Virtual Mouse: A Low Cost Proximity-based Gestural Pointing Device

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Abstract. Effectively addressing the portability of a computer mouse has motivated researchers to generate diverse solutions. Eliminating the constraints of mouse form factor by adopting vision-based techniques has recognized as an effective approach. However, current solutions cost significant computing power and require additional learning, thus making them inapplicable in industry. This work presents the Virtual Mouse, a low-cost proximity-based pointing device, consisting of 10 IR transceivers, a multiplexer, a microcontroller and pattern recognition rules. With this embedded device on the side of a laptop computer, a user can drive the cursor and activate related mouse events intuitively. Preliminary testing results prove the feasibility, and issues are also reported for future improvements.

Keywords: Proximity based device, IR sensor, pointing device, virtual mouse.

1 Introduction

According to statistics of the International Data Corporation (IDC), the global consumption of laptop computers has passed the “Gold Cross” for the first time, exceeding that of desktop computer in 2010. This phenomenon reflects the importance of “portability” among computer users [2][3].

However, in addition to a touch pad or a track point already embedded in a laptop computer supporting pointing tasks, carrying an additional pointing device, i.e. a full size computer mouse, to enhance performance and ergonomics is inevitable and inconvenient. This additional device is owing to that the event structure of a touch pad or a track point requires two fingers, mostly a thumb and a forefinger, acting awkwardly to activate a drag action or a drag-selection action; meanwhile, that of a computer mouse needs only one finger to activate such action. This feature lowers the efficiency and comfort of a touch pad or a track point over those of a conventional computer mouse.

Effectively addressing the portability of a computer mouse has motivated industrial designers to flatten a computer mouse for easy carry [2] and even to slot into the laptop body while not in use [3]. Conversely, computer scientists create a computer mouse without a physical body to achieve ubiquitous computing. These invisible mice can translate hand gestures and movements into mouse events by using computer cameras as a signal input [1][5][6][7].

Still, those inflatable mice can not fulfill stringent the ergonomic requirement of intensive operations. In contrast, despite eliminating concern over ergonomic constraints, vision-based approaches expend a significant amount of computing power, i.e. equal to almost a high performance GPU, to recognize predefined hand gestures, which increases the mental load of user, thus making these solutions inapplicable in industry.

This work, describes a novel proximity-based pointing device consisting of 10 pairs of inexpensive infrared transceivers, a multiplexer, a microcontroller and a pattern recognition algorithm. This embedded device on the side of a laptop computer detects the intuitive hand-movements of users on the tabletop and further translates them into mouse movements and events (Fig. 1). Equipped with full mouse functions without a physical mouse body, the proposed device is referred to as a Virtual Mouse, similar to terminology used in previous works.

