Stiffness Augmentation using an Electromagnetic-based Haptic Interface

Alaa Adel, Mina Maged and Islam S. M. Khalil

Abstract—In this study, we develop an impedance-type algorithm for an electromagnetic-based haptic interface to provide a stiffness augmentation for a three-dimensional(3D) Virtual objects. A wearable haptic device is used and contains a magnetic dipole, the capability of the system is evaluated to render 3D virtual objects in mid-air using magnetic force in excess of 2 N within a workspace of 150 mm $\times$ 150 mm $\times$ 60 mm. As a target for rendering soft medical tissues for surgical training applications, our system is capable of rendering low range values of stiffness (0-500 N/m). We combine our system with an augmented reality (AR) tool to provide a combination of haptic perception and 3D visual representation. In order to show the effect of this combination, we conduct an experiment to evaluate the accuracy of stiffness perception with/without using an AR tool. Participants experimentally demonstrate an average success rate -% and -% in distinguishing between six values of stiffness with/without using an AR tool, our statistical analysis shows that effect of integrating an AR tool on the average success rate is statistically significant/ not significant, for 95% confidence level.

Index Terms—Augmented reality, haptic rendering, interaction, stiffness.

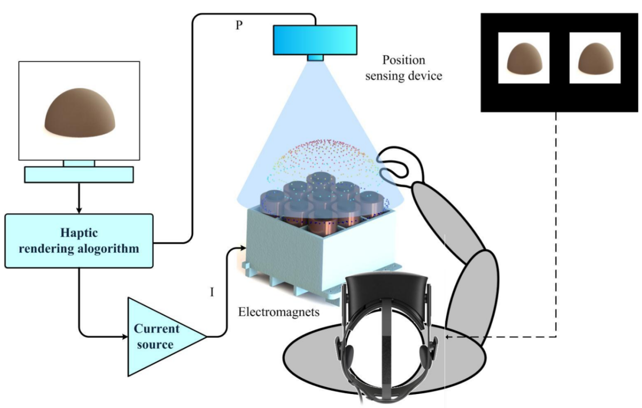

Fig. 1: Electromagnetic-based haptic interface enables the operator to interact with virtual objects in three-dimentional space. The system consists of an array of electromagnetic coils. Each coil is powered independently using a current source. A current input ($\mathbf{I} \in \mathbf{R}^9$) is provided to the coils based on the morphology of the object and the position ($\mathbf{p} \in \mathbf{R}^3$) of the user using a haptic rendering algorithm. Electromagnetic coils convert the input current into magnetic field gradient to exert magnetic force on the dipole moment (attached to a wearable user interface) at the sensed position. An AR tool was added with our system to provide a combination of haptic perception and 3D visual representation.

References

[1] A. Adel, M. Abou Seif, G. Hoelzl, M. Kranz, S. Abdennadher, I. S. M. Khalil, "Design and development of an electromagnetic-based haptic interface," *in Proceedings of the IEEE International Conference on Intelligent Robots and Systems (IROS)*, Vancouver, BC, Canada, September 2017.

[2] Q. Zhang, H. Dong, and A. El Saddik, "Magnetic field control for haptic display: system design and simulation," *in IEEE Access*, vol. 4, pp. 299–311, January 2016.

[3] N. Magnenat-Thalmann and U. Bonanni, "Haptics in virtual reality and multimedia," in *IEEE Transaction on Multimedia*, vol. 13, no. 3, pp.6–11, 2006.

[4] Salisbury, K, Conti, F, and Barbagli, "F. Haptic rendering: Introductory concepts," *IEEE Computer Graphics and Applications*, vol.24, No. 2, pp. 24–32, 2004.

[5] Y. Suzuki and M. Kobayashi, "Air jet driven force feedback in virtual reality," *IEEE Transactions on Computer Graphics and Applications* vol. 25, no. 1, pp. 44–47, January 2005.

[6] R. Sodhi, I. Poupyrev, M. Glisson, and A. Israr, "Aireal: Interactive tactile experiences in free air," *ACM Transactions on Graphics* , vol. 32, no. 4, pp. 134, July 2013.

[7] S. Gupta, D. Morris, S. N. Patel, and D. Tan, "Airwave: Noncontact haptic feedback using air vortex rings," *in Proceedings of ACM International Joint Conference on Pervasive and Ubiquitous Computing* , pp. 419–428, September 2013.

[8] B. Long, S. A. Seah, T. Carter, and S. Subramanian, "Rendering volumetric haptic shapes in mid-air using ultrasound," *ACM Transactions on Graphics*, vol. 33, no. 6, pp. 181(1–10), November 2014.