US006317137B1

(12) **United States Patent**
Rosasco

(10) **Patent No.: US 6,317,137 B1**
(45) **Date of Patent: Nov. 13, 2001**

(54) **MULTI-THREADED TEXTURE MODULATION FOR AXIS-ALIGNED VOLUME RENDERING**

(75) Inventor: **John D. Rosasco**, Belmont, CA (US)

(73) Assignee: **Silicon Graphics, Inc.**, Mountain View, CA (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.

(21) Appl. No.: **09/201,814**

(22) Filed: **Dec. 1, 1998**

(51) **Int. Cl.**[7] **G06T 11/40**

(52) **U.S. Cl.** **345/582**; 345/467; 345/471; 345/472

(58) **Field of Search** 345/430, 424, 345/423, 419, 429, 505, 425, 439, 472, 471, 467, 25, 470, 128; 600/461, 407; 382/128, 203, 217

(56) **References Cited**

U.S. PATENT DOCUMENTS

5,570,460	*	10/1996	Ramanujam	345/424
5,786,826	*	7/1998	Kwok	345/505
5,797,849	*	8/1998	Vesely et al.	600/461
5,831,623	*	11/1998	Negishi et al.	345/424
5,891,030	*	4/1999	Johnson et al.	600/407
5,926,568	*	7/1999	Chaney et al.	382/217

OTHER PUBLICATIONS

Cabral, B. et al., "Accelerated Volume Rendering and Tomographic Reconstruction Using Texture Mapping Hardware," *Proc. Of ACM/IEEE Symp. On Volume Visulaization*, 1994, pp. 91–98.

Drebin, R.A. et al., "Volume Rendering," *Computer Graphics*, vol. 22, No. 4, Aug. 1988, pp. 65–74.

Foley, J.D., *Computer Graphics Principles and Practice—2nd Edition in C*, Copyright 1996, Addison–Wesley Publishing Company, pp. xvi–xxiii, 855–922 and 1034–1039.

Watt, A. and Watt, M., *Advanced Animation and Rendering Techniques: Theory and Practice*, Copyright 1992, ACM Press, pp. xi–xiv and 297–321.

* cited by examiner

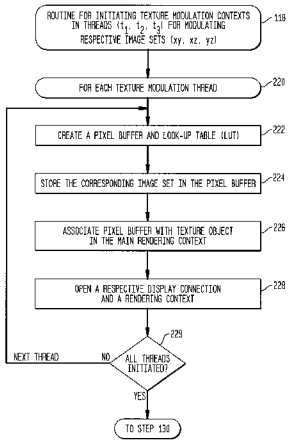
Primary Examiner—Matthew Luu
Assistant Examiner—Thu-Thao Havan
(74) *Attorney, Agent, or Firm*—Sterne, Kessler, Goldstein & Fox, p.l.l.c.

(57) **ABSTRACT**

A method, system, and computer program product are provided for multi-threaded texture modulation in axis-aligned volume rendering. Three texture modulation threads are used to modulate texture of three sets of the volumetric data (image sets) in accordance with a texture modulation request. Control is returned from the first texture modulation thread to a main rendering thread while the first texture modulation thread is executing. A user can then interact with a display view while the first texture modulation thread is executing. An intermediate display view of a texture modulated set of volumetric data can be rendered. In one example, a plurality of display connections and contexts are opened for the main rendering thread and each texture modulation thread respectively. Sets of pixel buffers and look-up tables are provided for the respective texture modulation threads. A texture object is included in a context of the main rendering thread. Each pixel buffer stores a respective image set and is associated with the texture object. According to further feature, the sets of volumetric data are sorted based on the angle between normals to the sets and a current viewpoint. The texture modulation threads are then executed (unblocked) based on the sorted order of the sets. For a given graphics machine and especially on a low end machine, the multi-threaded texture modulation of the present invention increases speed, provides interactive control, and gives intermediate display views in axis-aligned volume rendering. A clinician or other user can see intermediate information and interact with the intermediate display view accordingly.

