Design and Evaluation of Realtime Integral Videography using Three-dimensional Ultrasound

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Abstract. This paper designs and evaluates realtime three-dimensional surgical navigation system using Integral Videography (IV) with intra-operative three-dimensional ultrasound data acquisition. We used a trans-vaginal ultrasound transducer with volume data acquisition rate of 5 volumes/s. Experiments using a human hand as phantom showed that the online IV image frame rate is around 2 frames/s. As an attemp to increase system performance, the use of smart multi-threading has completely resolved performance decrease due to nonuniform data distribution.

1 Introduction

Integral Videography(IV) is a method to visualize three-dimensional(3-D) data, which provides 3-D image without using supplementary glasses or tracking devices. IV with image overlay system can provide surgeons with accurate position of an object inside human body [1]. Compared to other image overlay system such as ultrasound overlay system [2], IV has merits on the capability of providing 3-D information. However, efforts to use intra-operative data for IV have not been made so far. The objective of this paper is to design and evaluate an IV 3-D surgical navigation system with intra-operative data acquisition, including fast data acquisition using ultrasound, 3-D data preprocessing specialized for IV rendering, and IV image displaying system integration.

2 System and Methods

The system consists of ultrasound device (Aloka SSD-5500), data acquisition PC, data preprocessing and rendering PC, and IV image displaying PC. Three dimensional ultrasound data is acquired using a fast moving trans-vaginal ultrasound transducer with data acquisition rate of 5 volumes/s.

The whole system is divided into data acquisition part and data processing part. Data acquisition part and data processing part are done asynchronously and are connected to each other by using shared folder of data acquisition PC that can be accessed from data preprocessing and rendering PC.

Due to coordinate system difference and high noise level of ultrasound data, acquired volume data needs to be preprocessed before it can be used for IV rendering. Preprocessing includes coordinate transformation with interpolation profile, and noise reducing using median filter.

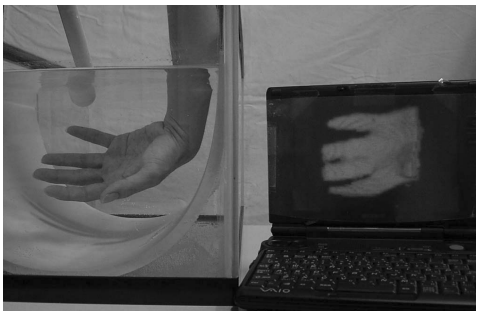

Fig.1. Online IV image: visualizing phantom (human hand) with IV image.

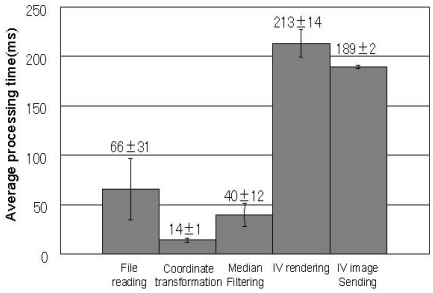

Fig.2. System's evaluation: average processing time of each process.

In order to increase system performance, we developed smart multi-threading to omit performance decrease in nonuniform data distribution. In smart multi-threading, we divided the whole job into many small tasks(number of tasks >> 1), and then allocated those tasks one by one to threads. By doing this, all threads will finish at almost the same time, which means optimal processing time is achieved.

3 Experiments and Results

In phantom experiment, acquired data of human hand is visualized in 3-D IV image (Fig.1.). Phantom movement can be observed smoothly.

As system performance strongly depends on data preprocessing and rendering PC's performance, we evaluated each process of data preprocessing and rendering PC. As the result, average total time of 522 ms (Data: 64x64x64 voxel, PC: Intel P4, 3.2GHz) is measured(Fig.2.). IV rendering and IV data sending have relatively long processing time, while file reading through shared folder has relatively low stability.

The use of smart multithreading has completely resolved performance decrease due to nonuniform data distribution. Increase in average performance of 11% is measured.

4 Conclusion

We have developed prototype of realtime IV three-dimensional surgical navigation system with intra-operative data acquisition using three-dimensional ultrasound. Visualizing human body in realtime IV image has become possible. Combining the quickness of ultrasound and the image quality other imaging modalities such as CT or MRI is being considered for future developments in intra-operative image-aided surgery.

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References

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