In-Vivo Measuring Surgical Workflow Activities in the OR

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ABSTRACT

Measuring surgical workflow activities in-vivo is a crucial task for medical computing to both track errors and reduce the costs in the OR. In this abstract we discuss our deployed framework for measuring surgical activities. Further we discuss the results of a previous pilot study using the proposed framework to measure surgeon activities in Laparoscopic Cholecystectomy procedures.

Author Keywords

Surgical workflow, environmental cues, HMM, signal simulation, sensing devices.

INTRODUCTION

Within the hospital, the Operating Room (OR) is one of the most resource intensive environments in healthcare, because it involves expensive labor resources (surgeon, anesthetists, nurses, etc.), expensive equipment and daily maintenance. In the Netherlands, the aggregated estimated cost of an OR is € 1100 per hour. It is therefore very important to maximize the OR efficiency.

In the Netherlands, each year more than 1700 patients die from preventable surgical errors, which are commonly known as Adverse Events (AEs) [1]. Surgical AEs account for one-half to three-quarters of all AEs in healthcare [2]. The annual cost of all AEs in the Netherlands is estimated to amount to a total of € 355 million, of which € 161 million is for preventable AEs in 2004 [3]; this is approximately 1% of the annual hospital budget of €14.5 billion. Therefore, any improvement of patient safety by preventing AEs is cost saving.

Another aspect of OR cost management problems is the delay time between surgeries. A benchmark study showed that the average delay in surgery start times ranged from 25 to 103 minutes [4]. This is shown to be caused by the failure of commonly used planning tools which do not account for the unpredictable time duration of operations. In the Netherlands those lost hours add up to 2150 hours, a loss of € 2.3 million per annum.

By having an adequate in-vivo workflow registration system for the OR deployed in the hospital, AEs can be consistently tracked allowing the hospital administrators to investigate the root cause of the problem and associated departments, staff or surgeons. Moreover, high quality data from the registration system can be used to reduce the start time delays in the OR and better estimate the length of a procedure for the planning system.

The goal behind this research is to measure surgical activities in-vivo in the OR in order to track the source of AEs and reduce the cost in healthcare, whilst keeping the quality and quantity of provided care equal. The general framework of such measuring system is discussed in section 2. Section 3 discusses a pilot study using the framework in section 2 for measuring Laparoscopic Cholecystectomy procedures. Our conclusions and future directions are discussed in section 3.

SYSTEM FRAMEWORK

Figure 1 illustrates the general framework of a surgical workflow registration system as used in our previous work [5, 6].

In step 1, we define the surgical workflow activities that need to be monitored in the OR. For this purpose we utilize existing surgical guidelines and protocols. At the end of this step we have a workflow model of the surgical activities

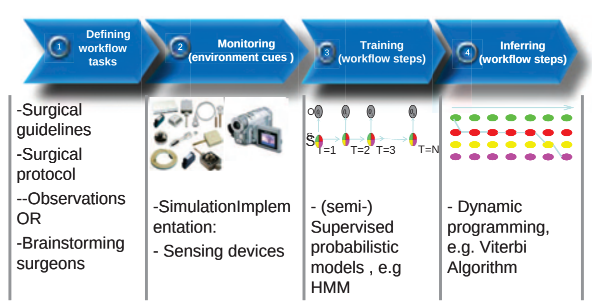

Figure 1. General framework for a surgical workflow system.

that needs to be in-vivo monitored in the OR.

In the second step we monitor environmental cues in the OR that may be significant for the activities derived in step 1. If the cues are easy to monitor with available easy-to-use sensors we acquire them automatically from the OR. In case adequate sensors are not available yet, we simulate the signal cues by means of video annotation and test their significance for the identification process (steps 3 and 4). In the third step, a probabilistic classification system is trained to infer the workflow steps from the environment cues. The system is trained with the cues (of step 2) as input features, and the workflow activities (of step 1) as different classes of surgical behavior.

After the system has been trained, we use dynamic programming to infer workflow activities from the input cues. The aim of the system is to record surgical activities in the OR in such a way they can be compared to the surgical protocol [5, 6].

PILOT [5]: LAPAROSCOPIC CHOLECYSTECTOMY

Laparoscopic Cholecystectomy (LC) is chosen because it is one of the most frequent and standardized procedures in minimally invasive surgery.

Step 1: Defining Workflow Steps

In the first step we defined the workflow activities of LC procedures by using LC protocol and discuss those activities with the cooperating surgeon. The workflow model of LC consists of 5 main surgical activities that need to be monitored. By further brainstorming with surgeons we assumed that instrument signals (i.e. instruments is usage) are significant cues in the OR to measure surgical activities.

Step 2: Monitoring Environment Cues

At the moment we do not have an adequate in-vivo sensing device to measure which instruments are being used in the LC procedure. In a previous study [5], we simulated the instrument signals by annotating laparoscopic video recorded during the operation. Figure 2 illustrates the simulated instrument cues as binary signals corresponding to instrument utilization; 1 if an instrument is in used, 0 if not in use; As ground truth data we measured also the surgical workflow activities (in step 1) as discrete time signals (Figure 3).

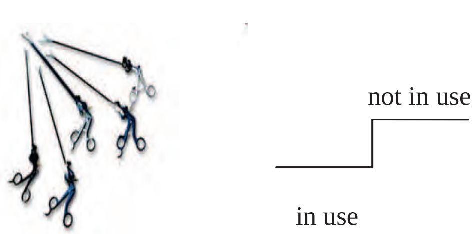

Figure 2. simulated instrument signals.

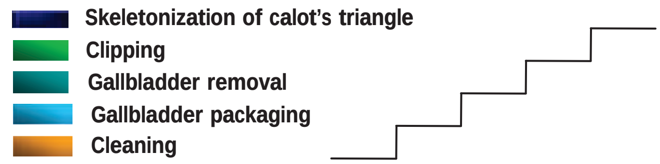

Figure 3. simulated instrument signals.

Step 3 & 4: training & Inference

In the training step [5], a Hidden Markov Model (HMM) is trained with 10 datasets from (step 2) using the binary instrument signals as observations and the ground truth surgical activity signals as hidden states.

After the training step, the system is ready for use. For a new set of instrument signals, derived form a new LC procedure the Viterbi algorithm is used to infer the surgical activities from instrument cues. The system shows a total accuracy of 90% of detected states as discussed in [5]. As expected, activities with higher accuracies were generally those with more data points (i.e. more instruments used).

CONCLUSIONS AND DISCUSSION

Recording surgical activities is crucial to save both lives and money in hospitals. After proving the significant cues for recording activities, we need to design appropriate sensing hardware or software solutions for in-vivo measurement. In the pilot study in section 3, we showed that instruments utilization is an important cue for the OR. The next step is to design a sensing device to allow tracking of instrument cues in-vivo during surgery.

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