SurgTrak — A Universal Platform for Quantitative Surgical Data Capture

Kevin Ruda

Darrin Beekman

Mechanical Engineering Department,
University of Minnesota

Lee W. White
Bioengineering Engineering Department
University of Washington

Thomas S. Lendvay
University of Washington,
Department of Urologic Surgery,
Seattle Children's Hospital

Timothy M. Kowalewski
Mechanical Engineering Department,
University of Minnesota

1 Background

The climbing costs of healthcare coupled with the alarming rate of malpractice suits have highlighted the need for an efficient and effective method of surgical training. In 2009, approximately 3.4 billion dollars in malpractice payments were awarded. A quarter of these claims stemmed from adverse events in the surgical setting [1]. Surgical errors also increase hospitalization time and adversely affect the health of patients, often resulting in death or major injury [1–3]. Improving surgical training methods has become a priority because the majority of mistakes in the operating room have been attributed to lack of skill and experience [4–6].

While the need for an improved surgical training system is clear, quantifying surgical competence has proved more elusive [7]. By capturing the metrics of surgical training, a surgeon's skill can be objectively evaluated. Expensive, procedure-specific simulators are frequently utilized as a means to gather data. But this method is limited by the simulator's capabilities. Surgical systems such as the Da Vinci surgical robot have also been used to collect data in the operating room [2]. This approach, however, is restricted to measuring the limited number of procedures performed with Da Vinci tools. Financial and legal obstacles also hinder system customization and preclude widespread use. Fabrication of a surgical metrics system is a cost effective alternative. Emphasis must be placed on how tool positioning is tracked and recorded as a wide variety of solutions are possible and prove to be effective. A variety of tool tracking techniques prove to be effective [2,8]. However, each new experiment requires a new tracking software implementation, which can be both costly and time consuming.

To address these issues we present SurgTrak^{TM}, an open, configurable software platform to enable quantitative data collection in surgical environments. SurgTrak combines a multitude of inputs from cameras, USB devices, or network devices and writes the values to a computer file. The biggest advantage of SurgTrak is the system flexibility. Many different sensors are available. SurgTrak has been designed for the surgical setting as a development platform to enable quantitative data collection and thus create objective metrics for surgical skill [9].

Manuscript received March 15, 2013; final manuscript received April 29, 2013; published online July 3, 2013. Assoc. Editor: Arthur G. Erdman.

2 Methods

SurgTrak was programmed in Microsoft Visual Studio 2012 using C++ on the Windows 7 Operating System. Configuration files let users define sensor variables to be logged by SurgTrak. Fig. 1 shows the user interface that includes a start/stop button, input fields for relevant labels such as a user ID, task name, date and time stamp, and automatically combines them into file names for each data acquisition session.

An error monitoring loop provides specific and constant feedback in real time, displaying SurgTrak's status in the user interface. SurgTrak implements a high resolution multi-media timer to synchronously time-stamp and record all sensor values. The output file can be seamlessly converted into computational programs such as Matlab and Excel for data analysis. Fig. 2 shows a diagram of SurgTrak software components.

SurgTrak hardware varies depending on the application. Motion tracking of the surgical tools includes a 3D Guidance trakSTAR electromagnetic tracking system (Ascension Technology Corporation, Burlington, VT, USA). DVI Video sources are recorded through the Epiphan DVI2USB device, (Epiphan Systems Inc., Ottawa, Ontario). Custom USB-enabled hardware based on PhidgetInterfaceKit 8/8/8 (Phidgets Incorporated, Calgary, Alberta) was developed, including a set of inexpensive potentiometers that extract absolute spindle angle of surgical tools and additional environmental signals.

A typical recording provides video synchronized with sampled sensor data. To benchmark timing performance for data logging, we extract the time difference between subsequent samples for a recording from a typical task. Similarly, we benchmark video performance with characteristics extracted from video file.

3 Results

The characteristics of a typical video taken by SurgTrak are presented in Table 1 below.

