Development of Virtual Reality Surgical Simulator with Online Database

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***Abstract*—Conventionally, assessment of surgical skill in medical trainees is based on direct observation of outcomes by expert surgeons. This method is too subjective and is prone to inter and intra-rater's variability. Therefore, a computer and sensor-based assessment is proposed to standardize the evaluation. Using appropriate sensors can measure and record some hand motion parameters that cannot be detected by the human eyes, yet are essential for skill evaluation. Hence, a virtual reality surgical skill assessment system was developed to complement the conventional assessment method. The software assessment modules were developed on Visual Studio C++ and integrated with a Phantom Omni haptic device with an encoder resolution of 0.055mm for recording hand movements. The subject will perform simple virtual reality tasks that examine their basic psychomotor movements. The sensor recordings of their hand movements will be saved onto the Microsoft Azure Structural Query Language (SQL) database. A website was created to display the data of each individual trainee and this data can be accessed by an expert surgeon for review.**

***Index Terms*—Internet of Things (IoT); Objective Assessment Surgical Skill; Virtual Reality.**

I. INTRODUCTION

Surgery is one of the medical specialities related to the cutting of human body or animals, for the purposes of providing treatment to pathological conditions, improving body function and to repair unwanted ruptured organs or tissues. Microsurgery is a type of surgery, which requires high precision and good hand-eye coordination. A surgeon who is involved in microsurgery should have sufficient amount of practice and a high level of dexterity to execute the surgery well.

Conventionally, assessment of surgical skill requires the presence of an expert surgeon [1]. The expert will typically rate the outcome of surgery based on a standard global rating scale. Despite the objectivity of the scale, assessment is still subjective and highly dependent on the human manual observation and ratings. The method suffers from inter and intra-rating variability because different surgeons may have different evaluations; even the same surgeon may have different evaluations on different days. Hence, a sensor-based approach was proposed to complement the existing assessment method, by providing some form of quantifiable parameters of hand movements such as precision and motion smoothness [2]. These measurements cannot be sensed through direct observations but are important to identify trainees with innate dexterity and control that are essential for some surgical tasks. This paper presents the development of a three-dimensional (3D) virtual reality surgical simulator to assess the basic needle grasping movement and some basic hand reaching motion. The assessment system has cloud storage feature to allow the data to be accessed by expert surgeons or the user themselves from anywhere, if required. This virtual reality modules were validated with surgeons and non-surgeons to identify the measureable parameters that can differentiate between the two groups [3].

II. LITERATURE REVIEW

Surgical skills have commonly been assessed through supervision and feedback in the operating room [4], 5]. This method has been criticized for being too subjective and it cannot represent a surgeon's actual level of skills [6]. Nowadays, the healthcare demand is becoming more stringent; government and insurance companies call for clear and transparent quality measurements. Therefore, surgeons and trainees are increasingly scrutinized for their performance [7], [8], [9]. Rapid improvements in computer technology allow us to consider the use of computer-assisted learning (CAL) for teaching technical skills in surgical training [10]. One proposed method involves instruction in surgical skills by using computer-based and sensor-based virtual reality simulators [11], [12], [13]. This has clear advantages over other methods of instruction, not only in terms of teaching operative skills, but also in terms of assessing the performances of the surgical skills [14]. However, these simulators lack reporting features and cloud-based data storage.

Some cloud databases have been evaluated for their functions. Database is an organized collection of data such as schemas, tables, queries, reports, views, and other objects [15]. The data is typically organized to model aspects of reality in a way that supports processes requiring information. There are many types of databases used for different functions, for example, the Structural Query Language (SQL) and Not Only SQL (NoSQL) databases. SQL supports high performance and stores the data in structured format but has limited space and slower data transmission rate compared to NoSQL database. NoSQL database supports high transfer rates of data and able to store huge amount of data.

Traditional SQL databases have been used for a long time and have proven to be reliable tools for all kinds of applications. NoSQL databases have gained momentum in the last couple of years. However, because of growing scalability and availability requirements, SQL databases are often chosen to store and query large amounts of data. This is mainly due to developers' higher familiarity with the implementation of the database and also because of the stability of these databases. However, distributing SQL databases at very large scale is difficult because these databases are built for the support of consistency and availability, there is less tolerance for network partition [16].

