Exhibit 1009

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United States Patent [19]

Glassman et al.

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[54] **IMAGE-DIRECTED ROBOTIC SYSTEM FOR PRECISE ROBOTIC SURGERY INCLUDING REDUNDANT CONSISTENCY CHECKING**

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[73] Assignee: **International Business Machines Corporation**, Armonk, N.Y.

[21] Appl. No.: **170,540**

[22] Filed: **Dec. 20, 1993**

Related U.S. Application Data

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[51] **Int. Cl.**[6] **B23Q 15/14**; A61B 6/00

[52] **U.S. Cl.** **364/413.13**; 395/80; 395/94

[58] **Field of Search** 395/80, 94; 364/413.14, 364/413.13, 413.02; 128/653.1, 782

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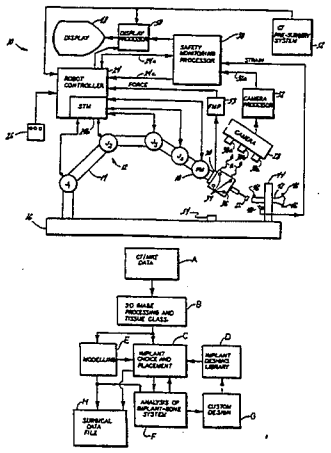
Assistant Examiner—George Davis
Attorney, Agent, or Firm—Perman & Green

[57] **ABSTRACT**

A robotic surgical system (**10**) includes a multiple degree of freedom manipulator arm (**14**) having a surgical tool (**22**). The arm is coupled to a controller (**24**) for controllably positioning the surgical tool within a three dimensional coordinate system. The system further includes a safety monitoring processor (**38**) for determining the position of the surgical tool in the three dimensional coordinate system relative to a volumetric model. The volumetric model may be represented as a constructive solid geometry (CSG) tree data structure. The system further includes an optical tracking camera system (**28,32**) disposed for imaging a region of space that includes at least a portion of the manipulator arm. An output of the camera system is coupled to the processor (**38**) that processes the volumetric model for determining if the surgical tool is positioned outside of the volumetric model. The system further includes a strain gage (**40**) for detecting slippage in three dimensions between an immobilized tissue, such as bone, and a reference point (**44**). The system also includes multiple and redundant safety features for suspending a motion of the surgical tool to prevent the tool from operating outside of the predetermined volume of space.

10 Claims, 4 Drawing Sheets



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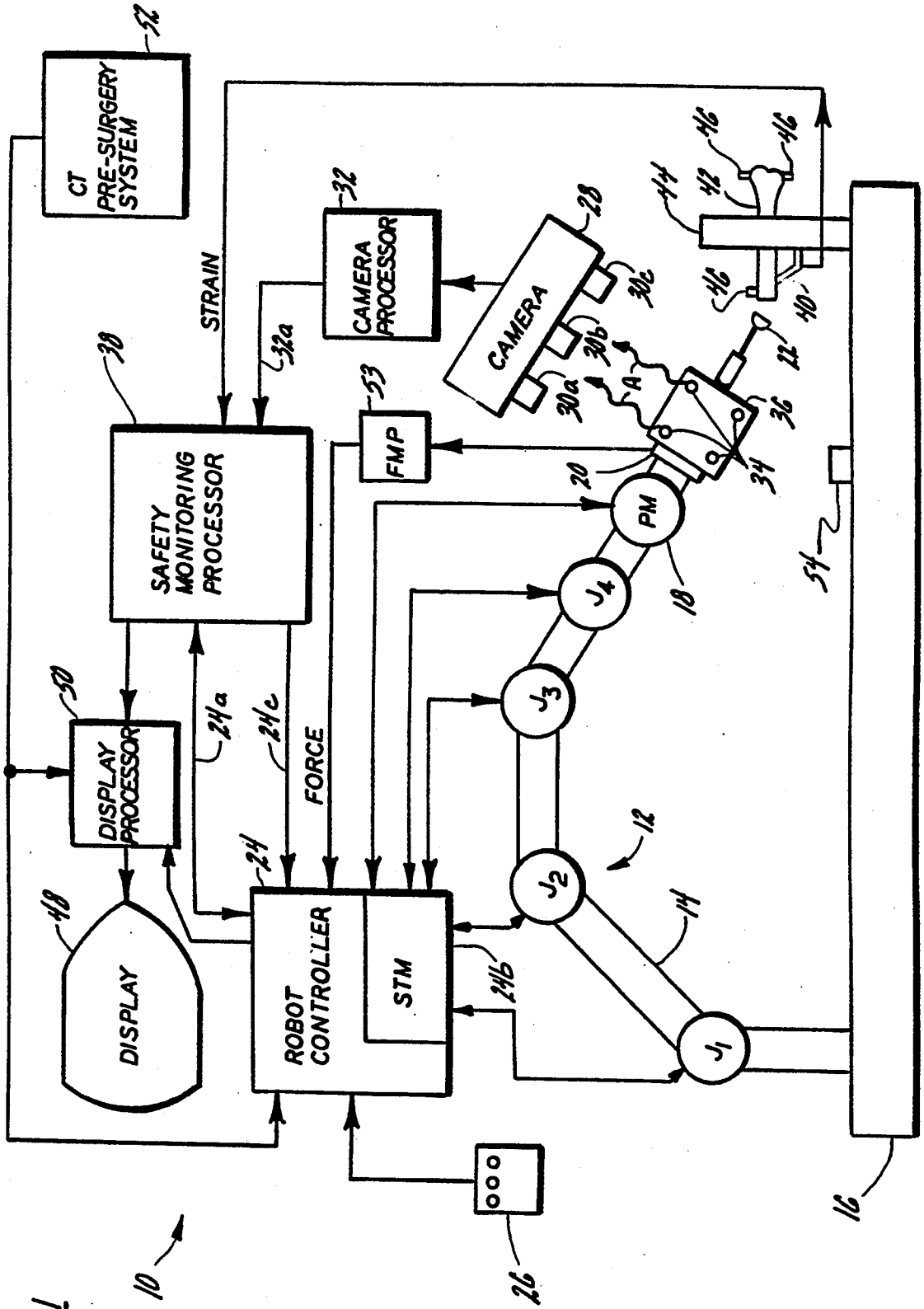