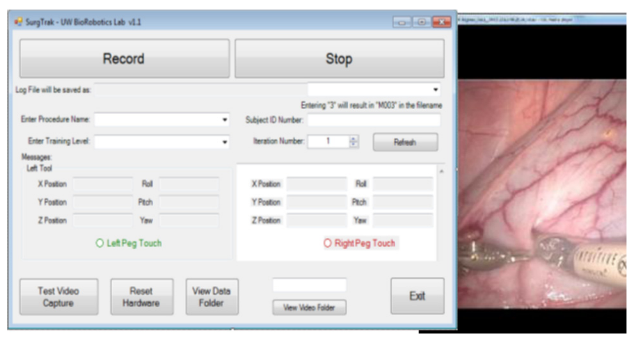

Fig. 1 SurgTrak Interface screenshot during a robotic pig surgery

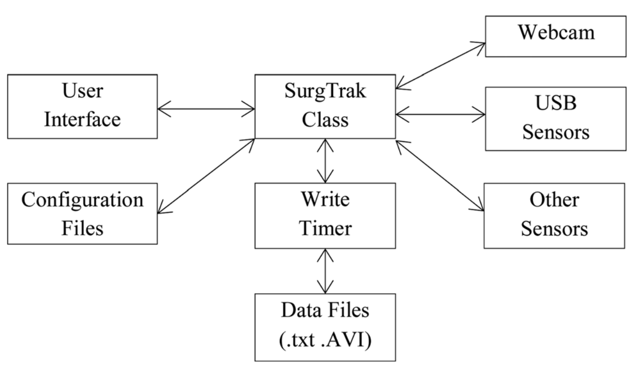

Fig. 2 SurgTrak architecture

Table 1 Typical SurgTrak video characteristics

Frame rate	30 frames/s
Media data size	32.0 MB
Playing Time	3 min. 52 sec.
Content bitrate	1642 kb/s
Lost	2 frames
Dropped	0

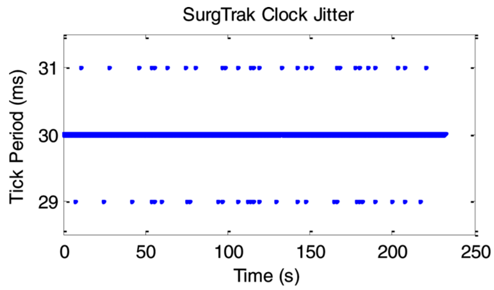

Fig. 3 Plot of sampling times during a typical data collection session

Table 2 Sensor values at a given instant in time

	Left tool	Right tool	Units
Time	6.001	6.001	(sec)
x Position	35.996	29.711	(cm)
y Position	−36.000	−2.628	(cm)
z Position	32.256	−7.211	(cm)
Roll	26.982	73.147	(deg)
Elev	−26.301	−79.299	(deg)
Azimuth	−79.189	75.564	(deg)
Left Jaw	174.24	176.04	(deg)
Jaw Roll	189.36	103.68	(deg)
Wrist Angle	182.16	197.28	(deg)
Right Jaw	175.32	202.32	(deg)
PegTouch	false	false	boolean

The clock jitter (non-constant sampling period of a multitasking operating system) of a typical SurgTrak data recording is presented in Fig. 3. The minimum and maximum recorded time difference between sensor readings is .029 seconds and .031 seconds. On average, this occurs for 0.7% of samples. The empirical standard deviation about the 30 ms period is 85.1 ns.

Table 2 shows sensor values for the corresponding video frame shown at the screenshot of SurgTrak ™ in Fig. 1.

Figure 4 illustrates the tool-tip path taken by a novice surgeon and an expert surgeon. The visual display of the path data is often an effective metric for surgical skill.

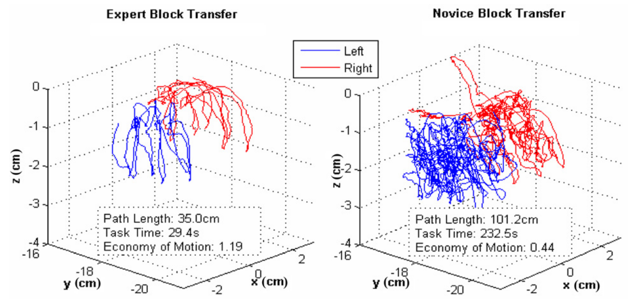

Fig. 4 A tool-tip path comparison of two surgeons performing a robotic laparoscopic peg transfer task with performance metrics derived from SurgTrak data

4 Interpretation

We present a system to conveniently collect synchronous data in surgical environments from various sources. Our clock jitter was observed to be 2 ms, implying that for a typical 1 m/s tip velocity SurgTrak will induce an error of +/−2 mm/s. Video encoding performance results in manageable file sizes of approximately 8.3 MB per minute with an acceptable frame rate and drop rate.

Future work will include adding an Arduino serial hardware interface to SurgTrak to enable easier sensor integration for a wider, less technical audience.

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