2012 International Conference on Information and Computer Applications (ICICA 2012)
IPCSIT vol. 24 (2012) © (2012) IACSIT Press, Singapore

An Investigation of Contact Forces using a Kinaesthetic Feedback

Abdouslam M. Bashir[1a] and Robert Bicker[2b]
[1]Higher Institute of Industrial Technology, Tripoli-Libya
[2]School of Mechanical & Systems Engineering, Newcastle Upon Tyne University-UK
[a]bash74@hotmail.com, [b]robert.bicker@ncl.ac.uk

Abstract. This work investigates contact forces of different visual / tactual feedback modes using VisiTact system [1]. Different immersion levels and the visibility of the participant's hand led to significant differences in the task performance, i.e. wearing a Head Mounted Display (HMD) demonstrated a superior performance over other VR modes, in terms of peak contact force.

Keywords: Contact forces, force feedback system, virtual reality.

1. Introduction

Many studies have postulated [2,3 and 4] that the measurement of peak contact force is a meaningful criteria to evaluate the performance of a haptic interface, inasmuch good fidelity should be reflected in a correspondingly lower magnitude in peak force, [5 and 6].

2. Contact Force Study

A typical force profile from the pilot study [7] illustrated that the magnitude of the peak force (force applied at point (B) on the virtual wall in the Y-axis) was somewhat lower with the real prototype than when VisiTact was used (reported in 11 out of 13 of the participants), as expected. Fig 1 presents the mean (and standard deviations) of the peak contact force (along the Y-axis) across the four modes for one of the participants.

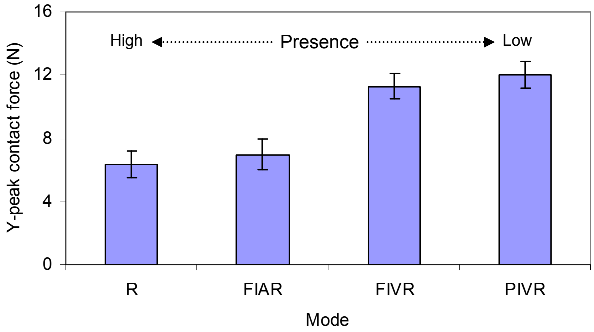

Fig.1 The overall mean peak contact force and standard deviations for the four different modes

Fig 2 shows that the peak forces recorded in the PIVR and FIVR modes was substantially higher than the R and FIAR modes, in which the participant's hand is present. It should be noted that all unfamiliar abbreviations (such as FIVR, FIAR, etc) are explained in [7].

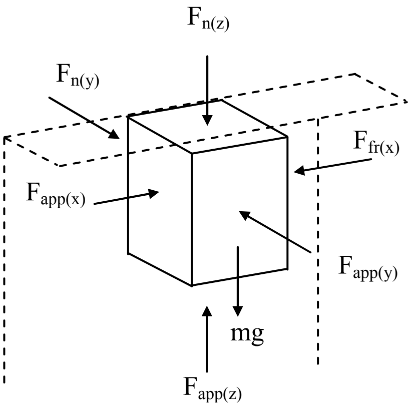

Fig.2 The contact forces considered in the study

The ANOVA analysis showed a significant mean effect across mode R, FIAR, FIVR and PIVR (F(3,48) = 7.39, p = 0.0003, ω^2 = 0.269). A Post-hoc Tukey analysis indicated significant differences between mode R and either of modes PIVR and FIVR. However, no significant difference in the mean peak force was reported between mode R and FIAR; mode PIVR and FIVR. Evaluation of contact force during the sliding phase using the real prototype, during which the participant slides the block along the X-axis until it reaches a position adjacent to the aperture slot, shows that relatively large forces occur in the Y and Z directions ($F_{app\ (Y)}$ and, $F_{app\ (Z)}$ respectively), as shown in Fig 2.

The friction forces generated during the sliding phase on the X direction was calculated using. $F_{fr(X)} = \mu_{(y)}F_{n(y)} + \mu_{(z)}F_{n(z)}$

Based on previous tests [7], the static and kinetic friction constants were set to 0.36 and 0.4 respectively in all directions.

The contact force data was extracted using MatLab, and recorded using the Qmotor graphics user interface (GUI) application. The average Y and Z contact forces was calculated using the following formula, adopted from [8], as follows:

$$Average \quad force = \frac{\sum_{i=1}^{N} f_i}{N}$$

Where N is the number of data samples in the sliding phase and f_i is the magnitude of the i^{th} force, assuming all forces are positive [9]. The mean of the Y and Z contact forces was calculated for each of the four trials for every participant. A typical example of the average contact force occurring during sliding, across each of the four modes for one participant, is shown in Fig 3.

