M Li, S Sareh, M Ridzuan, L D Seneviratne, P Dasgupta, H A Wurdemann, K Althoefer, Multi-fingered palpation using pseudo-haptic feedback, Hamlyn Symposium on Medical Robotics, 2014, London, pp 8-9.

Multi-Fingered Palpation using Pseudo-Haptic Feedback

M. Li[1], S. Sareh[1], M. Ridzuan[1], L.D. Seneviratne[1], P. Dasgupta[2], H.A. Wurdemann[1], K. Althoefer[1]

[1]Centre for Robotics Research, Department of Informatics, King's College of London,

[2]MRC Centre for Transplantation, DTIMB and NIHR BRC, King's College London
k.althoefer@kcl.ac.uk

INTRODUCTION

The inclusion of haptic palpation in training simulators is beneficial for the acquisition of practical experience. Pseudo-haptic feedback, which creates an illusion of force and haptic feedback using only visual information, can replace expensive haptic devices [1]. In this paper, a multi-fingered palpation simulation using pseudo-haptic feedback with three indenter avatars is introduced and evaluated to prove the hypothesis that multi-fingered palpation is more time-efficient than single-fingered palpation. Multi-fingered palpation is more common than single-fingered palpation in real practice when attempting to detect differences in stiffness in the examined tissue [2]. With multiple indenter avatars, a wider tissue area can be investigated during one indentation instead of only one spot using a single indenter avatar. Moreover, the user can conveniently compare the stiffness values at different locations by observing the differences of indentation depths of those separate indenter avatars.

MATERIALS AND METHODS

Our pseudo-haptic-based feedback approach utilizes a cursor speed-changing strategy. The trace of the cursor movement at the same time intervals is shown in Fig. 1. When the cursor (indenter avatar) slides over a tissue area whose stiffness value is higher than the surrounding tissues, reduced indentation depth and tissue surface deformations are displayed. To simulate multi-fingered palpation, three indenter avatars are aligned in a triangular-shape during the operation. In this way, users are able to explore three neighbouring tissue areas simultaneously as if they were using three fingers to palpate (see Fig. 2).

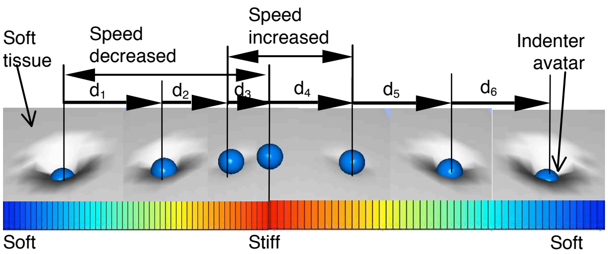

Fig. 1 Pseudo-haptic feedback: modification of the cursor speed when passing over a hard nodule ($d_1>d_2>d_3$, $d_3<d_4$).

Two types of tablet computers are used in this study – Samsung Galaxy Note 10.1 (using an S-pen input) and Motorola Xoom (using the user's bare finger input). A virtual model of a tissue block with a flat surface is displayed on a graphical interface. The stiffness information of the tissue model is described by reaction force matrices acquired from rolling indentation tests [1], [3]. The coordinates of the program window are linearly mapped to the tissue surface. The user moves a special force-sensitive pen or a bare finger over the surface of a tablet computer tangentially providing 2-DOF movement kinematics and a normal force as two inputs. The outputs are the normal reaction force from the tablet computer, the virtual resistance along the movement direction generated by using pseudo-haptic feedback, and the soft object deformation shown on the graphical interface.

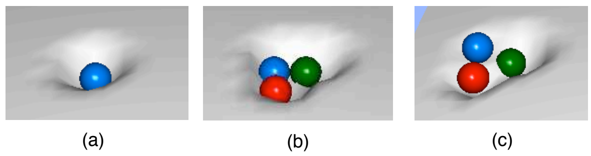

Fig. 2: (a) A single indenter avatar represents one finger; (b) three indenter avatars, representatives of three fingers, are at the same height indicating no abnormalities; (c) avatars are at different heights indicating possible tissue abnormalities.

The Samsung Note (using a Wacom S-pen) is force-sensitive and has 1024 levels of pressure sensitivity. The force level-force value relationship is described as

$$f_n = 0.1008e^{4.2081 f_l}, \quad (1)$$

where f_l is the force level reading from Android SDK and f_n is the corresponding normal force values. The Motorola Xoom tablet senses the area of touch: when the touched area is broader, it recognizes the applied force as larger. The force level-force value relationship is described as

$$f_n = 0.0772e^{3.0727 f_l}. \quad (2)$$

The modification of the indenter avatar speed is achieved by adding a time delay to the rendering task of the indenter avatar when it is approaching a stiffer area. If the indenter passes over the stiffer area, the indenter avatar continues to follow the contact point. The delay time is expressed as

$$t_d = \Delta f_t \cdot m, \quad (3)$$

where the value of the tangent reaction force f_t is acquired from the reaction force matrices formed during the rolling indentation; Δf_t is the reaction force difference ($\Delta f_t = f_t - f_{tl}$); f_{tl} is the tangent reaction force value at the last avatar position; m is a scalar value set to be 500 in this study.

