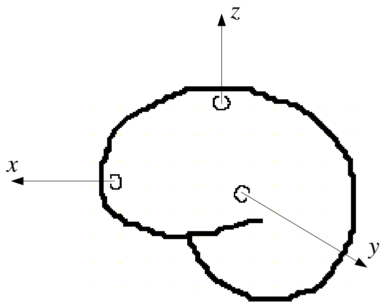

Figure 6-4: Model of patient's brain with coordinate axes.

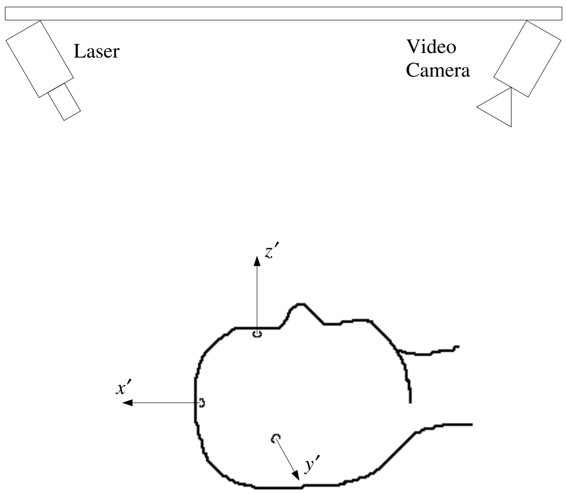

Figure 6-5: Patient, scanner and coordinate axes.

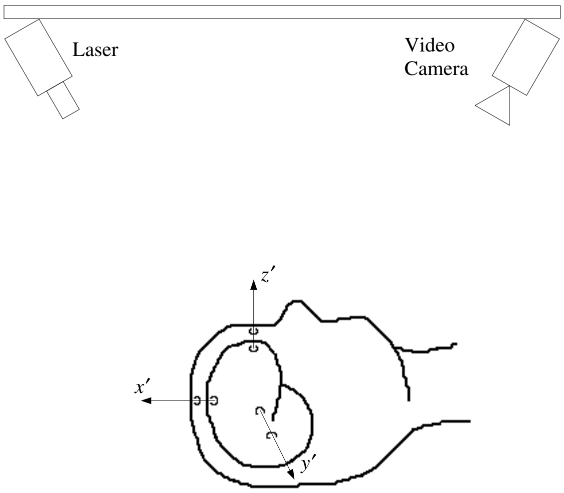

Figure 6-6: Model of patient's brain aligned with patient (valid only for the scanner).

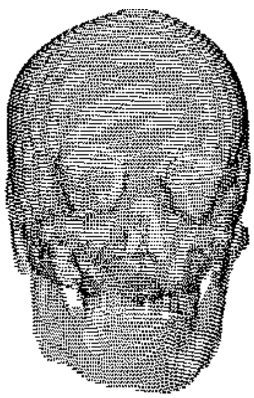

Figure 6-7: Model of a skull.

Figure 6-8: Laser data from skull.

Figure 6-9: Video of skull being scanned.

Figure 6-10: Laser data aligned with skull.

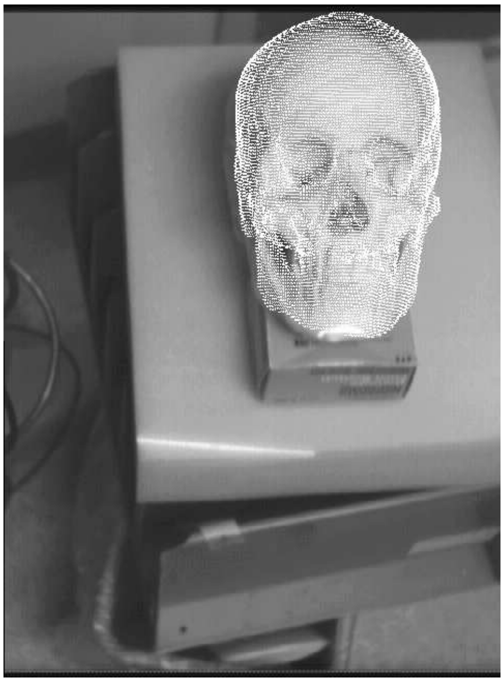

Figure 6-11: Model aligned with video of the same skull.

local minima. This produces a transformation from the coordinate frame of the model to that of the patient. Figure 6-4 shows a brain model and its coordinate system. Figure 6-5 shows the patient, scanner and their coordinate system. Figure 6-6 shows the result of aligning the model and the patient coordinate systems. It should be noted that Figure 6-6 is valid only from the perspective of the camera attached to the laser scanner.

Figure 6-7 shows a model obtained from CT imaging of a plastic skull. Figure 6-8 shows the three dimensional data obtained from laser scanning the same skull. Figure 6-9 shows two images of the skull containing laser scan lines. Figure 6-10 shows the laser data aligned with the skull. Figure 6-11 shows the model of the skull aligned with and superimposed upon video of the skull. The accuracy of this registration is believed to be on the order of the resolution of the MR or CT data ($\approx$ 1mm).

6.2 Calibration Routine

The transformation used to produce Figure 6-11 essentially maps model coordinates to image coordinates. This is exactly the inverse of what we need to calibrate our fiducials. What we would like to be able to do is measure the image coordinates of the fiducials and then use an inverse mapping to determine their model coordinates. The inverse mapping is not in general a one to one mapping. The image coordinates of a fiducial determine the ray in three space along which the model coordinates of the fiducial must lie. By intersecting this ray with the model and Z-buffering the result we can determine the model coordinate of the fiducial.

The initial calibration is limited by the accuracy of the registration performed using the laser scanner. The laser scanner registration produce results which are both repeatable and good for the single view in question. It is not clear how accurate the registration is in an absolute sense. Absolute accuracy is important for calibrating the fiducials. For example, small errors which are imperceptible from one point of view frequently lead to large errors from different view points. Perturbing the laser scanner solution by less than 1° can change a fiducial's location by over 6mm. The uncertain accuracy of the fiducial calibration bears significantly on the quality of enhanced reality visualizations which can be produced. In spite of this issue, the results shown in Chapter 7 are promising. The exact source and nature of the errors in the initial calibration needs to be explored further. The method of initial calibration presented here, while it requires the use of a laser scanner, has the advantage that it can be made fully automatic. Of course, other methods of initial calibration could be used. The only requirement is that the fiducial locations be determined accurately. How this information is obtained does not matter.