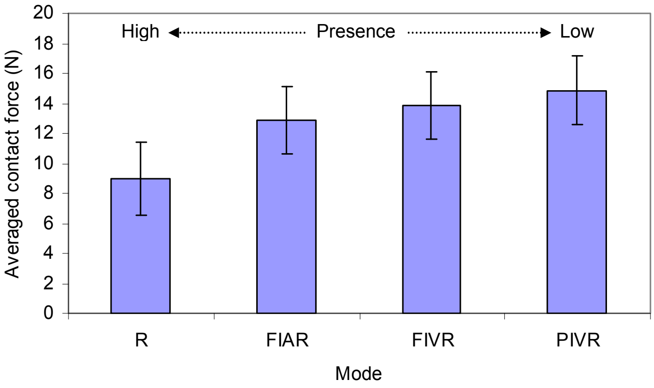

Fig.3 averaged contact forces across the four modes

It is evident from Fig 3 that participants tend to apply greater force (averaging 15N) with the VisiTact than that in the real task (around 8N) during the sliding phase. An ANOVA analysis explicitly revealed that there were significant difference between the averaged contact forces during sliding (F(3,48) = 11.99, $p < 0.0001$, $\omega^2 = 0.388$).

Post-hoc Tukey tests indicate significant differences between the real task (mode R) and any of the other conditions (i.e. modes FIAR, FIVR and PIVR). However, no significant differences were reported between modes PIVR and FIVR; PIVR and FIAR; and between FIVR and FIAR.

The final aspect of the contact force analysis focused on the peak force occurring during the insertion phase of the block-in-hole task. An ANOVA analysis was conducted which didn't provide any clear indication on which mode recorded the least insertion force, in other words, there was no significant difference in the peak insertion force among the modes as verified by ANOVA (F(3.48) = 1.88, $p = 0.14$, $\omega^2 = 0.048$).

3. Discussions of Results

The participants, in general tended to contact the virtual wall with a markedly greater force, particularly in those modes in which the hand was not present ($p = 0.0003$) – in agreement with the third hypothesis. Thus, it can be inferred that the participants experienced some difficulty in judging the distance between locations A and B on the simulated prototype, again resulting in greater impact forces, which was generally in agreement with the participants' comments. During the sliding phase, the results reveal that the participants applied greater force, especially when the VisiTact was used, regardless of whether they could see their hand or not, which suggests that the dynamic interaction of the force feedback system was a significant factor in performing the task. However, the measure of peak force occurring during the insertion phase showed no significant difference in the mean values between each of the modes ($p = 0.112$).

4. Conclusions

The results suggest that participants found hard in judging distance, in terms of a measure of accuracy (between the locations A and B on the simulated prototype), which led to some difficulty in accurately locating the virtual surrogate object at the desired contact point, which in turn may have led to greater impact force.

5. Acknowledgments

The support of the EPSRC is acknowledged for the construction of the system.

6. References

[1] DUAN Ming-de; GAO Zuo-bin; MA Wei; LI Ji-shun. Application of RE in the Development of Tractor Covering Parts. Tractor & Farm Transporter [J], 2007, PP:86-88

[2] GUO Liang-gang; CHEN Yong; LIU Xiong-wei. Study of the Application of the Reverse Engineering Technology in the Design of the Complex Cavity-Surface Dies & Moulds, Die & Mould Industry [J], 2002.1, PP12-17.

[1] BASHIR, A. M. BICKER, R. and TAYLOR, P. M. . An Investigation into Different Visual/Tactual Feedback Modes for a Virtual Object Manipulation Task, ACM SIGGRAPH International Conference on Virtual Reality Continuum and its Applications in Industry, Proceedings VRCAI 2004, Nanyang Technological University, Singapore, June 16 – 18, 2004, pp359-362.

[2] WELCOME D., RAKHEJA S., R. DONGA, WU J.Z. and SCHOPPER A.W., "An investigation on the relationship between grip, push and contact forces applied to a tool handle", International Journal of Industrial Ergonomics, Volume 34, Issue 6, December 2004, Pages 507-518.

[3] WANG Fu-Jun, , WANG Li-Ping, CHENG Jian-Gang and YAO Zhen-Han, "Contact force algorithm in explicit transient analysis using finite-element method", Finite Elements in Analysis and Design, Volume 43, Issues 6-7, April 2007, Pages 580-587.

[4] KARTIK M. Varadarajan, MOYNIHAN A. L., Darryl D'Lima, COLWELLC C. W. and Guoan Li, "In vivo contact kinematics and contact forces of the knee after total knee arthroplasty during dynamic weight-bearing activities", Journal of Biomechanics, Volume 41, Issue 10, 19 July 2008, pp 2159-2168.

[5] HAYWARD, V. GREGORIO, P., ASTLEY, O.,GREENISH, S., DOYON, M. Freedom-7: A high fidelity seven axis haptic device with application to surgical training, dept. of Electrical Engineering and Center for Intelligent Machines. McGill University, Montreal, Canada Lecture note in control and information science 232, 1998, pp 445-456.

[6] Chen, E. (1999). Six Degree-Of-Freedom Haptic System for Desktop Virtual Prototyping Applications, Virtual Reality and Prototyping - SensAble Technologies, Inc., June 1999, Laval, France, pp 1-10.

[7] BASHIR, A. M. Design And Evaluation of A Virtual/ Augmented Reality System with Kinaesthetic Feedback, PhD thesis, University of Newcastle upon Tyne, UK, 2005.

[8] DAS, Zak H., KIM, W.S. BJCZY, A.K and SCHENKER, P.S. Operator performance with alternative manual control modes in teleoperation, Presence, 1, 2. As referred to by Burdea and Coiffet (2003).

[9] BURDEA G. C. and COIFFET W. (). Virtual Reality Technology, Hoboken, N.J. : J. Wiley-Interscience, New York, USA, ISBN 0471360899, 2003.