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Asynchronous Teaching of Psychomotor Skills Through VR Annotations: Evaluation in Digital Rectal Examination

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Abstract. Many VR technology based training systems use expert's motion data as the training aid, but would not provide any short-cut to teaching medical skills that do not depend on exact motions. Earlier we presented Annotated Simulation Records (ASRs), which can be used to encapsulate experts' insight on psychomotor skills. Annotations made to behavioural parameters in training simulators enable asynchronous teaching instead of just motion training in a proactive way to the learner. We evaluated ASRs for asynchronous teaching of Digital Rectal Examination (DRE) with 3 urologists and 8 medical students. The ASRs were found more effective than motion-based training with verbal feedback.

Keywords. VR based training, haptics, simulation.

Introduction

Many VR technology based systems have been created with the aim of asynchronous (i.e. record and replay) training (e.g. [1,2]) of psychomotor skills. Such systems use expert's motion data as a training aid typically for handwriting, but they would not provide much aid to teaching medical skills that do not depend on exact motions but relative performance on every patient's unique anatomy.

Earlier we presented ASRs that encapsulate experts' insight on psychomotor skills and represent in an interactive way [3]. The underlying VR annotations based on behavioural parameters enable asynchronous teaching instead of just motion training. In this paper, we present an evaluation of using ASRs for asynchronous teaching DRE, a daily procedure in urology that relies on haptic feedback. The experiment consisted of two parts: First, experienced urologists recorded and annotated "the essence" of DRE skill into the recorded data, which was then learned asynchronously by medical students by only using the simulator. The experiments act as a proof-of-concept of improved expert-novice communication in an asynchronous teaching situation.

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1. Urologists' VR Annotations

In the first part of the experiment, the following hypothesis was tested: If experts made annotated their recorded performances on a simulator, the VR annotations could be assumed useful for teaching psychomotor skills. VR annotations could be used to encapsulate "the essence" of the skill rather than just the visual appearance of skilful performance by conventional record-and-replay.

1.1. Experiment Setting and Procedure

MVL [4] simulating Finite Element Method based reaction forces and soft-tissue deformation was utilized for constructing the DRE simulator (Figure 1). The simulator was running on a Xeon 3.2 GHz dual processor with 4 GB RAM. Sensable's PHANToM™ Desktop® device was used as the haptic interface. User wore a rubber glove when touching a virtual prostate via the haptic device. The forefinger's motion was restricted by a soft rectum dummy that was connected to the table by a metal frame. The virtual patient was laying on his side which made the user's finger movements to be directed to the right in order to touch the prostate.

3 urologists from Kyoto University Hospital recorded one performance on the 6 different prostate models (see Table 1) with the aim of correct diagnosis. Urologist 1 made 5/6 correct diagnoses whereas the other 2 urologists scored 3/6. On a separate day, each urologist annotated his own recorded performance in order to explain skilful DRE performance to inexperienced medical students. Successfully diagnosed performances were skimmed and obvious slips of finger were removed by using SiRE – Simulation Record Editor [5]. The experimenter inputted annotation according to the urologist's wishes so that skilful behavior in DRE became described, as illustrated in Figure 2. 13 annotatable physical parameters collected were implemented into the system: Direction, Precision and Contact area were represented as intuitive 3D visualization whereas Power, Power integral, Velocity, Acceleration, Smoothness (jerk), Path length, Distance between contacts, Finger's distance to target, Surface's deviation and Time represented in 2D. The 2D parameters were possible to show as visual, vibro-tactile or auditory Virtual Fixtures (see [6]).