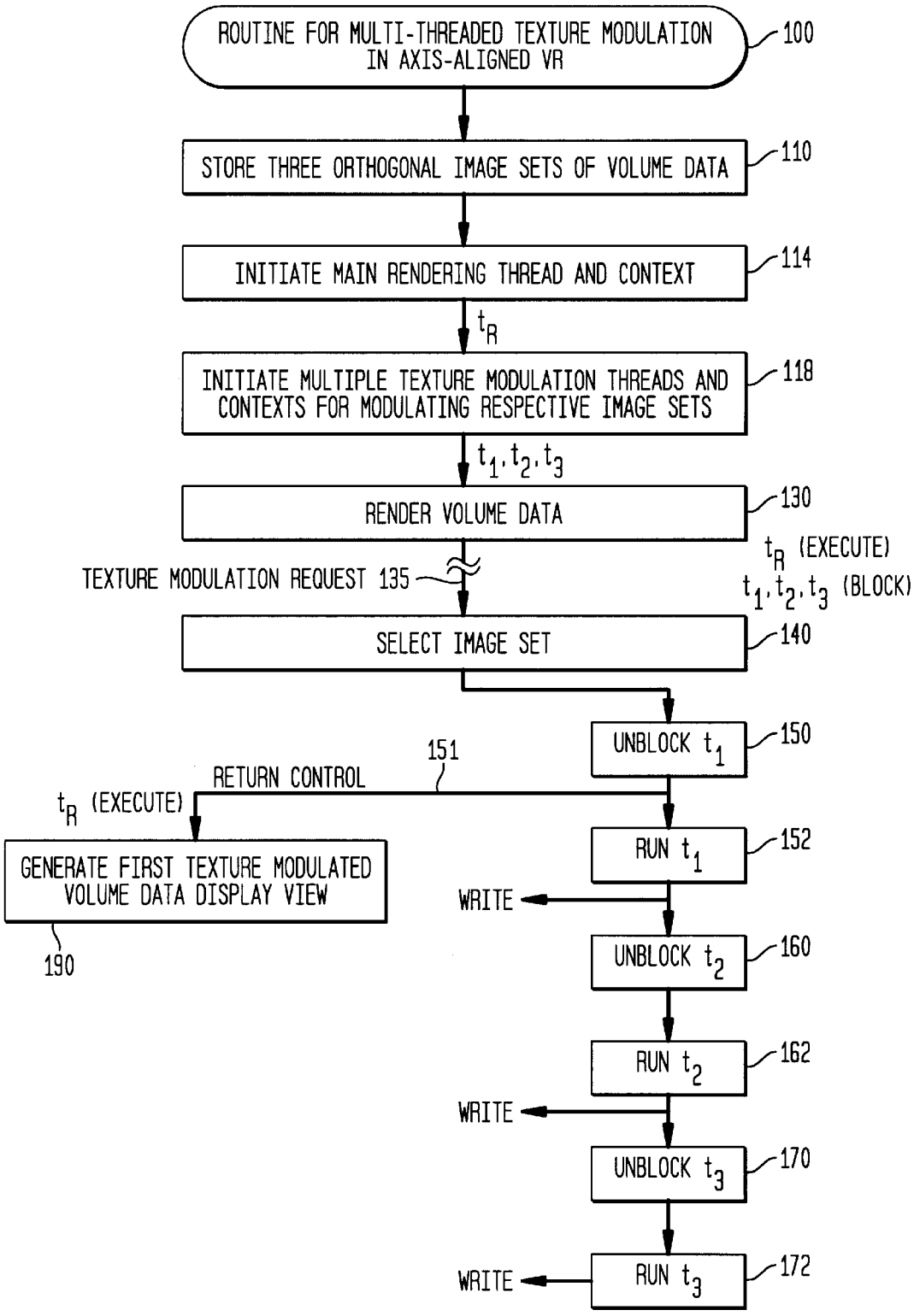
16 Claims, 13 Drawing Sheets

(1 of 13 Drawing Sheet(s) Filed in Color)



