C-arm Relocation Guidance System for Repeatable Operating Room Imaging

Pain Statement: Repeatable positioning of C-arm imaging equipment during surgery is currently time-consuming, difficult to reproduce, and results in excessive scans (i.e., radiation to the patient).

Background:
Historically surgeons guessed where internal anatomy was located and sometimes guessed wrong. X-rays were used to improve pre- and post-op evaluation, but took up to 30min to obtain and develop. A flouroscope uses an x-ray emitter on one side of a C-shaped arm and a fluorescent screen on the other to view X-ray images in real time without the time required to first develop X-ray photographs. The downside to fluoroscopy is lower resolution than can be achieved with X-ray photographs, but the advantages provided by quicker (or even real-time) imaging far outweigh this disadvantage during surgery. Anatomy can shift between subsequent x-ray images leading to incorrect surgical sites. The setup for photographs require specific body positions and clamps to get the image you want and may not be repeatable if the subject is relocated for surgery. When there is an open wound, time is of the essence. A fluoroscope can provide real-time visualization during surgery when the space occupied by the fluoroscope isn't needed for the operation (e.g., stent placement), and otherwise can be moved out of the way during surgery and replaced back in as close to the same position and orientation as possible for later comparison. Sometimes removal and replacement must be done multiple times, each time requiring new scans, and thus subjecting the patient to additional rounds of radiation in order to verify the correct replacement of the flouroscope.

Flouroscopes are used anywhere that surgeons place metal into bone, or other implants into the body; these include threading an artery, putting a stent into an artery, hip replacement, implanting cardiac pace makers, minimally-invasive vascular surgery, and others. Flouroscopes are used millions of times per year during surgeries in the US. A flouroscopic C-arm can weigh over 700 lbs, so repositioning efficiently saves both time and energy of skilled technicians. A "good" technician can replace a C-arm correctly about 60-80% of the time, while the success rate for a "poor" technician may drop as low as 10%.

Although some surgeries allow the C-arm to remain in place during the surgery, most of the time you have to remove the system during the procedure and then replace it. Some procedures need 2 distinct views during the operation and require switching back and forth between views. While some fluoroscopes have 4 heads (allowing two simultaneous views), most flouroscopes have only 2 heads (limited to 1 view at a time).

The typical setup procedure requires positioning the C-arm base and the C-arm, sometimes iteratively:

1. Position the base: translates and rotates on the floor via lockable wheels.

Figure 1. C-Arm OEC 9900 Elite https://pacifichealthusa.com/benefits-ge-oec-9900-elite-c-arm/

2. Position the C-arm: translates up and down, horizontally in and out; rotates about a vertical axis on the base, about a horizontal axis along the C, and about a central axis through the center of the C.

Getting exact positioning of a C-arm is essential to a successful surgical outcome.

A successful positioning guidance solution has huge economic potential. For reference, new C-arm systems costs on the order of $200K without navigation and make up about 90% of systems currently in use. Systems with navigation can cost upwards of $1M.

Approach Options:

1. Topography
    a. Match topographical map between current and desired orientation
2. Image detection
    a. Cameras on the fluoroscope
    b. Cameras in the environment looking at the flouroscope
3. Laser pointers mounted on the fluoroscope pointing to markers on the subject

Preferred Approach:

Image Detection. Use high-resolution cameras mounted on the fluoroscope to visualize the desired system position and orientation. After removal of the system from the desired setup, the desired and current camera views can be used as guidance in relocation and to predict and display the approximate relative adjustment needed at each joint of the flouroscope. Images can provide key views of the surgical site and the fluoroscope setup. Known kinematics of the robot can be used to compute more precise relative joint movements needed and be displayed via realtime feedback to the operator in precise relocation of the system.

Requirements:

1. Detect and store desired relative system position and orientation
2. Provide visual feedback to operator of desired and current system joint positions
3. Guide operator in repositioning system within 1 mm and 1 degree of accuracy

Budget:
$1000

Ideal Team:

- 2 CS
- 2 ME (or 1 ME, 1 BE)
- 1 CompE