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CIS Critical Summary

Computer Generated Integral Photography

Image Overlay is a system designed to incorporate 3D pre-operational patient information with a live video feed. This would create a superior surgical navigation system, in which the surgeon is able to see the target points of operation minimal invasively and with a high degree of precision. This would greatly benefit the surgeon to visibly see the areas of interest (intended place of operation on the patient) and its surrounding features. This surgical navigation system could be used for either the preoperational planning phase of the surgery to help the surgeon plan the operation or during the actual operation as a surgical assistant. For any 3D image display system used for the medical world, the basic requirements for a good surgical navigational system are as follows. High Image Quality, recognition of 3D positions of surgical devices w/ accuracy, minimal eyestrain and fatigue (due to the display) and be able to see areas surrounding the intended target on the patient's body.

There are various implementations of image overlay each with its own set of problems. Using a Binocular stereoscopic implementation, it is difficult to register 3D medical images and end up creating distortion because of the binocularity of the system and significant errors ensue. Factors such as mechanical accuracy, depth perception, distortion, and geometric accuracy are the key points in analyzing a surgical navigational system.

For Background reading the following two Ken Masamune papers from the MICCAI conferences were used:

Papers:
Three Dimensional Slice Image Overlay System with Accurate Depth Perception for Surgery
Ken Masamune, Yoshitaka Mautani, Susumu Nakajima, ichiro Sakuma, Takeyoshi Dohi, Hiroshi Iseki and Kintomo Takakura

Surgical Navigation System with Intuitive Three-Dimensional Display
Susumu Nakajima, Sumihisa Orita, Ken Masamune, Ichiro Sakuma takeyoshi Dohi, and Kozo Nakamura

The methods that were implemented by the authors are as following:

The setup used in the first paper consists of a personal computer, a lens array, a liquid crystal display, and a half silvered mirror, data input from a 3D source such as MRI or CT was used. Using computer-generated integral photography, 3D images are generated in real time. Then using the half silvered mirror, they superimposed the 3D image onto the patient during surgery.

The authors wanted to use a computer generated IP in which 3D space is reconstructed through a convergence of rays from pixels ton the LcD through the lens array. The authors used the fact that points can be seen as light sources and that objects could be formed as a reconstruction of these light sources.

One of the roadblocks the impeded the efficiency of this system is the fact that since current LCD technology cannot support the same resolution as photographic film. Information is lost when trying to display the pixels coordinates of these light sources. The unique way the University of Tokyo researchers used this to their advantage was that they computed coordinates of one point for each pixel on the LCD.

The computer generated IP algorithm consisted of one very important equation $H_i = \frac{D * h}{i * r} = \frac{H_1}{i}$ which is used to compute Hi , the distance of the ith furthest point for the reference plane by an intersection of two light rays that were generated from adjacent lenses. From this algorithm, we can calculate the values for what should be in each pixel coordinate on the LCD as well as the spatial resolution depth, which is equal to H_{iMax} (the largest possible value for i). Using this algorithm, the image can be observed from multiple viewpoints with the correct motion parallax.

Registration during the experiment was very straightforward. First the usage of a optical tracking system in this case POLARIS, was used to measure coordinates in real time and initially detect 4 calibration point pre-defined as Psys. After the MRI 3D image is acquired, the computer generated IP algorithm is used to render the 3D object and project the image on to the display. Then the use of human intervention to adjust the projected image with the corresponding place on the patient's body. As one can already tell, this is not the most ideal and accurate way of aligning the projected image. Then an image transformation occurs to align the coordinates of the markers for a precise adjustment.

Accuracy from location of the projected point to the system.

In medical imaging, Geometric accuracy is the most important factor in evaluating a system. Using a 100 mm square displayed at 10mm to 40mm from a 3D display as their test of accuracy, the square was then acquired by the optical tracking system and the differences between the actual and theoretical coordinates was less than 3.8 mm, which is pretty good considering the 100mm X 100mm X 40mm object.

Accuracy from location of the registered image to the object.

To determine the average of the various errors for the position of points, a 50mm vitamin E capsule with 4 MRI markers is used. A 3D MRI image is then superimposed with the actual capsule. The magnitude of the errors generated was equal to the radius of the marker, which indicates that this part of the system is pretty accurate.

The authors then tried to apply this procedure in a continuous manner. After data acquisition, segmentation 3D rendering and convergence from 3D to 2D, they were able to see the structures of superimposed bone by many people at the same time. This is what the authors had hoped to produce.

This system seems highly accurate with only an error of 3-4mm. This error can be improved and then this system can be utilized to its fullest by being more than a surgical navigational device. If this was done, the operation could be more minimally invasive.

The other problem with this project is the spatial resolution is dependant on the pixel pitch of the LCD, which at the time of the article, the pixel pitch is not up to par with the ideal pixel pitch.

Improvements in the two aforementioned problems would greatly aid the clinical usage of this surgical navigational system in surgical planning and surgical navigation. They have developed a practical display system that can have 3D locations of projected 3D objects be recognized with an error of 2.0 mm using the computer generated IP algorithm discussed above.