Anywhere Touchtyping: Text Input on Arbitrary Surface Using Depth Sensing

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Figure 1: The actual system and its components of our real-time hand posture depth sensing for touch typing on arbitrary surface. (a) Hardware configuration: DLP projector dispatch fringe pattern onto the surface and video camera captures the projection area. (b) Computer vision software result for depth sensing, virtual keyboard area estimation, fingertip detection, and keystroke event sensing. (c) Usage scenario: users put their hands in the depth sensible area of the system and perform touch typing.

ABSTRACT
In this paper, touch typing enabled virtual keyboard system using depth sensing on arbitrary surface is proposed. Keystroke event detection is conducted using 3-dimensional hand appearance database matching combined with fingertip’s surface touch sensing. Our prototype system acquired hand posture depth map by implementing phase shift algorithm for Digital Light Processor (DLP) fringe projection on arbitrary flat surface. The system robustly detects hand postures on the sensible surface with no requirement of hand position alignment on virtual keyboard frame. The keystroke feedback is the physical touch to the surface, thus no specific hardware must be worn. The system works real-time in average of 20 frames per second.

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General terms: Design, Human Factors, Algorithms

Keywords: Touch typing, virtual keyboard, depth sensing.

INTRODUCTION
Even in the evolving computing environments, text input still holds the important role in Human-Computer Interaction. In surface computing, software keyboard is widely used. However, in software keyboard users need to gaze the keyboard area and perform fingertip-to-area point mapping [1, 2]. Thus, not applicable for touch typing scenario. Touch typing excludes the need of using sense of sight to find the keys, therefore fast typing is possible (more than 60 word per-minute achieved by trained user).

In this research, we propose virtual keyboard architecture with touch typing capabilities. Using hand posture depth sensing system on arbitrary surface, simultaneous hand posture and dynamic movement of fingertips on the surface are robustly detected. The depth sensing software is based on phase shift algorithm for DLP fringe projection. The usage scenario of this system is simple: a user put his/her hand in the depth sensible area and performs touch typing. Our prototype system architecture uses a computer, a high-speed camera, and an off-the-shelf DLP projector. Overall, our system is both financially and computationally low cost.

DEPTH SENSING ON ARBITRARY FLAT SURFACE
The summary of our depth sensing method is explained as follows:

- **Active synchronization of DLP projector illumination timing and camera capture.** The independent light color illumination (RGB channel) of the DLP projector sensed by a phototransistor is sent to the camera as an external shutter trigger signal. Effects of the ambient light can be excluded by simple frame subtraction.

- **Color-encoded three-step phase shift algorithm for depth calculation.** We implemented three-step phase shift algorithm for our real-time hand posture depth sensing system. Three phase-shifted fringe images are encoded in three primary color channels (RGB) of the projector. Phase shift algorithm has been used in previous research to calculate objects height relative to the reference plane [3].
posture depth sensing is described in Figure 2 acquired. The result of our phase shift method based hand matching is performed to the sequential image frame. A typing task with hand posture database.

**Typing Task**

**Apparatus.** We conduct sequential touch typing of a word “TABLETOP” in our depth sensible surface system. Database matching is performed to the sequential image frame.

**Event Detection**

To detect the movement of fingers, the proposed system applies a series of computer vision algorithms to the gray-scale depth map image explained as follows:

- **Fingertip detection.** Hand posture’s contour is examined for concavity defects to find contour peaks (fingertips).
- **Surface touch sensing.** The contacts between fingertip and surface are detected by examining the pixel value in the area of fingertips. 4×4 window of pixel area around fingertip are accumulated and compared to the threshold value to determine the touch event.
- **Keystroke detection.** Our system detects keystroke by hand posture depth map appearance matching. The matching algorithm is a straightforward method by examining grayscale pixel value of the hand posture depth map combined with hand contour and compares them with the ones that previously registered into the hand posture database.

**Experiment**

In this section, preliminary experimental results of the proposed system are presented as follows:

**Key-hit Evaluation**

**Apparatus.** First, the hand posture’s depth maps and contours for standard QWERTY keyboard layout alphabet (from A to Z) typing are registered into database. Second, test data containing key-stroking hand postures are captured separately and then database matching is performed.

**Result.** Our keystroke detection system achieved 76% of key-hit rate. In several test data, the major detection error keys are keys that lie in home position (A, S, D, F, J, K, L).

**REFERENCES**


**Figure 2:** Schematic diagram of our real-time hand posture depth sensing system.

**Figure 3:** Our system result for sequential touch typing of a word “TABLETOP”. (a) Input depth map. (b) Matched database entry. (c) Detected text input.

**Result.** Our system successfully detects designated touch typing sequence for several test data. Figure 3 showing the last frame of the sequence and the typing result in our system.

**Conclusion and Future Work**

A touch typing enabled virtual keyboard system based on a depth sensing on arbitrary surface is presented. Fingertip detection and surface touch sensing are robustly conducted for keystroke event detection. The requirement of hand position alignment on virtual keyboard frame is excluded. The system could capture images and process them in approximately 50 ms intervals, i.e. 20 frames per second on average. This frame rate is enough for normal typing, which requires finger speed of at most 10 cm/s. User independent keystroke hand posture database is necessary, but no training is required. No specific hardware must be worn. Further works on computer vision software can lead to better robustness for practical use. A robust predictive algorithm for inaccurate input in touch typing scenario such as BlindType[4] can also be used to increase the usability of the proposed system.

The result of key-hit experiment shows that detection errors often occur on the keys in home position. These keys provide less appearance difference. In further work, this issue can be addressed by detecting which fingertip lifted off from surface before touch event occurs. By removing color filter and defining external trigger for the internal light projection timing in DLP projector, higher depth sensing frame rates can be produced. Changing the light source in DLP projector to an infrared light can produce invisible fringe projection. Multi-touch interaction modalities using hand’s proximity sensing on surface are also applicable.