III. IMPLEMENTATION

This project involved hardware platform for measurement of hand movements and software development of some virtual reality modules to assess the microsurgical skills between surgeon and non-surgeon groups. For the hardware implementation, the PHANTOM Omni haptic device from Sensable Technologies was used in this study to record position measurements during movement. The haptic feedback loop ran at 1000 Hz. This haptic device provided 6-DOF positional and orientation sensing using digital encoders with nominal accuracy of 0.055 mm. Besides that, 3-DOF force feedback can be provided with continues force of 0.88 N and maximum force of 3.3 N within 160x120x70mm3.

For the software implementation, the basic framework of user interface in the assessment task modules was developed using Microsoft Visual Studio C++ while the graphics of virtual environment and objects were developed using OpenGL library. The user interface was able to display the motion of the haptic stylus. For this study, visual display was provided through a 3D monitor Acer HS244HQ with a pair of active 3D shutter glasses (built-in IR emitter). The 3D monitor also has 23.6-inch display with 1920x1080 pixel full HD resolution at 120Hz refresh rate. The graphics card used together with this study is the nVidia GeForce 54m series. A user was able to view the virtual reality module in 3D view, with depth perception. The system flow chart is shown in Figure 1.

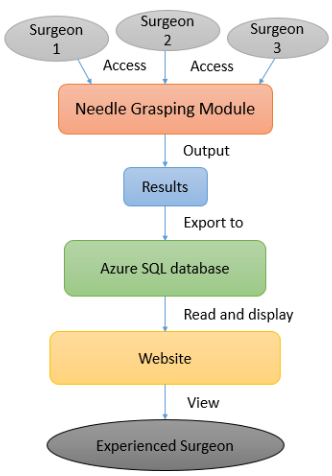


Figure 1: System flowchart

A. *Needle Grasping Module*

One of the assessment modules in this 3D virtual reality surgical simulator was the needle grasping module. This module was developed because suturing was one of the most common task performed during surgical procedure, to close a wound or to join tissue. Needle grasping technique need to be refined because wrong grasping technique may lead to undesired surface damage of the tissue. If the needle is grasped too close to the tip, the tip will point downward and suturing range would be limited. On the other hand, if it is grasped too far from the tip, the tip will point too far upward, and the needle would be prone to bending and breakage. The ideal grasping angle should be perpendicular to the needle jaw and the ideal grasping position is between midway and 2/3 from the needle tip point.

In this module, a needle holder and a curved suture needle are modelled. A total of six needles will appear one after another, with different positions and orientations, to test the dexterity and technique of needle grasping. This module was tested with surgeons and non-surgeons for validation. Figure 2 shows the flow chart of the needle grasping assessment module and Figure 3 shows the 3D visual display of needle grasping module.

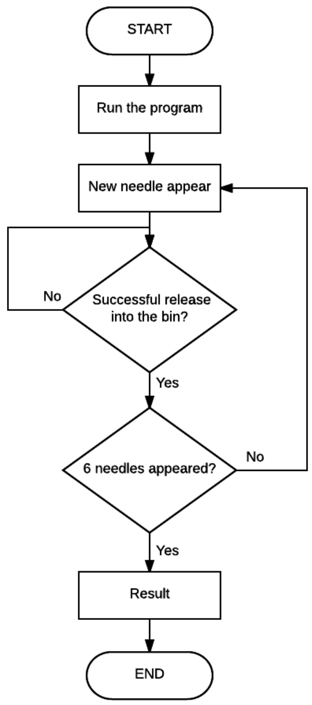


Figure 2: Needle grasping module flowchart

A group of subjects without known of hand pathology participated in the validation study. They were divided into two groups, which were surgeons and non-surgeons. Their movement data was collected and analyzed offline. The study had shown that the dynamic and static hand motion of surgeons were significantly different than that of non-surgeons.

