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Interactive evaluation of surgery skills in surgery simulators: A novel computational approach based on string matching algorithms.

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Purpose

In this paper we propose an evaluation method more oriented towards surgeon self-learning than towards surgeon classification (as previous surgical simulators). To this purpose, each surgeon gesture has been considered as a letter in a special surgical language. Based on this principle, expert sessions on the simulator are transcribed to a kind of character sequence which represents a specific surgical procedure. The goal of the novice is to replicate the expert sequence as faithfully as possible. We have adapted the LCS algorithm [1] to allow the comparison between a string (expert sequence) and an ongoing (partial) string (novice sequence). We have called this method the on-line LCS algorithm (oLCS). This incremental string-matching algorithm is the core of the developed system which allows the interactive evaluation and assessment of the novice during surgical training.

Methods

The surgical trainer developed for analyzing the applicability of string distances in interactive surgical training has four main components: The Tracker, The Virtual Scene, the String Generator and the Distance Calculator.

As Figure 1 shows, the Tracker detects the movement and state of the surgical tool in each time step (in our case, at a frequency of 45 Hz). The movement read by the tracker is sent to the Virtual Scene and to the String Generator. The Virtual Scene translates this movement into a new virtual tool state whilst the String Generator translates the movement into a character and sends it to the Distance Calculator. Each time the Distance Calculator receives a character, it is add to the end of the ongoing novice string and this “enlarged” ongoing string is compared with the expert string (see section 2.3). The result of the comparison is a Score and a sequence of Suggested Movements. The Score is an indicator of how novice is doing the training and the Suggested Movements represent the movements that novice must do if he wants to follow the expert indications and improve his Score. Both Score and Suggested Movements appear in the upper right corner of the Virtual Scene. The processes of String Generator and Distance Calculator are synchronized with the movement translation in the Virtual Scene. This means that all the processes are done at a frequency of 45 Hz.

Bearing in mind that the tracked tool has 5 degrees of freedom, 10 characters are needed to represent the possible movements: left, right, up, down, in, out, clockwise rotation, counterclockwise rotation, open clamp and closed clamp. Furthermore, the Movement Generator differentiates between a tool movement with something clamped and the same movement with an empty clamp. Considering this, the final number of characters needed to represent all possible movements is 16 for tool movement and 2 for clamping tool state. The evaluation system also analyzes the speed of the novice training and the fluidness of the surgeon movements. For these reasons, the movement generator also issues two characters directly related to the speed (which is generated each 5 seconds) and fluidness of the surgical training (which is generated each time the tool stops more than 5 seconds). All this makes that the String Generator can generate 20 different characters depending on the kind of movement (or time events) the laparoscopic tool has performed.

The oLCS algorithm applies the LCS Equation only to the same number of characters of the two strings (expert and novice). Therefore, the R matrix of the oLCS is always square. The novice success level (or relative similarity) is measured as the ratio between the number of hits, i.e., the length of the oLCS, and the total number of characters introduced by the novice.

Results

To validate the usefulness of our approximation, we have done a set of experiments to test if our proposal was able to distinguish between different levels of skills. To perform that, ten strings corresponding to ten experts were constructed. The ten experts have demonstrated their knowledge in the handling of laparoscopic instruments and the use of new technologies. The string with lowest mean distance to the rest of strings was used as the reference string. 15 students were chosen to perform the experiments which were divided in three groups of surgical knowledge: high, intermediate and novice. The "High" knowledge group consisted of students with some experience in laparoscopic surgery and the use of new technologies. The "Intemediate" knowledge group consisted of students that have little experience in laparoscopic surgery. Finally, the "Novice" group consisted of student without experience in laparoscopic surgery. Each group had 5 students who performed 4 repetitions in each scenario. Therefore, 20 samples were obtained for each group, 60 samples for each scenario and 120 samples in total. Figures 4 and 5 show the experimental results. The experiments performed show differences between the mean level of success for each group and, as expected, with greater levels of success for high level group and lower for novices. Since the repetitions were performed over the same scenarios, the students learned and achieved better results as the number of repetitions increased. Applying the Tukey's Test, significant differences were found between novices and high-level group ($p<0.05$).

Conclusions

To the authors' knowledge, this is the first time that a virtual laparoscopic environment incorporates an interactive evaluation system. This system not only allows surgeon classification but also a guided learning of novice surgeons. The simulator act as an expert supervisor and this can represent an important improvement for the surgical training through surgical simulators.

References

[1] L. Bergroth, H. Hakonen, and T. Raita, "A Survey of Longest Common Subsequence Algorithms," in Proceedings of the Seventh International Symposium on String Processing Information Retrieval (SPIRE'00), A Coruña (Spain), 2000, p. 39. Doi: 10.1109/SPIRE.2000.878178

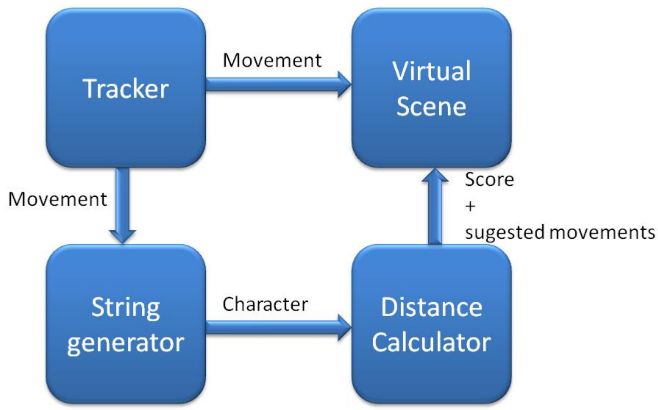

Fig. 1. Global view of the main components of the developed system.