Shadow: One-dimensional Proactive Sensing for Enlarging Gesture-interaction Space

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Abstract
Leap Motion is the state-of-art commercial gesture sensing system which implements in camera-based sensing technique. However, Leap Motion has its limitation on sensing area hinders user from the smooth interaction. To address this issue, we propose Shadow, a low-cost proactive sensing technique that enlarges the sensing area. Shadow allows sensors one-dimensionally moving on a conveyor belt and continuously repositioning to keep tracking the interacting hand. Two studies are conducted on a large screen and the results reveal significant improvement in both coverage area and accuracy.

Author Keywords
active; gesture sensing; machine adaptation; proactive sensing

ACM Classification Keywords
H.5.2 [Information interfaces and presentation]: User Interfaces

Introduction
In-air gesture sensing plays an important role in the natural interface. Among all techniques, Leap Motion, build on the traditional camera-based solution, is considered to be the most reliable and also the off-the-shelf solution which benefits sensing without cumbersome wearing on hands.

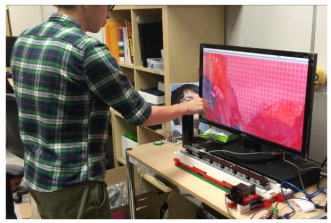

Figure 2: Task of user study 1: users are asked to fill grids on 27-inch screen with their index finger which is sensed by Leap Motion with and without Shadow system.

Figure 3: Task of user study 2: users are asked to push buttons randomly assigned on 27-inch screen with their index finger which is sensed by Leap Motion with and without Shadow system.

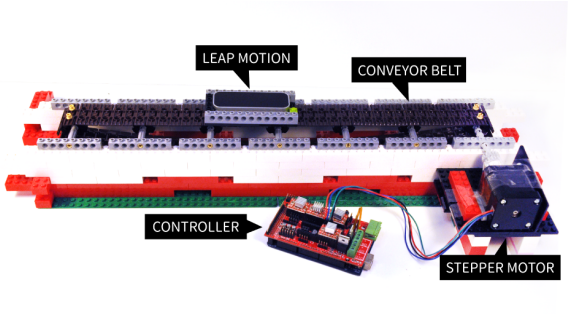

Figure 1: The Shadow system is a LEGO conveyor belt system which is driven by the stepper motor.

However, the sensing area of Leap Motion is quite limited. The detection fails in two ways once the hands are out of the sensing area: the virtual hand on the screen either disappears or recognized as incorrect gestures. To avoid the out-of-sensing-area situation, users need to visually track the physical hands and the virtual hands in the screen simultaneously, resulting in interruption of the experiences and reduces the immersiveness. One intuitive approach to solve this problem is adding cameras in the environments to capture gestures could be a common solution; however, it requires extra cost on purchasing sensors and setting up the environment.

Inspired by proactive sensing [1], we introduce a novel and low-cost approach, *Shadow*, which allows the camera-based sensor to move one-dimensionally along a LEGO conveyor belt. Studies revealed that Shadow has significantly enlarged the interaction space and enhances the accuracy.

Shadow

We built a conveyor belt to move camera-based sensor one-dimensionally, which is driven by a stepper motor. The conveyor belt is 36 cm length which is sufficient for interacting in 27-inch LCD and its highest speed is 23 cm per second. The circuit and the motor cost around 2700 NTD which is cheaper than buying another Leap Motion.

Evaluation

Two eight-participants user studies were conducted to compare the performance in two conditions, interacting with a 27-inch screen by Leap Motion with and without Shadow system, under counterbalanced conditions. User study 1 shows a significant difference in sensing area (100% vs. 89.7%) while user study 2 shows that Shadow has significantly improved the sensing accuracy (92% vs. 82%).

Conclusion

We introduced Shadow, proactive sensing by allowing the camera-based sensor to move one-dimensionally. The results of evaluations show that Shadow has significant improvement on both interaction space and accuracy. Future works consider 1) extending the movement of Shadow from 1D to 2D space, and 2) enhancing the stability and speed of the Shadow system.

References

[1] Dun-Yu Hsiao, Min Sun, Christy Ballweber, Seth Cooper, and Zoran Popović. 2016. Proactive Sensing for Improving Hand Pose Estimation. In *Proc. CHI'16*.