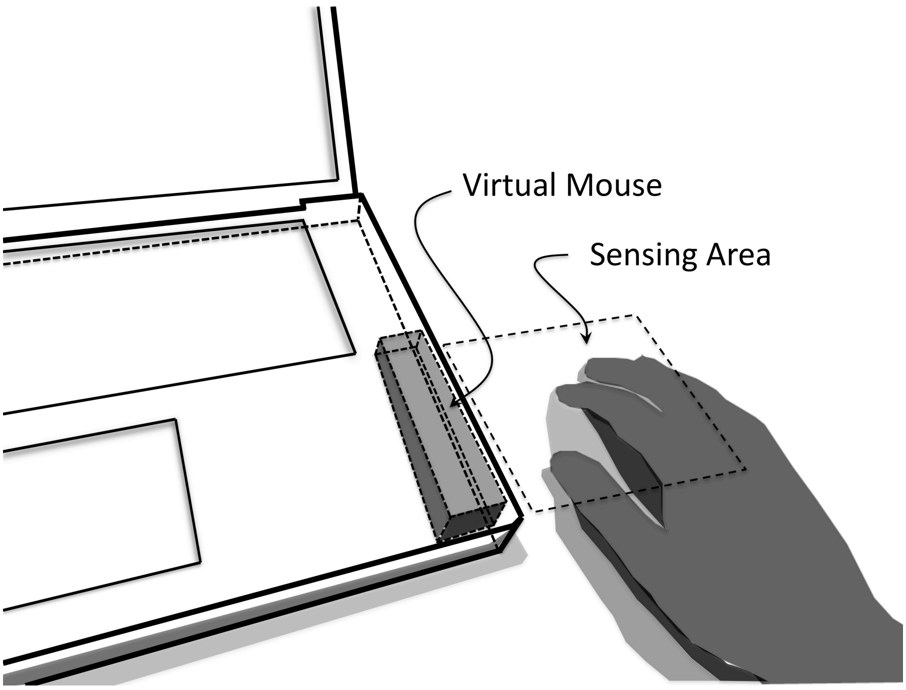

Fig. 1. Concept of Virtual Mouse

2 Implementation

2.1 Cost Savings Infrared Transceiver

The arrangement of transmitter and receiver for an infrared (IR) transceiver, i.e. a well-developed device in the market, allows it to detect an object and determine the distances to it accurately. IR transceiver is thus extensively adopted as a reliable input device in security, robotics and home automation.

Rather than purchasing these mature products ranging from US$ 30 to 100 or even more expensive ones designed for specific purposes, researchers without an electronic engineering background can still easily assemble components to construct an IR transceiver in order to resolve diverse laboratory problems and explore new sensing possibilities. Therefore, this work presents a simple IR transceiver rapidly by using only an IR LED, phototransistor, capacitor and two resistors, which cumulatively cost less then US$ 0.5.

Specifically, a 3mm IR LED is powered through a 330-Ohm resistor, while a 3mm phototransistor is powered through a 20K-Ohm resistor with 5-Volt DC power supply. Additionally, the Base pin of the phototransistor is connected to an additional 0.1u capacitor for stabilization. The Base pin allows us to acquire linear signals within 6cm range, which is sufficient for our Virtual Mouse prototype (Fig. 2).

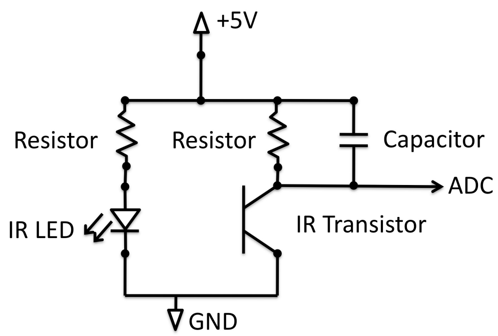

Fig. 2. Circuit scheme of homemade IR transceiver

2.2 Infrared Transceiver Bar

The customized IR transceiver provides a one-dimensional sensing ability. Combining 10 identical IR transceivers and arranging them in parallel allow us to create a device capable of detecting objects on a 4cm * 6cm two-dimensional plane. The shape of an object or its movement can be recognized after analyzing the sensor signals. Restated, this customized device is nearly equal to a touch pad that enables finger touch and gesture recognition.

Ten IR transceivers require a prohibitively expensive 10 analog input-pins of a microcontroller to read signals, explaining why the proposed device uses a multiplexer (MUX) as a digital switch to reduce the number of input pins. Therefore, 10 transceivers are connected to the MUX and the MUX is connected to a microcontroller as a de-multiplexer (Fig. 3).

