Embedded Optical Sensing with Display Systems for Virtual-Physical Interactions

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ABSTRACT

This talk introduces embedded optical sensing techniques with display systems for virtual-physical interactions. With advances in ubiquitous sensing technology, we can design embedded optical sensing systems for various purposes, such as sharing facial expressions and wind for communications, to extend our possibilities in cyber-physical spaces.

1 Introduction

Interactions in between virtual and phsyical elements is an essential component to connect our daily environment and virtual environment seemlessly. Virtual physical interactions can be made by measurement and control of the states of a physical environment with a physics simulation in a virtual environment [1].

In ordinal cases, the measurement of a physical element can be made with various configuration with optical sensing systems such as a camera device. When we think about the minimum configuration of optical sensing, we see a single point photo sensor as one of such instances. By designing arrangements of single point photo sensors, we can make flexible sensing systems for virtual-physical interactions [2][3][4].

2 Virtual-Physical Interactions

Virtual physical interactions allow us to have a strong sense of reality for virtual elements in extended reality environments. By having interferences between virtual and real elements, we are able to perceive illusion as if the virtual elements are there. Fig. 1 shows a possible interaction between a virtual element and physical robots.

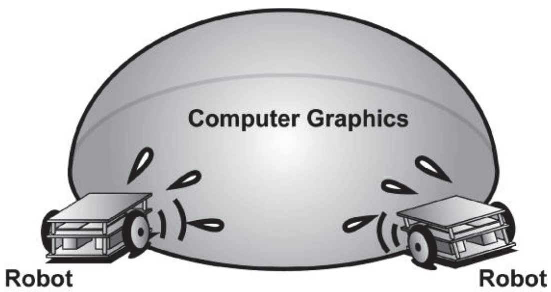

Fig. 1 An example of Interactions between a virtual object and physical robots [1]

3 Implementations

Detecting the position and rotation can be made with fiducials. By projecting gradient patterns [2], we are able to obtain these parameters with sensing units attached to robots.

Facial expression is one of the essential components in our daily communication to express non-verbal gestures with emotional states. By embedding reflective photo sensors in wearable devices such as glasses [5][6] and head-mounted displays (HMDs)[7][8][9], it is possible to recognize the facial expressions of users. Fig. 2 shows an implementation of such an HMD.

Fig. 2 An embedded optical sensor array with a Head-Mounted Display [8]

The atmosphere is an essential element in sharing our experiences in daily life. Suppose we can have a sharing functionality of a parameter of the atmosphere: wind speed between virtual and physical spaces. In that case, that can be a reasonable extension of remote communications with video chatting. We can realize such functionality by embedding photo reflective sensors with a projection screen [10]. And the sensor values can be used to reproduce the wind speed in the physical space.

Fig. 3 A wind communication interface to make virtual physical interaction [10]

Fig. 3 (left) shows a snapshot of a wind speed-based interaction with a virtual teddy bear robot [11]. Fig. 3 (right) shows wind communication with video streaming.

Furthermore, we can also utilize such measurement results for controlling various items. Fig 4. shows an example of a facial expression-based control system of virtual wearable robot arms [12]. By using facial expressions that can be measured with ubiquitous optical sensing, we can drive such extended embodiment while keeping the degrees of freedom to move our hands and feet.

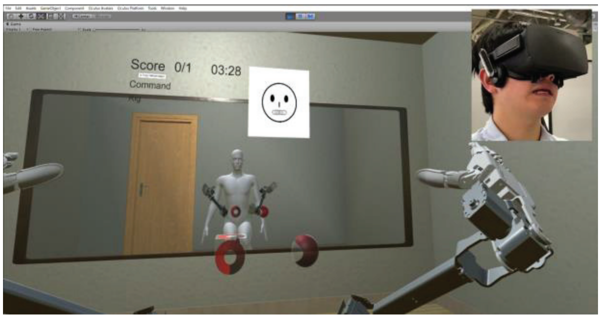

Fig. 4 A facial expression-based control system of virtual wearable robot arms [12]

4 Conclusion

This talk introduced the possibility of extending interactions with virtual and physical spaces through ubiquitous optical sensing. Our ubiquitous optical sensing allows us to measure basic information, such as the position and rotation of physical instances, and advanced properties, such as facial expressions and wind speed distribution, with display devices. We can enhance our immersion in cyber physical spaces by having such information.