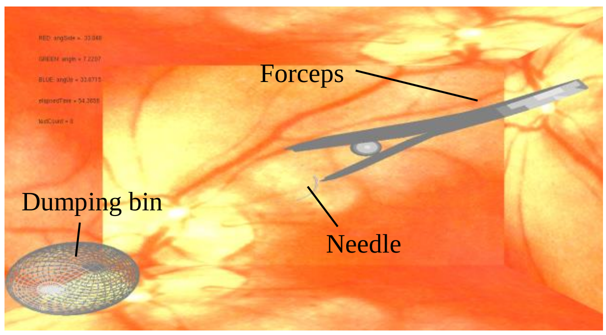


Figure 3: The needle grasping module

B. Results View

The values of parameter were recorded after each subject access the assessment. The result is stored in the text file.

C. Azure SQL Database

Azure SQL database, as shown in Figure 4, is the cloud database that allow us to store data. Before storing the data into the Azure SQL database, the text file must be converted into excel file so that it can be exported to the database. By using the SQL Server Management Studio 2008 (SSMS) as shown in Figure 5, the excel file can be exported easily into the Azure SQL database.

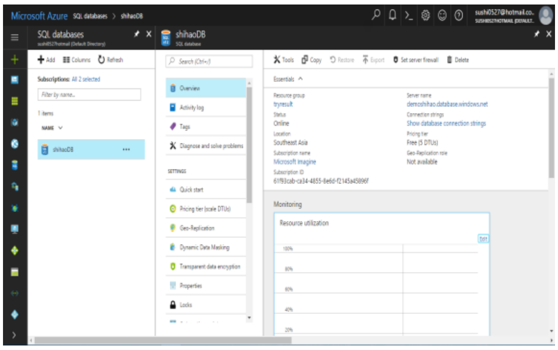


Figure 4: SQL database in Azure portal

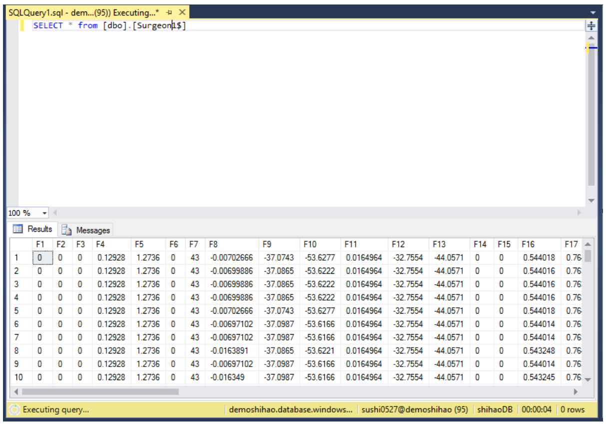


Figure 5: Microsoft SQL Server Management Studio 2008

D. Website

A website was created by using the Azure web apps service and Microsoft Visual Studio 2015. The interface is shown in

Figure 6. The website was designed using the ASP.NET framework and controlled by C# language in Microsoft Visual Studio 2015. After the project was compiled successfully, the project can be published to the Azure website. Azure web app service provides a domain for us to publish the website. An experienced surgeon can access to this website to view the trainees' assessment result anytime, anywhere.

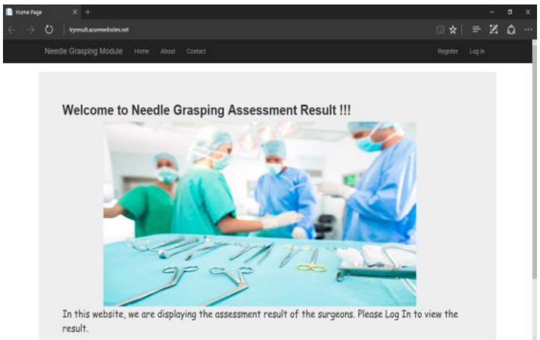


Figure 6: Home page

The Log In page as shown in Figure 7 allows the experienced surgeons to log in by using their username and password so that they can view the result of trainees who took the test.