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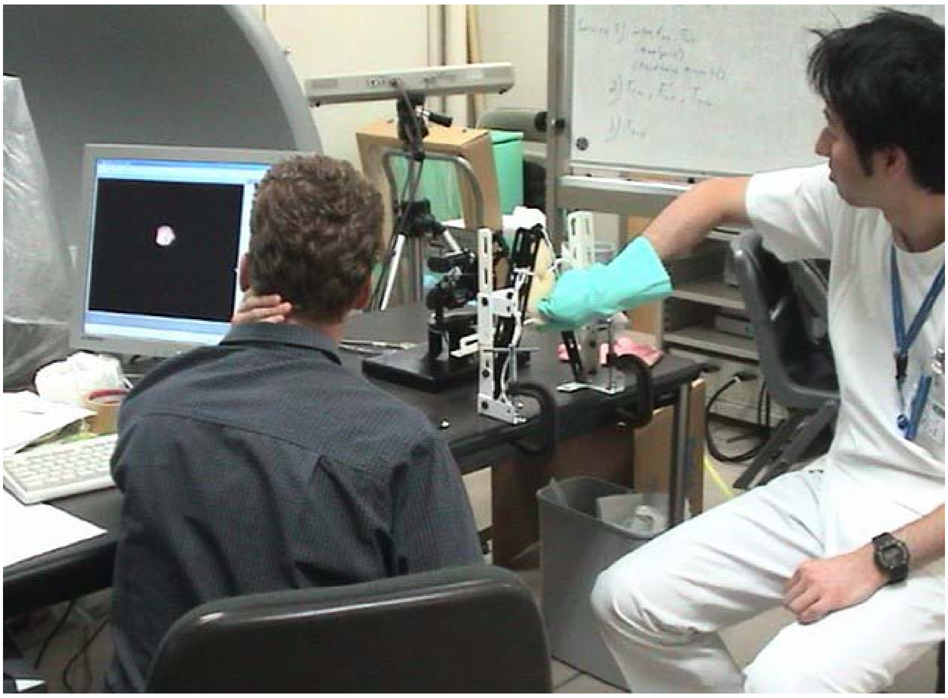

Figure 1. Urologist 1 (on the right) recording an example performance of DRE as in a real situation. Prostate on screen is not shown to the user.

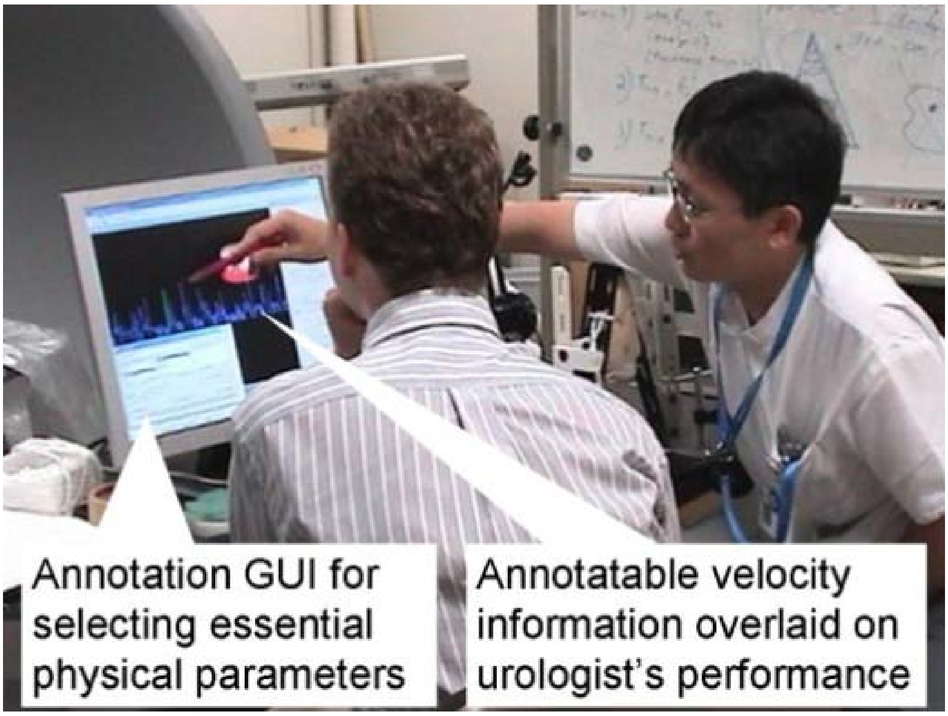

Figure 2. Urologist 2 pointing at a velocity peak in a transition phase between contacts when making VR annotations, experimenter inputting data.

1.2. Results and Discussion

The urologists' annotations were all similar and the hypothesis was supported adequately. Of the 13 parameters, Power and Contact area were selected by all three urologists and Velocity by Urologist 1 and 2. Only priorities differed between the annotations. Urologist 1 emphasized adequate coverage when in contact with the prostate whereas Urologist 2 preferred velocity to contact area. These results act as a proof-of-concept of VR annotations capturing "essence" of skill, since a consensus was achieved among the urologists who independently came to almost the same conclusion of what should be taught to novices through the system. It can be assumed that the VR annotation could capture expert's relevant instructions on psychomotor skills.