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References

[1] M. Kojima, M. Sugimoto, A. Nakamura, M. Tomita, H. Nii and M. Inami, "Augmented coliseum: an augmented game environment with small vehicles," *First IEEE International* Workshop on Horizontal Interactive Human-Computer Systems (TABLETOP '06), 2006

[2] M. Sugimoto, K. Kodama, A. Nakamura, M. Kojima and M. Inami, "A Display-Based Tracking System: Display-Based Computing for Measurement Systems," 17th International Conference on Artificial Reality and Telexistence (ICAT 2007), 2007, pp. 31-38, doi: 10.1109/ICAT.2007.50.

[3] J. Leitner, M. Haller, K. Yun, W. Woo, M. Sugimoto, M. Inami, A. D. Cheok, and H. D. Been-Lirn. Physical interfaces for tabletop games. Comput. Entertain. 7, 4, Article 61, December 2009

[4] H. Nii, M. Sugimoto and M. Inami, "Smart Light-Ultra High Speed Projector for Spatial Multiplexing Optical Transmission," *2005 IEEE Computer Society Conference on Computer Vision and Pattern Recognition (CVPR'05) - Workshops*, 2005, pp. 95-95, doi: 10.1109/CVPR.2005.528.

[5] Masai K, Kunze K, Sugiura Y, Ogata M, Inami M, Sugimoto M. Evaluation of facial expression recognition by a smart eyewear for facial direction changes, repeatability, and positional drift. ACM Transactions on Interactive Intelligent Systems (TiiS). 2017 Dec 13;7(4):1-23.

[6] N. Asano, K. Masai, Y. Sugiura, and M. Sugimoto, “Facial performance capture by embedded photo reflective sensors on a smart eyewear,” in Proceedings of the 27th International Conference on Artificial Reality and Telexistence and 22nd Eurographics Symposium on Virtual Environments, ser. ICAT-EGVE ’17. 2017, p. 21–28.

[7] K. Suzuki, F. Nakamura, J. Otsuka, K. Masai, Y. Itoh, Y. Sugiura, and M. Sugimoto, Recognition and Mapping of Facial Expressions to Avatar by Embedded Photo Reflective Sensors in Head Mounted Display, Proceedings of IEEE Virtual Reality 2017, 2017

[8] M. Murakami, K. Kikui, K. Suzuki, F. Nakamura, M. Fukuoka, K. Masai, Y. Sugiura, and M. Sugimoto, “AffectiveHMD: Facial expression recognition in head mounted display using embedded photo reflective sensors,” in ACM SIGGRAPH 2019 Emerging Technologies, 2019

[9] Fumihiko Nakamura, Masaaki Murakami, Katsuhiro Suzuki, Masaaki Fukuoka, Katsutoshi Masai, Maki Sugimoto, Analyzing the Effect of Diverse Gaze and Head Direction on Facial Expression Recognition with Photo-Reflective Sensors Embedded in a Head-Mounted Display, IEEE Transactions on Visualization and Computer Graphics, 2022

[10] Sawada E, Ida S, Awaji T, Morishita K, Aruga T, Takeichi R, Fujii T, Kimura H, Nakamura T, Furukawa M, Shimizu N. BYU-BYU-View: a wind communication interface. InACM SIGGRAPH 2007 emerging technologies 2007 Aug 5 (pp. 1-4).

[11] Noriyoshi Shimizu, Naoya Koizumi, Maki Sugimoto, Hideaki Nii, Dairoku Sekiguchi, and Masahiko Inami. 2006. A teddy-bear-based robotic user interface. Comput. Entertain. Vol. 4, No. 3 , 2006

[12] M. Fukuoka, A. Verhulst, F. Nakamura, R. Takizawa, K. Masai, and M. Sugimoto, “FaceDrive: Facial expression driven operation to control virtual supernumerary robotic arms,” in SIGGRAPH Asia 2019 XR, ser. SA ’19. New York, NY, USA: Association for Computing Machinery, 2019, p. 9–10.