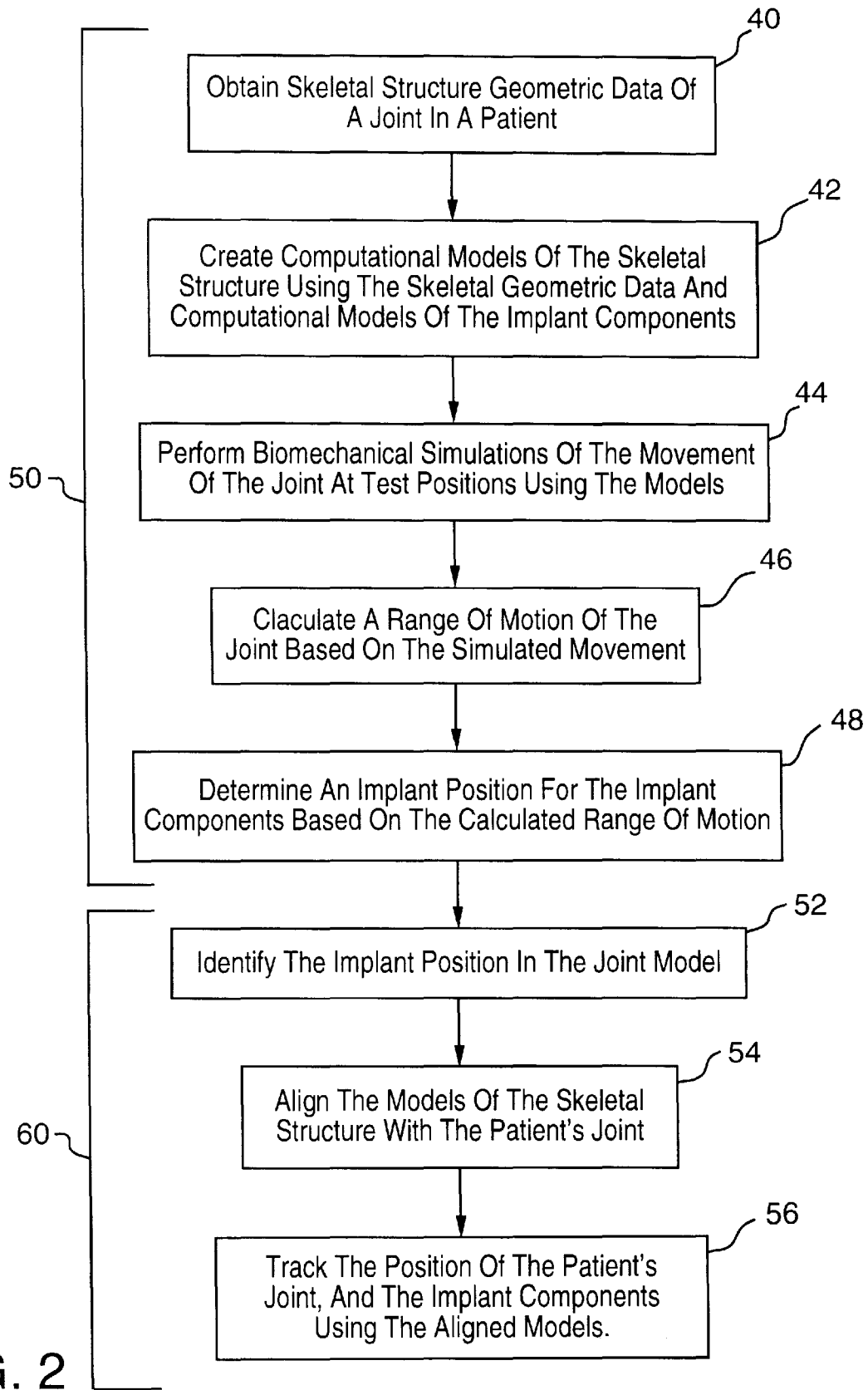


FIG. 2

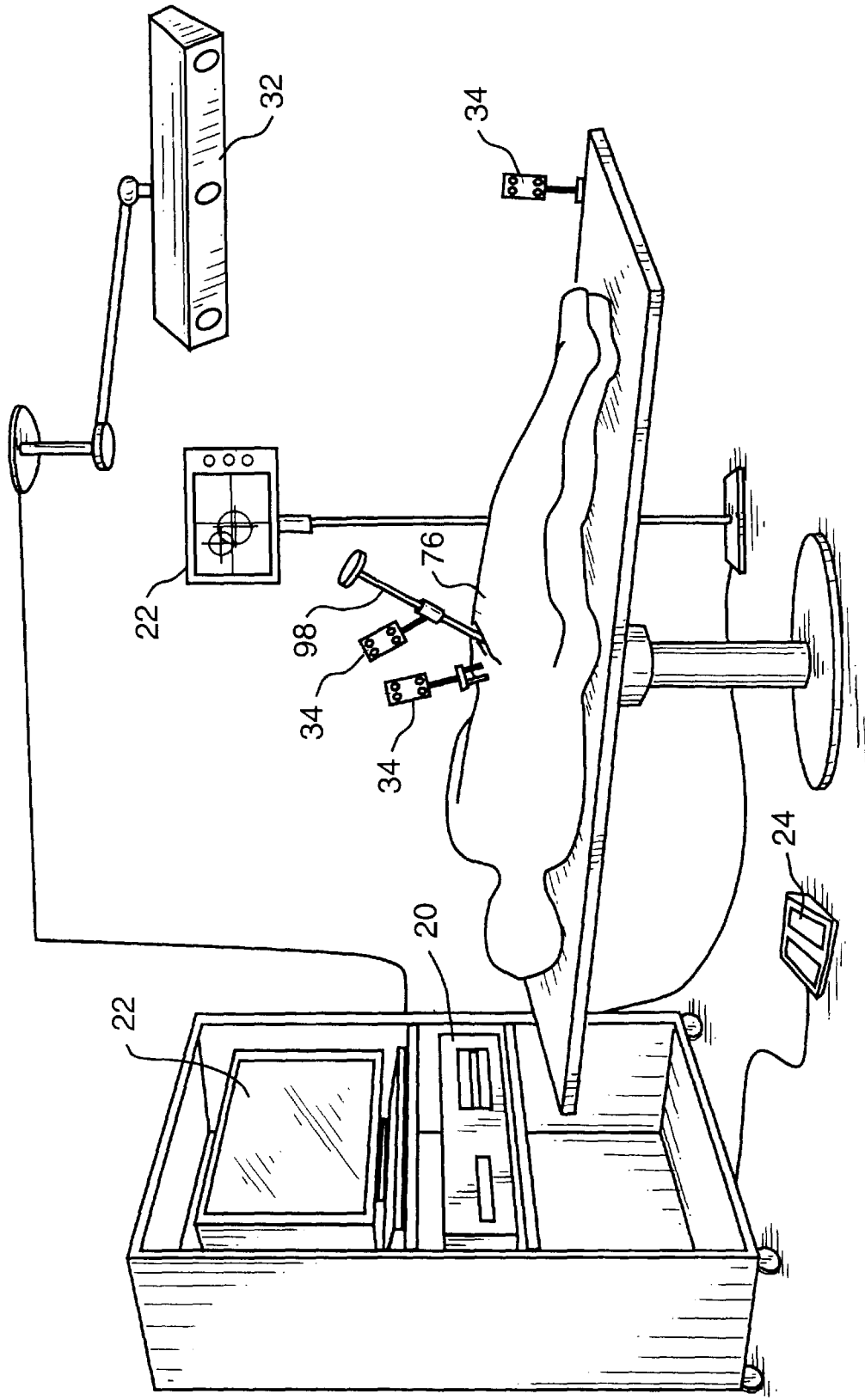


FIG. 3

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.