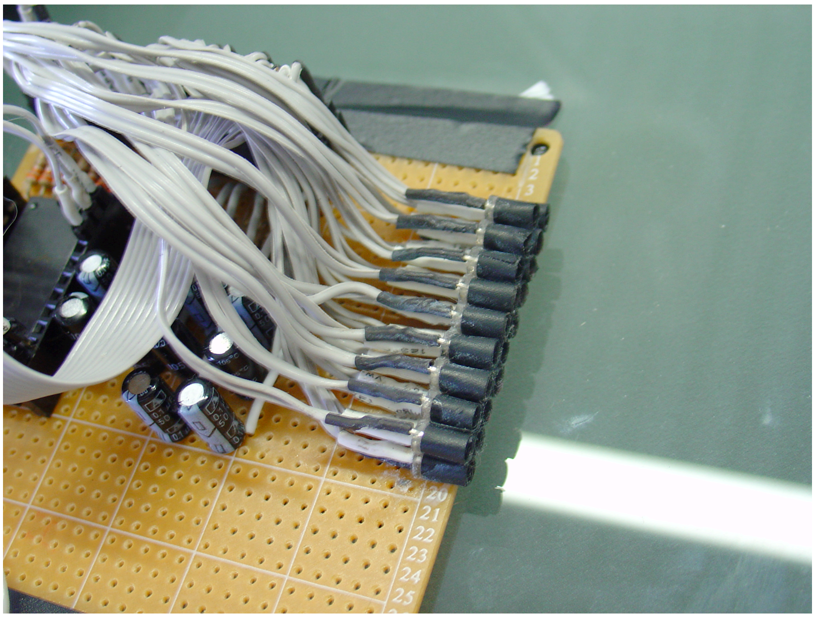

Fig. 3. Prototype of IR sensor bar

2.3 Pattern Recognition

Based on 10 IR transceiver signals, this work also develops sequential rules to recognize diverse signal patterns, which are fundamental to driving a mouse cursor and triggering corresponding events by hand, i.e. button down, button up, click, double click. In contrast with training models to achieve a high performance directly, this set of rules originates from observation of invited users and is intended mainly for rapid proof of concept to facilitate the future development involved in additional resources, e.g., software and firmware engineers.

Ten subjects, i.e. 5 male and 5 female, were invited to collect hand gesture patterns. Subjects were instructed to perform 6 actions within the sensing area, i.e.

vertical move, horizontal move, diagonal move, forefinger click, forefinger double click and middle-finger click. Sensor signals were further recorded and analyzed.

Eventually, 4 rules derived from the previous 6 testing actions are placement, forefinger-up, middle-finger-up and move. A pattern in which the signal pattern is divided into two stages and the stage values subsequently decrease is recognized as placement, implying that the middle finger and forefinger appear in the sensing area (Fig. 4-a). A pattern in which the value of the second stage increases and exceeds that of the first stage is recognized as forefinger up (Fig. 4-b). If the value of first stage increases and exceeds that of the placement pattern, this pattern is recognized as middle finger up (Fig. 4-c). A pattern in which the value of second stage changes horizontally or moves vertically (or both) in comparison with that of the previous pattern is interpreted as move (Fig. 4-d).

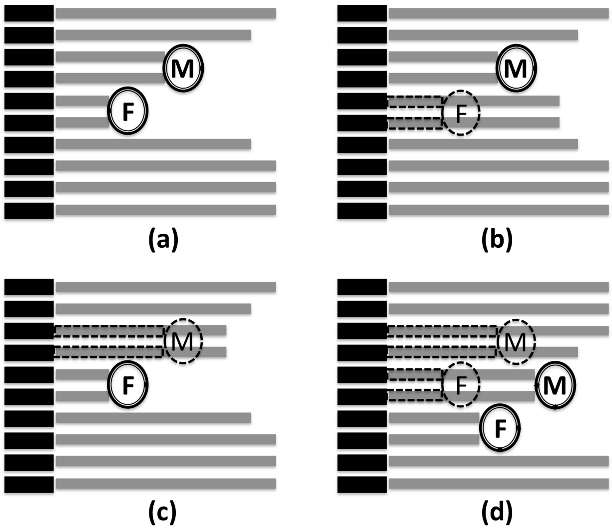

Fig. 4. Pattern recognition rules

2.4 Finite State Machine

Based on the above rules, a finite state machine (FSM) is designed to interpret hand gestures and trigger their corresponding mouse events. Consider a drag action, in which a touch pad or a track point requires two fingers to activate. The proposed FSM begins with the none-detection state (N). While the placement pattern is recognized, the FSM moves to ready state (R). While the forefinger-up pattern and placement are subsequently detected within 100 milliseconds, the FSM moves to left-button-down state (LBD) and triggers the left-button-down event. Notably, the FSM goes to ready state (R) again if no new pattern is detected within 300 milliseconds. At this moment, while the move pattern is recognized, the FSM moves to new position state (NP) and triggers new X-Y coordinate event. While forefinger-up is detected, the FSM moves to left-button-up state (LBU) and triggers the left-button-up event. Once the placement is recognized, the FSM returns to ready state (R). Rather than using a computer mouse, the above sequence completes a drag action with hand and our Virtual Mouse (Fig. 5).