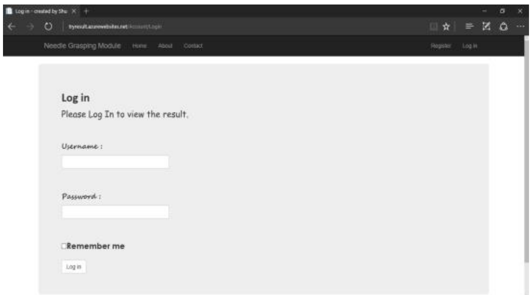


Figure 7: Log in page

Each surgeon's assessment result can be displayed in list view as shown in Figure 8. When an expert surgeon logged into the system, the expert can view the list of trainee surgeons and click on the individual results to view their performance. The individual trainee can also view their own performance. Each of the content in the list was hyperlinked to a specific set of results.

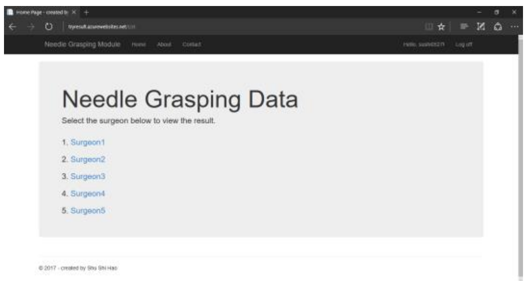
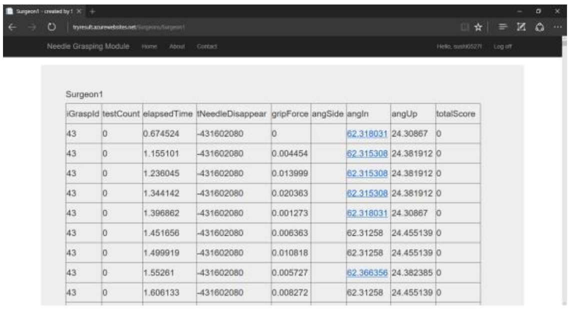


Figure 8: List of surgeons' results

After clicking the hyperlink, the page will be directed to the specific individual and the result will be displayed in table form, as shown in Figure 9.



iGraspId	testCount	elapsedTime	tNeedleDisappear	gripForce	angSide	angIn	angUp	totalScore
43	0	0.674524	-431602080	0		62.318031	24.30867	0
43	0	1.155101	-431602080	0.004454		62.315308	24.381912	0
43	0	1.236045	-431602080	0.013999		62.315308	24.381912	0
43	0	1.344142	-431602080	0.020363		62.315308	24.381912	0
43	0	1.396862	-431602080	0.001273		62.318031	24.30867	0
43	0	1.451656	-431602080	0.006363		62.31258	24.455139	0
43	0	1.499919	-431602080	0.010818		62.31258	24.455139	0
43	0	1.55261	-431602080	0.005727		62.366356	24.382385	0
43	0	1.606133	-431602080	0.008272		62.31258	24.455139	0

Figure 9: Surgeon's result in http://tryresult.azurewebsites.net

IV. DISCUSSION

Medical trainees are highly reliant on the availability of experts to provide feedbacks for their improvement, but mostly, the trainees have to practice without feedbacks due to the busy schedule of experts. With this virtual reality assessment module, trainees can obtain immediate feedback on their own performance through the sensor readings and can practice to achieve more precise movement. For recruitment into surgical specialty, the assessment system can also provide some form of information, just like the stereo acuity test, to identify if a trainee is suitable for this surgical route. Customized trainings can also be provided to improve a specific skill. Furthermore, with the implementation of Internet-of-Things (IoT) features, the expert can review the trainees from anywhere, without restricting themselves to be in the same premise.

For this project, the Azure services applied was the basic one without charges. As such, the quota for each service was limited. For example, the memory of database that can be used had 32MB threshold. The Azure SQL database also had firewall rules to protect the database. This firewall had to be set to allow an IP address to connect to the database. If using different source of internet service provider, there will be a different IP address. Each time we connect to a new internet service provider, we will have to reset the firewall rules to add the new IP address to the database.

To improve the system further, additional surgical tasks can be included in this surgical simulator for the assessment of surgical skills. More importantly, training modules to enhance specific skills, with increasing difficulty levels, can be implemented. Trainees can assess their performance and practice on the same platform, without having to look for training materials elsewhere. Additionally, results can be displayed in more formats, e.g. graph or charts, for better visualization.