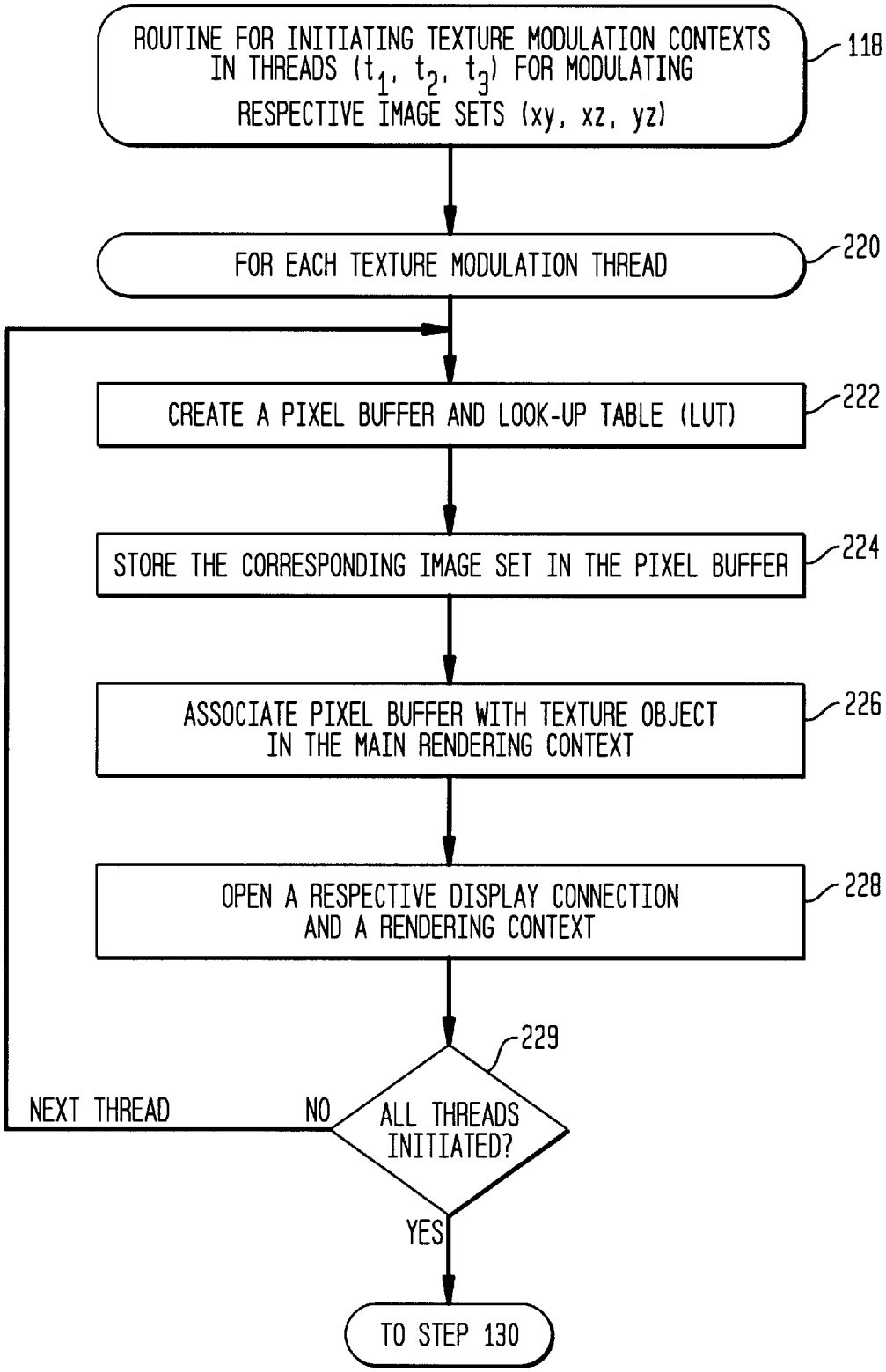
DOCKET ALARM
Find authenticated court documents without watermarks at docketalarm.com.

FIG. 1



DOCKET ALARM
Find authenticated court documents without watermarks at docketalarm.com.