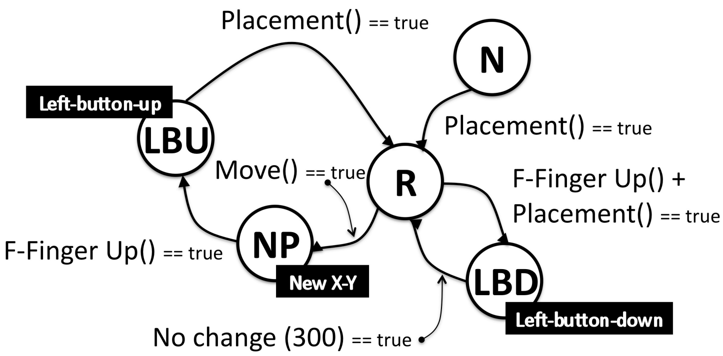

Fig. 5. Finite state machine for drag action

3 Preliminary Testing

Ten subjects invited for a previous observation used the virtual moue again to complete tasks in a 480px * 360px simulation window. The simulation window has three 40px * 40px squares: one is blue, another is red and the other is transparent with a dashed outline. Subjects were requested to click and double click the red square and, then, drag the blue square to the transparent square sequentially 10 times. Subject performances were recorded for later analysis.

Analytical results indicate that the average completion rate of a click (84%) is higher than that of a double click (70%) (Fig. 6). Specifically, incomplete tasks initially occur several times, a phenomenon attributed to the required learning period. A double click has a 300 milliseconds time constraint making it more difficult to get used to than with a single click and also requiring a longer time to learn.

Our results further demonstrate that the total average completion rate of a click (77%), single plus double, surpasses that of a drag (70%) (Fig. 6). Given the lack of a specific trend on the charts, subjects were interviewed to indentify potential reasons. Most subjects indicated that the sensing area of the Virtual Mouse prototype is insufficiently large. Their finger were thus always out of boundary when dragging; in addition, the FSM lost signals before the controlled square could reach the target area.

	Female					Male					
	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10	AVG
Click	8	7	8	9	8	9	8	9	9	9	84%
Double Click	6	6	7	7	7	8	7	6	8	8	70%
Drag	8	8	9	7	7	6	7	7	6	7	72%

Fig. 6. Statistic result for preliminary user testing

4 Potential Applications

With this IR transceiver bar, two of them can be embedded at two sides of a laptop computer. For ordinary mouse functions, a right hand/left hand (according to user's handedness) can easily drive the cursor and trigger events (Fig. 7-a). While using two hands simultaneously for manipulation, a user can achieve scale and rotation, which resemble those of a multi-touch pad and display (Fig. 7-b).