1.3. ASRs for Teaching DRE

Table 1 contains details of the different virtual prostates as well as the educational ASRs constructed from the urologists' VR annotations. Elasticity parameters of the prostates were 0.8Young/0.4Poisson for the normal areas and either 4.0 or 5.0Young/0.4Poisson for the hard areas, as shown in the table. "The essence" of DRE skill contained four separate cases dependent on the characteristics of the prostate. "The essences" covered power, contact area and velocity data as the physical parameters. Values were averaged from the urologists' performances, but the limit of success was fixed to 33.33% due to the limited number of the urologists' recordings. For example, one of the urologists used about double the power, which made use of

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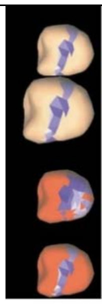
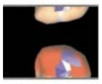
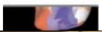
exact variance values cumbersome. The contact area was compared as the minimum amount of the triangles of the mesh between the whole time-series: user and example.

Table 1. Virtual prostates and annotated "essences" of skilful DRE.

Prostate type	Young value	Priority order	Contact area limit	Power limit (N)	Velocity limit (units/sec)
Normal	0.8	Contact area: Min. Force: Max. Velocity: Min.		1.1-1.6	9.1-12.1
Enlarged	0.8	Contact area: Min. Force: Max. Velocity: Min.		1.1-1.6	9.1-12.1
Full carcinoma I	4.0	Force: Max. Contact area: Min. Velocity: Max.		2.0-3.0	3.9-5.8
Full carcinoma II	4.0	Force: Max. Contact area: Min. Velocity: Max.		2.0-3.0	3.9-5.8
Right carcinoma: normal area	0.8	Contact area: Min. Force: Max. Velocity: Min.		1.1-1.6	4.6-6.1
Right carcinoma: carcinoma area	5.0	Force: Max. Contact area: Min. Velocity: Max.		0.7-1.1	2.2-3.3
Left carcinoma: normal area	0.8	Contact area: Min. Force: Max. Velocity: Min.		1.1-1.6	4.6-6.1
Left carcinoma: carcinoma area	5.0	Force: Max. Contact area: Min. Velocity: Max.		0.7-1.1	2.2-3.3

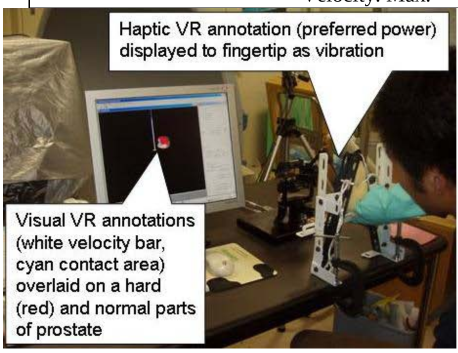


Figure 3. A subject of G2 practising with VR annotations during Training Session 2.

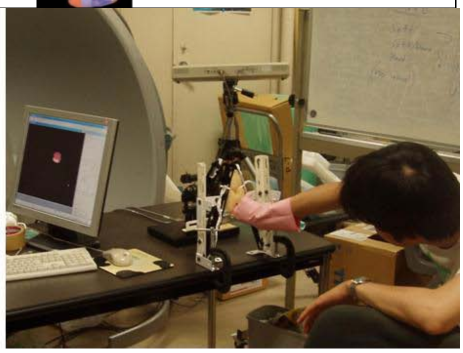


Figure 4. A subject of G1 performing the skill test in Skill Test Session 3 without visual feedback.

2. Medical Students Learning DRE Using ASRs

"The essence" of the DRE skill annotated by the urologists was presented to 8 medical students (3 women and 5 men) who were divided into groups of 4 (G1 and G2). "The essence" was presented to G1 verbally by the experimenter and the simulator showed the result numerically, whereas G2 received "the essence" through VR annotation.

2.1. Experiment Setting and Procedure

Figure 3 illustrates guidance and feedback given to G2 through VR annotations: Force limit was presented through a vibro-tactile effect (correct force resulted in vibration, extra force in strong vibration), velocity limit was shown visually (user had to match velocity bars visually) as well as the contact area (highlighted triangles of the mesh that faded from blue toward white according to order of the urologist's recorded contact).

