Integration of optical tracking system for determination of the position and orientation of instruments during the surgery

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Abstract

The purpose of this project was the design and implementation of a complete system for acquisition and fusion of data provided by an optical tracking system and a set of cameras (including an arthroscope).

Synchronous data acquisition was a major requirement. For this purpose we designed a Printed Circuit Board (PCB), that assures perfect synchrony between equipments, and can be configured to use different trigger sources. In addition, we developed a complete software architecture in C++ for the communication with the opto-tracker and cameras. The software enables the insertion of different modules for data processing.

In future work, the navigation system will be extended with 3D *reconstruction/registration computer vision algorithms. These algorithms will use the intra-operative endoscopic video, enhanced with the pose information, for estimating the 3D pose of organs and anatomical structures in the knee. The final goal is to build a complete navigation system to assist surgeons during arthroscopic interventions.*

1. Introduction

Arthroscopy is a minimally invasive procedure that aims decreasing the incision size and minimize the time for surgery recovery. Large incisions are replaced by a couple of small incisions (surgery ports).

The Arthroscopy is a difficult technique to perform. Visibility is very reduced throughout the procedure, and anatomic landmarks are difficult to localize. As the success of the surgery depends on the accuracy and precision of the surgeon, the final clinical outcome can be considerably influenced by these problems. Computer systems for enhancement of surgeons perception and precise navigation in the knee joint can improve the clinical success rate and decrease the practitioner training requirements. The development of such systems can bring great benefits in improving the life quality of patients [1].

The development of navigation systems for minimal invasive surgery is a difficult task. The main problem is the fact that tissues and organs can not be directly accessed. The surgeon observes the cavity in an indirect manner using the endoscopic camera, and it is virtually impossible to attach optical markers that can be tracked from the outside.

The *ArthroNav* project (major project to which this project belongs) aims to overcome this problem by employing computer vision techniques over the endoscopic video. The key idea is to employ optical tracking for the pose of the arthroscope and instruments (observable from the exterior), and estimate the rotation/translation of the organs with respect to the camera by registering pre-operative 3D models to intraoperative images.

The work of this research has concerned the hardware and software infrastructure that will support the *ArthroNav* project. The computer vision algorithms for reconstruction/ registration will require endoscopic video augmented with pose information provided by the opto-tracker. During the project we designed, developed and implemented a complete system, composed by a work-station connected to cameras and an optical tracker. The system was complemented by suitable hardware and software to enable synchronous acquisition of video and optical data.

2. Equipment

The developed surgical system employs an optical tracking system, an arthroscope, a *FireWire* camera (*Point Grey Flea2*), and a work-station (PC computer).

3. Hardware for the Synchronization

An essential requirement of the navigation system is the precise synchronism of their components. It is not possible to use the information from the devices together, if the capture is not done in the same time instant.

3.1. Problem

Both the opto-tracker and the *FireWire* Camera have an external synchronization port. The main challenge to achieve full synchronization was the arthroscopic system. It does not accept external synchronism signals, which means that it is impossible to trigger this device for the frame capture. Thus, to achieve synchronous acquisition between opto-tracker, *Flea 2* and arthroscope, the unique possibility is to use one of the arthroscope video outputs as triggering source.

3.2. Solution

The solution found to synchronize the system, was the extraction of the timing signals from the composite video output of the arthroscope (a pulse for each start of frame).

The synchronization part of the composite video signal is composed by the horizontal and vertical pulses, the beginning of a horizontal line scan, and the beginning of an even/odd field scan, respectively.

Each *Vertical Output Pulse* corresponds to the beginning of a field. To obtain the beginning of each frame, it is necessary to separate the odd fields from the even fields. The separation is achieved indexing each vertical pulse with the corresponding *odd/even* signal, as shown in Figure 1.

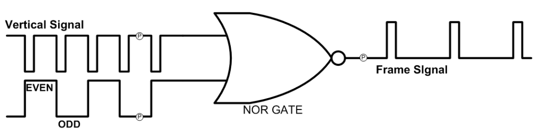

Figure 1: Logic circuit for frame signal extraction

4. Software for the Integration

The principal features of the navigation system created are:

- Integration of the information acquired from the cameras during an arthroscopy
- Process the information in real-time, and allow the surgeons to be guided based on it
- The acquisition follows the hardware timing
- Easy Configuration, allowing its use of investigators whit different acquisition needs
- Introduction of processing modules
- Time analysis, informing the user when synchronization errors occur.

This application will allow to use a normal computer in the surgery room, that captures the information from the complete acquisition system, processes the information intra operatively, and shows the result on a monitor to assist the practitioner during the surgery.

4.1. Maintaining the Synchronization implemented by hardware

The devices are configured to retrieve a new frame on every software request. Discarding one set of frames at the start of each iteration maintains the synchronization imposed by the trigger signals. Figure 2 shows an example of a capture involving the complete system. The situation in which a set of frames is readed out ensures that each iteration works with information captured in the same time instant.

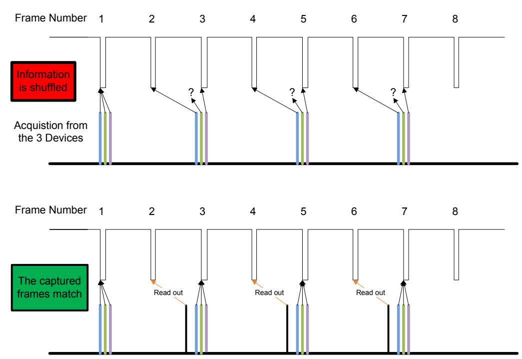

Figure 2: Acquired frames can be shuffled if the capture time is not controlled. Reading a set of frames out, ensures that each iteration works with information from the same time instant.

5. Conlusion

The outcome of the project was a system, capable of the synchronous acquisition of optical tracking data, and image data from the arthroscope and FireWire camera. In addition, we implemented modules for visualization and storing that can be easily inserted in the software application. Test were performed to confirm the synchronism and real-time processing.

References

[1] M. Hafez, B. Jaramaz, D. Gioia, and M. A. M. Computer-assisted knee surgery: An overview. In F. W. Norman Scott, MD, editor, *Insall and Scott - Surgery of the Knee, 4th Edition*, volume 2, pages 1655 – 1674. Elsevier, 2006.