V. CONCLUSION

Assessment and performance feedbacks are extremely important in a learning process, particularly for the technical skill acquisition such as the surgical skill. Surgeons require a large amount of training to be competent, not just in terms of medical knowledge, but also in terms of dexterity, precision and hand-eye coordination, to ensure a good surgical performance. The computer-based assessment can be complementary to the existing methods for surgical skill evaluation, providing sensor data that cannot be obtained through human observation. The implementation of IoT feature with an online SQL database to store performance data, also make it easier for an expert instructor to access the trainees' data, and make it possible to customize training based on individual skill levels.

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REFERENCES

[1] S. N. Z. Ahmmad, E. L. M. Su, C. F. Yeong, and F. K. C. Harun, "Assessment methods for surgical skills, world academy of science," *Engineering and Technology conference*, vol. 74, pp 752-758, 2011, Bali, Indonesia.

[2] E. L. M. Su, T. L. Win, W. T. Ang, T. C. Lim, C. L. Teo, and E. Burdet, "Micromanipulation accuracy in pointing and tracing investigated with a contact-free measurement system," in *Conf Proc 31st IEEE Engineering in Medicine and Biology Society (EMBC)*, 2009, Minneapolis, USA, pp 3960-3963.

[3] S. N. Z. Ahmmad, E. L. M. Su, C. F. Yeong, S. Sood, and A. Gandhi, "Objective measurement for surgical skill evaluation," *Jurnal Teknologi*, vol 78, pp145-152, 2016.

[4] R. K. Reznick, "Teaching and testing technical skills," *Am J Surg*, pp. 358-361, March 1993.

[5] W.S. Halsted, "The training of the surgeon," *Bulletin of the Johns Hopkins Hospital*, pp. 267-275, 1904.

[6] A. Darzi, S. Smith, and N. Taffinder, "Assessing operative skill. Needs to become more objective." *BMJ*, pp.887-888, 1999.

[7] S. Sekhri1, J. Mossner, R. Iyengar, A. Mullard, M. J. Englesbe, J. Papin IV, "Evaluating surgeon scorecards," *Michigan Journal of Medicine*, vol 1, pp 74-76, 2016.

[8] A. Darzi, V. Datta, and S. Mackay, "The challenge of objective assessment of surgical skill," *Am J Surg*, pp.484-486, 2001.

[9] L. T. Kohn, J. M. Coorigan, and M. S. Donaldson, "To err is human : building a safer health system," *National Academy Press : Washington, DC,* 1999.

[10] A. R. David , G. Regehr, K. A. Yeh , and T. R. Howdieshell, "Computer-assisted learning versus a lecture and feedback seminar for teaching a basic surgical skill," *Association of Surgical Education,* August 1997.

[11] S. N. Z. Ahmmad, Z. S. Chew, E. L. M. Su, and C. F. Yeong, "Force variability as an objective measure of surgical skill," *Jurnal Teknologi.*, vol 74, pp. 125-128, 2015.

[12] S. N. Z. Ahmmad, E. L. M. Su, C. F. Yeong, and A. L. T. Narayanan, "Experimental study of surgeon's psychomotor skill using sensor-based measurement," *Procedia Computer Science*, vol. 42, pp. 130-137, 2014.

[13] T. F. Then, E. L. M. Su, S. N. Z. Ahmmad, and C. F. Yeong, "Massed training versus interval training for computer-based suturing skill acquisition," *Journal of Medical Imaging and Health Informatics*, vol. 3, pp. 503-508, 2013.

[14] S. Yule, R. Flin, S. Paterson-Brown, and N.Maran, "Non-technical skills for surgeons in the operating room : A review of the literature," School of Psychology, University of Aberdeen, June 2005.

[15] H. Yue, L. Guo, R. Li, H. Asaeda, and Y. Fang, "DataClouds : enabling community-based data centric services over the internet of things", *Internet of Things Journal IEEE,* vol. 1, pp.472-482, 2014.

[16] J. S. Veen, B. Waaij, and R. J. Meijer, "Sensor data storage performance : SQL or NoSQL, Physical or Virtual", in *2012 IEEE Fifth International Conference on Cloud Computing*, USA, 2012, pp.431-438.