The subjects went through a training program that consisted of Training Session 1 (S1) on the first day and on the second day Training Session 2 (S2) and Skill Test Session 3 (S3). During S1 and S2, the subject followed the example data's segment by segment, after which the whole performance was repeated from memory 3 times. Only the Normal prostate (20 movement segments), Full carcinoma I (20 segments) and Right carcinoma (17 segments) were given. In S3 the subject had to perform correct diagnosis as in the real DRE in the learned way (Figure 4). In S3 all of the 6 prostates were presented in a random order so that the skill had to be adapted to cases that were not rehearsed before. Therefore, the results were expected to be the worst in S3.

2.2. Initial Skill Level

First, means of groups G1 and G2 in the first task, the normal soft prostate, were compared in order to verify possible differences in the initial skill level. Subjects followed the first example's 17 segments, after which the same task was performed from memory 3 times. Each continuous touch was separately evaluated.

Error on power, the first priority parameter, was about 15% in both groups during practice and when performing from memory. G2 performed worse on the velocity: G2's 28.1% (2.94 Standard Error, SE, n=68) against G1's 19.4% (1.77 SE, n=68) mean velocity error when following the example, and 33.2% (3.36 SE, n=133) against 25.9% (2.31 SE, n=155) when performing from memory. Following of the example's contact area was better in G2. 33.3% (3.51 SE) in G2 against 45.8% (4.70 SE) but performance from memory was about the same. Visual representation of both velocity and contact area was suspected to make the subjects choose which one to focus on at the first trial. The initial level of skill was about the same in both groups.

2.3. Results

In both groups, the subjects correctly diagnosed 9 to 12 out of 12 virtual prostates. Figure 5 summarizes the performances by comparing mean errors of G2 to G1 in each corresponding phase of training (S1 and S2: practice when following the example and test from memory repeated 3 times) and the Skill Test (S3).

For power, statistically significant differences were found by t-test ($p<0.05$) in S1 practice (G1: 17.9%, 2.87 SE; G2: 22.1%, 3.08 SE), S2 practice (23.7%, 2.46 SE; 17.0%, 1.53 SE) and the skill test (30.3%, 0.91 SE, 22.0%, 0.67 SE). As the main result on power, G2 demonstrated 27.4% decrease in error ($p<0.0001$) in the Skill Test (S3).

Differences on velocity errors were found in S1 practice (25.8%, 1.47 SE; 19.7%, 1.52 SE), the S1 test (35.1%, 1.36 SE; 21.8%, 1.35 SE), the S2 test (33.7%, 1.45 SE; 15.6%, 1.20 SE) and the skill test (38.8%, 1.01 SE; 24.0%, 0.96 SE). In S3, G2's mean error was 14.8 units than G1's error ($p<0.0001$), a 38.1% decrease.

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For contact area only S2 test (54.7%, 3.73 SE; 67.3%, 2.61 SE) and S3 (71.3%, 2.21 SE; 62.3%, 2.80 SE) showed a difference. In S3, the difference between the groups was 9 units in favour of G2 (p=0.0397), a 12.6% decrease.