In order to validate the proposed multi-fingered palpation using pseudo-haptic feedback, four evaluation tests were conducted: 1) single-fingered pseudo-haptic

M Li, S Sareh, M Ridzuan, L D Seneviratne, P Dasgupta, H A Wurdemann, K Althoefer, Multi-fingered palpation using pseudo-haptic feedback, Hamlyn Symposium on Medical Robotics, 2014, London, pp 8-9.

palpation using a tablet and S-pen as input devices, 2) multi-fingered pseudo-haptic palpation using a tablet and S-pen as input devices, 3) single-fingered pseudo-haptic palpation using a table and a bare finger of the user as input devices, 4) multi-fingered pseudo-haptic palpation using a table and a bare finger of the user as input devices. Twenty right-handed participants, who have normal or corrected vision, participated in this empirical study. Firstly, participants were asked to do a practice run with known tumour locations. Then, they were asked to manipulate the input device to "palpate" the virtual soft object and observe the change of the ratio between the indenter avatar displacement distance and their input. When they found hard inclusions, they reported their locations. The researchers recorded the nodule detection rates and the time consumed. The order of tests was pseudo-random and during all those tests, the same stiffness distribution was used, but the orientation of the soft object was different from test to test. So the participants would not know the nodules' locations from the earlier tests. Fig. 3 shows the user interfaces of the pseudo-haptic soft tissue stiffness simulation using the two tablet computers.

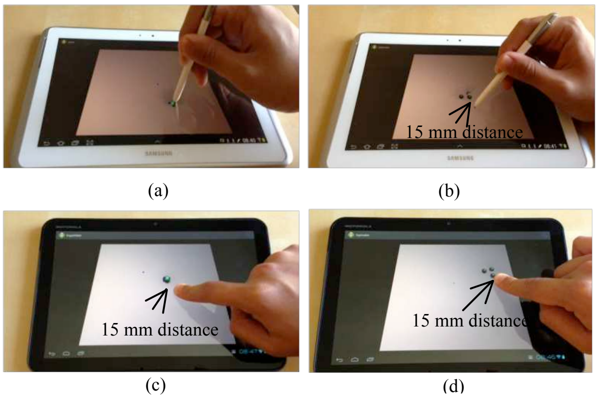

Fig. 3 Pseudo-haptic palpation: (a) single-fingered palpation using a tablet and an S-pen; (b) multi-fingered palpation using a tablet and an S-pen; (c) single-fingered palpation using a tablet and a bare finger of the user; (d) multi-fingered palpation using a tablet and a bare finger of the user.

RESULTS

Fig. 4 presents the nodule detection sensitivity *Se* [4] that is the measure of the test's ability to identify positive results. It is defined as sum over all *n* trials of the true positives divided by the sum of false negatives and true positives. Fig. 5 presents the consumed time for nodule detection. Wilcoxon signed-rank test [5] is used to compare the time consumed in pairs.

DISCUSSION

The user study results showed good performance of nodule detection sensitivities of pseudo-haptic palpation and there was no significant difference between single-fingered and three-fingered pseudo-haptic palpation. The multi-fingered pseudo-haptic palpation either using an S-pen or a bare finger input consumed significantly less time than single-fingered pseudo-haptic palpation. It reveals that multi-fingered pseudo-haptic palpation is more time-efficient than single-fingered pseudo-haptic palpation.

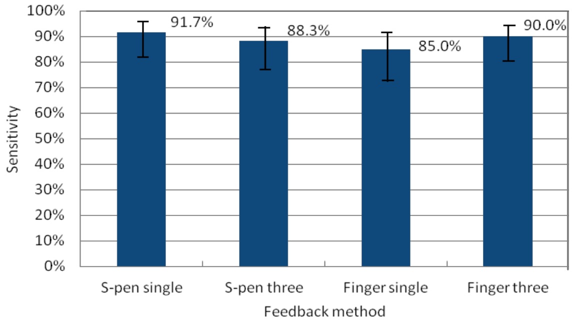

Fig. 4 Nodule detection sensitivities with Wilson score intervals [6] at a 95% confidence level.

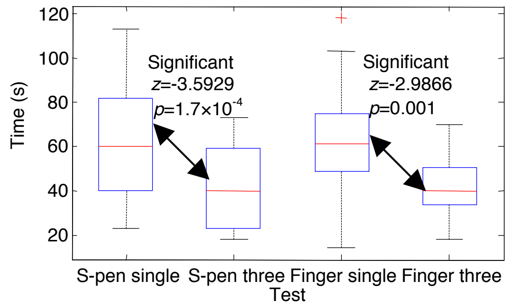

Fig. 5 The consumed time of single-fingered and multi-fingered palpation using pseudo-haptic feedback.

ACKNOLEDGMENT

The research was partially funded by the GSTT Charity and the Vattikuti Foundation, the European Commission's Seventh Framework Programme under grant agreement 287728 in the framework of EU project STIFF-FLOP, and the China Scholarship Council.

REFERENCES

[1] M. Li, H. Liu, L. D. Seneviratne, and K. Althoefer, "Tissue stiffness simulation and abnormality localization using pseudo-haptic feedback," in IEEE International Conference on Robotics and Automation, 2012, pp. 5359–5364.

[2] M. Dinsmore, N. Langrana, G. Burdea, and J. Ladeji, "Virtual reality training simulation for palpation of subsurface tumors," in IEEE Virtual Reality Annual International Symposium, 1997, pp. 54–60.

[3] K. Sangpradit, H. Liu, L. D. Seneviratne, and K. A. Althoefer, "Tissue identification using inverse finite element analysis of rolling indentation of Rolling Indentation," in IEEE International conference on Robotics and Automation ICRA, 2009, pp. 1250–1255.

[4] D. Altman and J. Bland, "Diagnostic test 1: Sensitivity and specificity," BMJ, vol. 308, p. 1552, 1994.

[5] F. Wilcoxon, "Individual comparisons of grouped data by ranking methods.," J. Econ. Entomol., vol. 39, p. 269, 1946.

[6] E. B. Wilson, "Probable inference, the law of succession, and statistical inference," J. Am. Stat. Assoc., vol. 22, pp. 209–212, 1927.