FIG. 2A



DOCKET ALARM
Find authenticated court documents without watermarks at docketalarm.com.

FIG. 2B

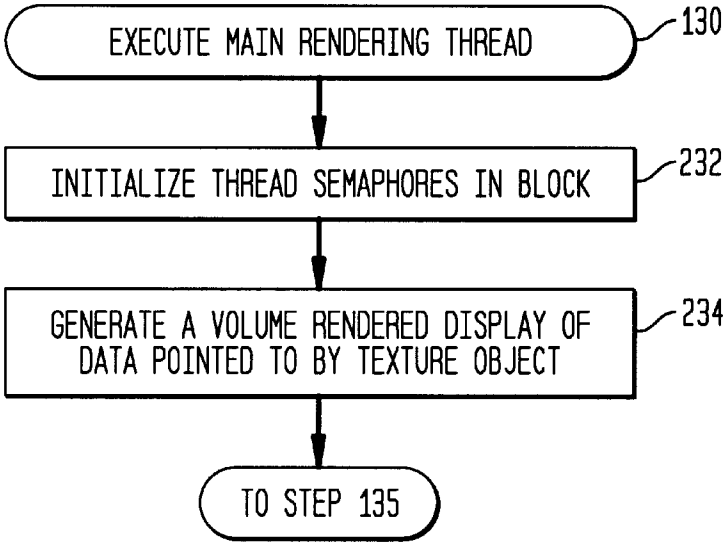
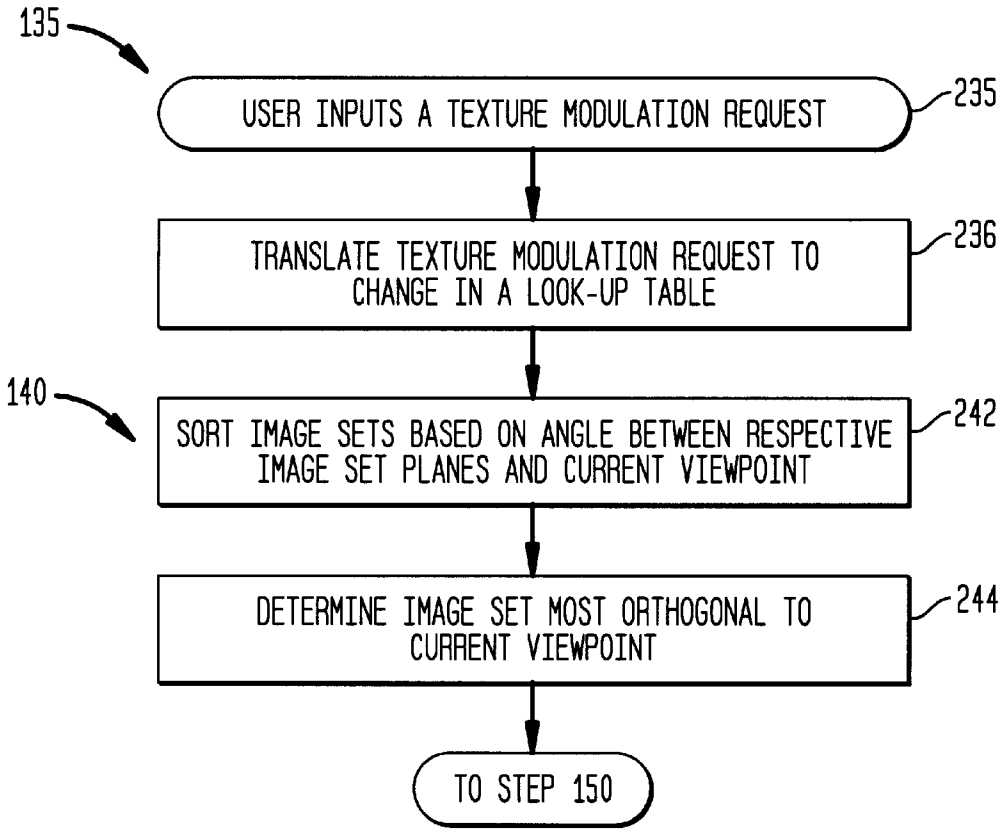


FIG. 2C



DOCKET ALARM
Find authenticated court documents without watermarks at docketalarm.com.