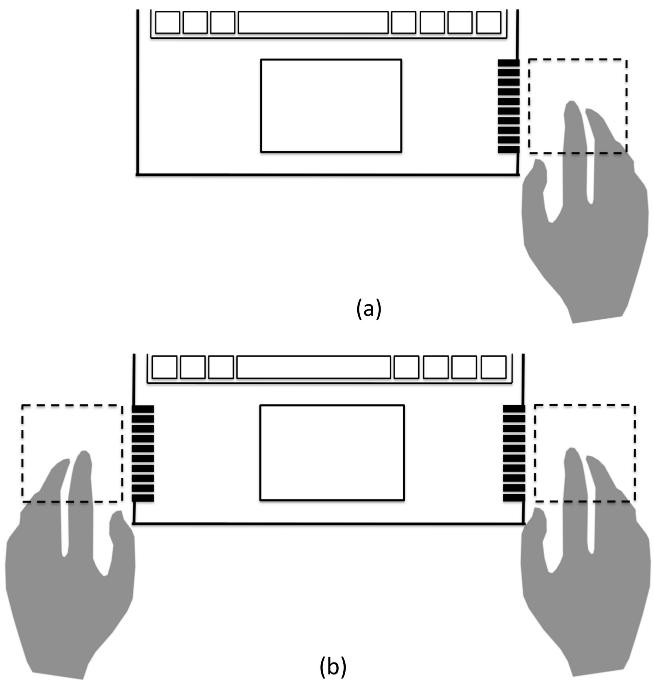

Fig. 7-a, 7-b. Ideas of potential application

A longer IR bar can also be embedded at the upper edge of a palm rest, which sends IR signals to the lower edge of the palm rest. With such an arrangement, this IR bar encompasses the entire area of the palm rest and turns it into a sensible surface. A user can perform all actions described above freely on the palm rest. Importantly, no additional plane area outside the laptop is required for operation, thus making the Virtual Mouse applicable under all circumstances (Fig. 7-c).

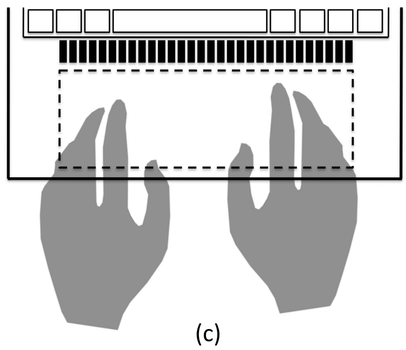

Fig. 7-c. Ideas of potential application

5 Related Works

To address the portability of computer mouse, researchers with industrial design background has developed volume-adjustable mice, e.g., Jelly Click [2] and Inflatable Mouse [3]. Jelly Click is a piece of soft plastic bag with a circuit board attached. Users are required to blow it up for use and flatten it for carry. Inflatable Mouse consists of a balloon-like inflatable structure. It can be a flat shape or a ready-to-grasp shape depending on the volume of machine-injected air. Users still need to carry the Jelly Click although it is flattened as thin as a piece of paper. Conversely, the Inflatable Mouse can be stored flat in a card slot of a laptop computer.

Computer scientists have adopted vision-based approaches to totally eliminate the constraints of mouse form factor and create invisible pointing devices, e.g., Visual Panel [7], Visual Touchpad [6], Hands Free Mouse [4] and virtual mice [1][5]. Visual Panel employed an arbitrary quadrangle-shaped panel and a tip pointer to realize a point device, whereas Visual Touchpad detected a fixed plane and finger tips to enable multi-touch. Hands Free Mouse simulated mouse clicks by simple hummed voice command, while head movements tracked by a webcam drove the cursor. Robertson et al.'s virtual mouse was a kiosk recognizing predefined hand signs to track hand movements. Conversely, Gai et al.'s virtual mouse recognized and tracked features of a scene captured by a camera of a mobile phone, thus turning camera motion into virtual mouse control.

6 Conclusions and Future Study

The Virtual Mouse has received considerable attention in both academic and industrial communities. Rather than focusing on a novel concept, the proposed Virtual Mouse prototype provides a cost-savings approach for mass production. Replacing the common vision-based scheme with an inexpensive IR sensor bar has cumulatively reduced the cost from $US 50 to $US 5.

Instead of adopting predefined gestures to activate mouse functions, emulating the intuitive finger gestures of conventional mouse to eliminate the learning curve is another benefit of this work. Unlike a camera collecting complicated imagery data for whole-hand gestures, our homemade IR sensor bar allows us to acquire adequate signals for subtle finger gestures.

Although issues such as increasing the smoothness and enlarging the sensing area require further improvement, this work significantly contributes to efforts to demonstrate the feasibility of a potential solution and develop technical specifications.

In addition to replacing the 3mm LED with a SMD one to increase the resolution and enlarge the sensing area, efforts are underway in our laboratory to modify the pattern recognition rules and link the signal to the operation system. Additional developmental results and evaluations will be published in the near future.

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