CHAPTER VII

Conclusions and Suggestions

7.1 Conclusions

In first experiment, section 6.1, Tsai's calibration method and Zhang's calibration had been used to calibrate 4 cameras. The results show that both methods give the geometric distance approximately the same value but in reconstruction process, for 4 and 3 cameras, the camera models from Tsai's calibration method give a better solution than Zhang's calibration method. In ideal, Zhang's calibration method should give the better result because it uses more information from more images than Tsai's calibration method. But in this research, the calibration performs in close-range and the lens head sets were set their focus on the calibration plane which is not plane at infinity. If the object or calibration pattern moves away from the calibration plane, then the captured images are blur. When Zhang's calibration was performed, the calibration pattern was moved to some different planes and this may cause the increasing of error.

For 3-D tracking experiments, section 6.2-6.4, the results show that the developed system can track the moving object in 3-space both position and velocity. The accuracy is acceptable when the object moves within control volume. The position error increases when the object was moved away from the calibration plane especially in normal direction because the effect of close-range calibration which is explained early. These experiments keep the distance between object and calibration plane less than 150 mm. For 4-cameras system, the 3-D position errors are less than 1 mm and for 3-cameras system, the position errors are less than 2 mm except when the PA10-7C move with circular path on yz plane and angular velocity 0.2 rps. The position error in this situation is a little bit greater than other results, because PA10-7C vibrates when it moves with high speed following that path.

In 3-D surface scanning experiment, section 6.5, shows that besides 3-D pose estimation, the system can be adapted to be a coordinate measuring system for the reverse engineering application. The system will be much cheaper than the conventional system available in the market.

7.2 Suggestions

7.2.1 Tracking Accuracy

There are many ways to improve tracking accuracy. The easiest way is done by incorporated the better quality cameras to the system, the better measurement can be obtained.

Calibration, recognition and reconstruction methods are also important thing that effect to the accuracy of the system. The development of these methods and using more accurate calibration pattern can improve the system accuracy.

7.2.2 Close-Range Calibration Effect

The developed system can track the moving object in 3-space. However, the position error increases when the object moves away form the calibration plane because the effect of close-range calibration. To reduce this problem, the object should move far enough to that the lens head sets focus on plane at infinity. For lens head sets in this research, the distance between cameras and the object should greater than 7 meter. Then more space is required for the system and the accurate calibration pattern should big enough to cover the region of interest of cameras.

By using the lens head sets with shorter focal length than used in this research can also reduce this effect, but the radial distortion will become more significant.

7.2.3 Tracking Speed

From the experiments show that the developed system can track the moving object with frame rate about 16-18 fps when using 4 or 3 cameras. There are four important things that effect to tracking speed of the system.

1) Camera ability: The cameras, which can capture high resolution image with faster frame rate, are used then the system can track the moving object with faster frame rate.

2) Light intensity: The environment with intensive light can reduce the exposure time of CCD and it increases the capturing speed of the camera.

3) Recognition algorithms: Usually the speed of recognition algorithm is depended on the size of captured image. If the more efficient algorithm is developed to predict the image position before searching, then the searching region can be reduced and increase speed of the system.

4) Reconstruction algorithms: The reconstruction algorithm that used in this research is linear triangulation with least-squares minimization. More efficient algorithm can also increase speed of the system.

7.2.4 Complex Shape Object Tracking

The developed system can only track the object whose projected shape on image plane is circle, such as spherical ball. To use the developed system for tracking a complex shape object, a new pattern recognition algorithm need to be developed for this purpose.