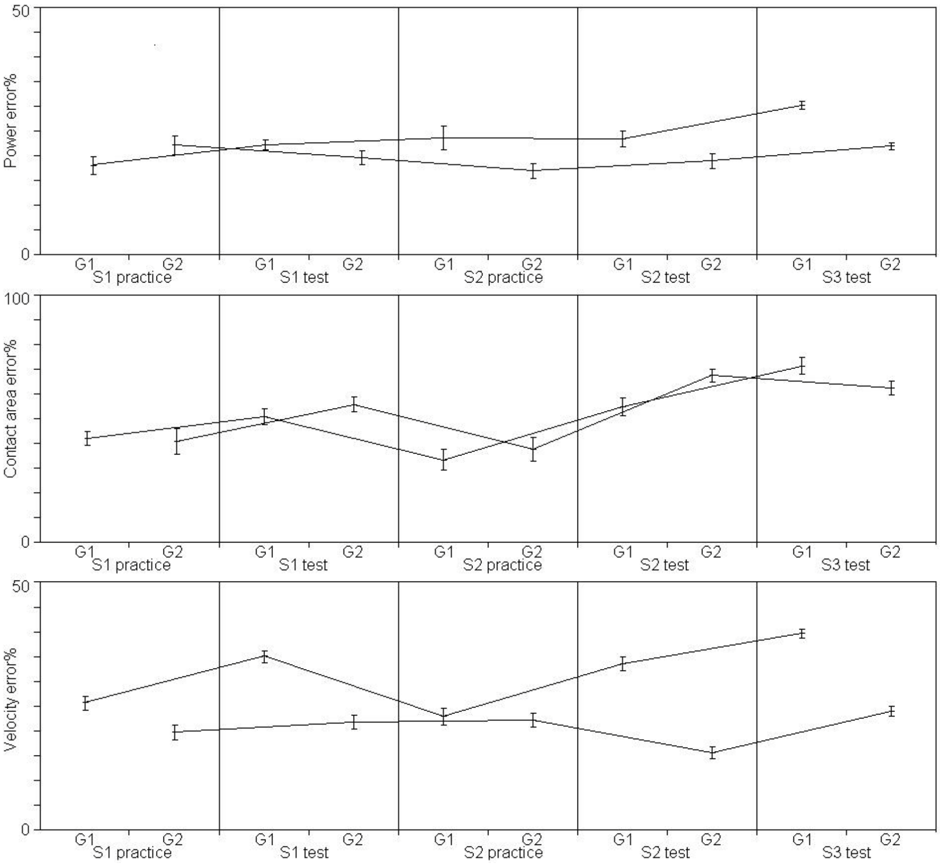

Figure 5. Mean errors of the medical student in each phase of the training program. Lines show the learning curve. (n=204 for both groups in practice phases. In the test phases for G1 n=612 in S1, n=501 in S2 and n=1132 S3, and for G2 n=431, n=376 and n=854 respectively.)

3. Conclusion and Discussion

“The essence” of DRE skill was agreed upon by urologists and mediated more accurately from urologists to medical students through the ASRs than through verbal instruction and numerical feedback. During training, learning curves were steeper when using the ASRs. G2 who learned from the ASRs demonstrated learning curves whereas G1 may have suffered from information overflow and lack of intuitive feedback. More accurate training of G2 in terms of “the essence” also led to improved skill after training. The experiment is a successful proof-of-concept that “the essence” of medical psychomotor skills can be communicated from experts to novices by through ASRs.

Future research will focus on other kinds of skills with better validated criteria of success. This study was limited by the challenging case of DRE which success criteria have not been well quantified and the number of experts as well as novices. The relationship between the DRE skill in the virtual environment and in the real world was not examined, only the expert-novice communication during asynchronous teaching. The number of correct diagnoses by the urologists' was lower than by the medical students, which lead us to suspect that the simulated environment required adaptation of the real world skill. As the future vision of simulator based education, ASRs encapsulating "the essence" of skilful behavior that does not depend on any specific setting of the training environment could be distributed on a global scale over network without time, space and even language restrictions between experts and novices.

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References

[1] C.L. Teo, E. Burdet, H.P. Lim, A robotic teacher of Chinese handwriting. In: Symposium on Haptic Interfaces for Virtual Environment and Teleoperator Systems, 2002, pp. 335-341.
[2] S. Saga, K. Vlack, H. Kajimoto, S. Tachi, Haptic video, In: SIGGRAPH 2005, DVD-ROM.
[3] M.J. Rissanen, Y. Kuroda, M. Nakao, T. Kuroda, K. Nagase, H. Yoshihara, A novel approach for training of surgical procedures based on visualization and annotation of Behavioural Parameters in Simulators, *Stud Health Technol Inform* **125** (2007), 388-93.
[4] Y. Kuroda, N. Nakao, T. Kuroda, H. Oyama, H. Yoshihara, MVL: Medical VR Simulation Library, *Stud Health Technol Inform* **111** (2005), 273-6.
[5] M. Rissanen, Y. Kuroda, M. Nakao, N. Kume, T. Kuroda, H. Yoshihara, Annotated surgical manipulation for simulator-based surgical skill-transfer using SiRE – Simulation Record Editor, 3rd International Symposium on Biomedical Simulation, 2006, pp. 122-131.
[6] L.B. Rosenberg, Virtual fixtures: Perceptual tools for telerobotic manipulation. In: IEEE Annual International Symposium on Virtual Reality, 1993, pp. 76-82.