FIG. 2D

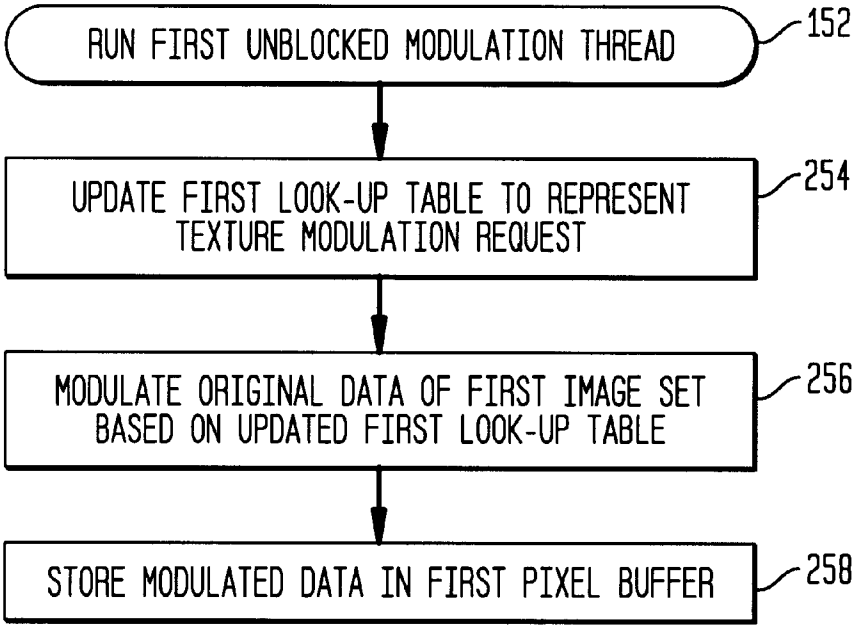
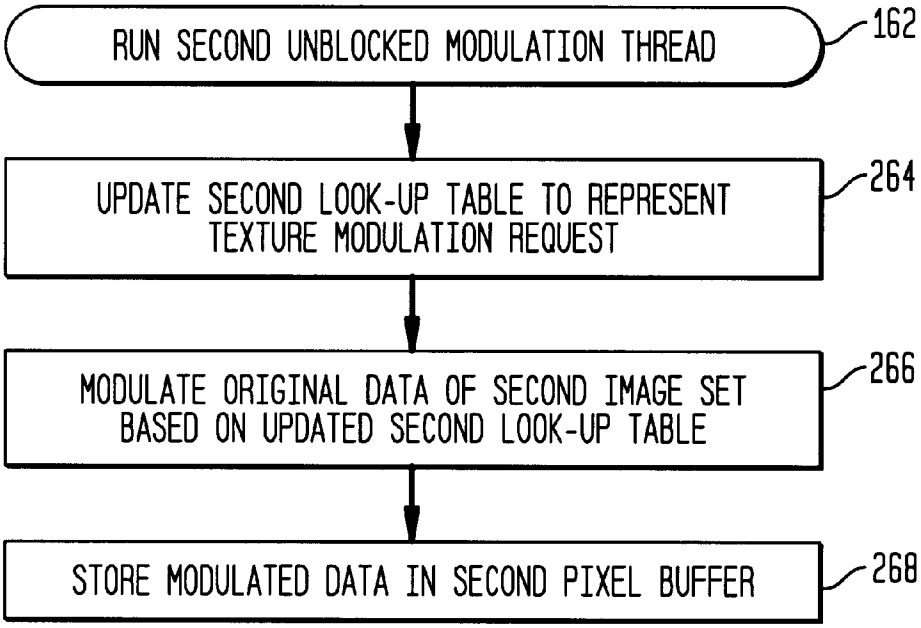


FIG. 2E



DOCKET ALARM
Find authenticated court documents without watermarks at docketalarm.com.

DOCKET ALARM

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.