FIG.1

FIG. 2b

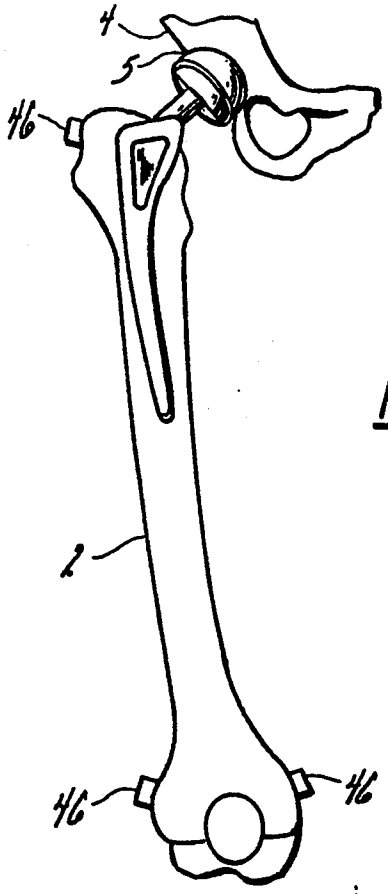


FIG. 2a

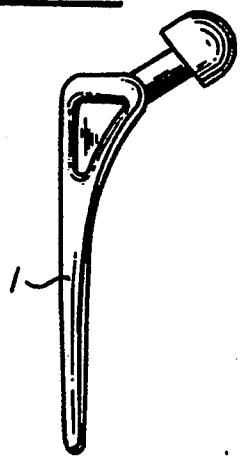


FIG. 3a

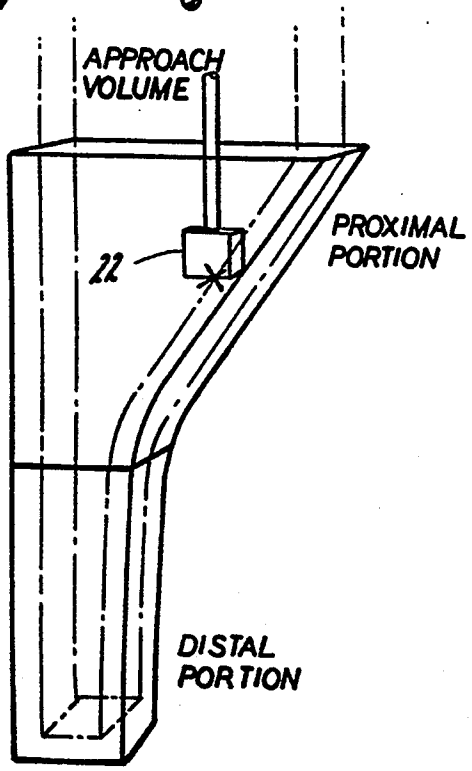
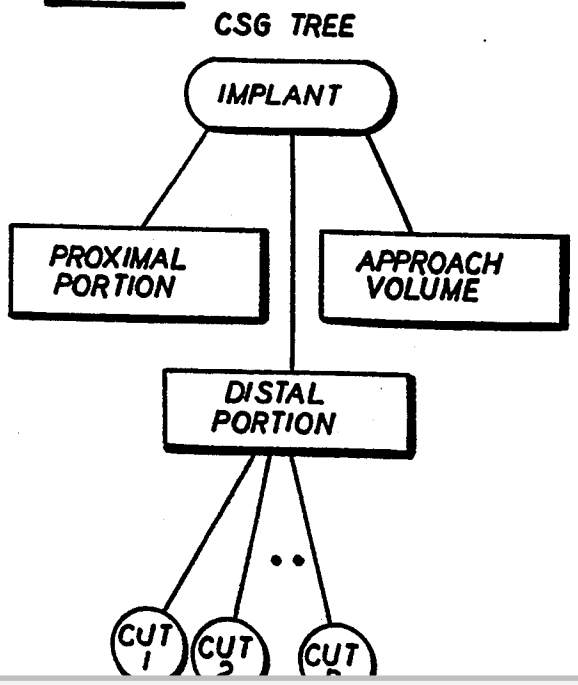


FIG. 3b



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