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# Dual Mode IR Position and State Transfer for Tangible Tabletops

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## ABSTRACT

This paper presents a method for tracking multiple active tangible devices on tabletops. Most tangible devices for tabletops use infrared to send information about their position, orientation, and state. The method we propose can be realized as a tabletop system using a low-cost camera to detect position and a low-cost infrared (IR) receiver to detect the state of each device. Since two different receivers (camera and IR-receiver) are used simultaneously we call the method *dual mode*. Using this method, it is possible to use devices with a large variation of states simultaneously on a tabletop, thus having more interactive devices on the surface.

**General Terms:** Algorithms, Performance

**Keywords:** Active tangible devices, tabletop, dual mode, IR tracking, multi TUI

## INTRODUCTION

The advent of widely available interactive tabletops, such as the MS Surface, has created high expectations among users for such systems. Today users expect a highly interactive experience when interacting at tabletops. Tangible objects emitting active infrared (IR) could be one possible way to provide a more interactive user experience with tabletops.

QualiTrack [1] delivers such an experience by providing users with active TUIs. In this system, TUIs have intuitive shapes such as brick, color-pallet, and pen, which may enable a more natural interaction style. Each of these TUIs has a set of state-triggering widgets, such as buttons on top of the bricks or a micro switch under the pen's tip. Thereby, users can interact with an object while positioning it on the surface. However, based on user feedback from studies on QualiTrack, a majority of users were not satisfied with the

level of interactivity they experienced with the TUIs provided. In other words, users expect tangible objects to be much more than simple point and click devices. Thus, we decided to improve the TUIs to achieve higher user satisfaction. We observed that a significant improvement in perceived interactivity in tangible tabletops could be achieved by increasing the number of states a TUI can deliver. This enables system designers to offer more complex forms of interaction. For example, a high-end pressure-sensitive stylus may have up to 2048 pressure levels. To implement such a pressure sensitive stylus for systems like QualiTrack, the TUI needs to send 11 state bits. We could not reach this number of states on the initial system since the update rate would then drop dramatically. In this paper, we address this problem by introducing a new tracking method for use in active tangible tabletops. This method allows us to build tangible tabletops with a high number of states using low-cost components.

## RELATED WORKS

Our work has been inspired by two contributions in the area of tangible tabletops using active TUIs: SmartFiducial [2] and MightyTrace [3]. In SmartFiducial, active tangibles communicate with a host computer using wireless radio frequency (RF) transmission. Object positions are detected using a visual tracking system, thus adding a further level of complexity to the TUI design, as well as the host computer. Moreover, there is always a risk of unintended interference with RF communication. Hence, we deemed this approach to be unsuitable for our project. In MightyTrace, a matrix of IR sensors is used to detect the position and state of TUIs. Each device is assigned a specific time frame during which its LED is turned on. Thus, each device can be detected unambiguously. For sending states, there are even more time slots for each device. For example, if a device has eight different states it then needs four time slots, one for detecting its position and three for sending its state bits (thus eight different states). However, the main restriction with such a time-multiplexed approach is that the system update rate is limited not only by the number of devices on the surface, but also by the number of states each device may have.

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## DUAL MODE TRACKING

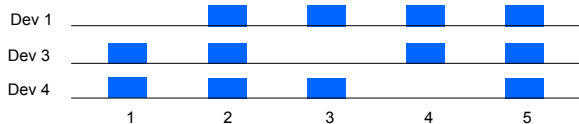
Here, we introduce a new approach to overcome current restrictions of time-multiplexed IR tracking of tangibles on tabletops. Mainly, we aim to design low-latency active devices, that is, devices with more states without reducing the high refresh rate of the system. Moreover, we are interested in a cost-effective solution. We suggest a distinct way to combine a low-cost camera for position detection and a low-cost IR receiver for state detection of each device, in what we call a dual mode approach.

### Design considerations

We are interested in having a relatively small number of tangible devices on the tabletop, each having a relatively high number of states. For example, considering the physical size of a table and the states required for a high-end pressure-sensitive stylus, we may simultaneously have five styli on the surface, each with 2048 possible states or pressure levels. To meet this requirement, we use two different receivers: a camera capable of detecting positions and an IR receiver capable of detecting the states of the devices. Concerning latency requirements, two terms are frequently employed: “update rate,” which is the number of positions and states being updated per second, and “lag,” which is the response time of the system to user input. We introduce a third term relevant to the method presented here: setup delay. This is the time from when a device becomes present in the tracked area until it is recognized.

### Tracking position and orientation

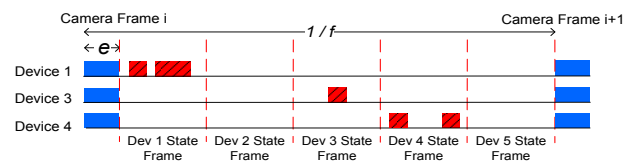
Much like in QualiTrack, the devices and the camera are synchronized. Moreover, each device is assigned to a specific time slot. All devices emit IR light on each frame, except on their assigned time slot (Fig. 1). Since the camera sees all the devices in every frame except one, the average update rate of the system equals  $f(M-1)/M$ , where  $f$  is camera frame rate (Hz) and  $M$  is the maximum number of devices we want to have on the table (which is preconfigured and constant in the system). Camera frames are indexed in cycles of  $M$  frames. Since newly placed devices wait for up to one cycle to start IR transmission, the maximum setup delay equals  $M/f$ . Thus, using the dual mode method, the number of devices does not reduce the system’s update rate, nor does it increase its lag. Only the setup delay will be negatively affected. We can now unambiguously identify each device and its position. Device tracking uses a blob-tracking algorithm [4]. While we assume that a device has one LED source only, instrumenting a device with two or more LED sources and combining their positions can give device orientation [3].



**Figure 1. Position information transfer example with  $M$  set to 5 and with devices 1, 3, and 4 (rows) present. A cycle of 5 frames (columns) is shown. Blue cells are IR flashes sent by the devices to be detected by the camera.**

## Identifying states

Each device transmits its state information using its IR LED between two synchronization signals, i.e. the speed of transmitting the state information is significantly higher than the speed of the camera (Fig. 2). This is feasible since the state information is read by a simple IR receiver and not by the camera. The interval between two consecutive camera frames is further divided into  $M$  sub-frames. Within each sub-frame, only the corresponding device sends its state information. The bit rate,  $R$ , of the sensor we employ can be up to 22 kbps. Hence, with the camera exposure time,  $e$ , and  $f$  and  $M$  as defined above, the maximum number of state bits per device equals  $R((1/f - e)/M)$ . For example, with  $M$  set to 5,  $f$  at 60 Hz, and  $e$  at 10 ms, each device can transmit up to 29 bits of state information, allowing more than half a billion states per device.



**Figure 2. State information transfer example with  $M$  set to 5 and with devices 1, 3, and 4 (rows) present. One interval between camera frames  $i$  and  $i+1$  is shown. Blue cells are IR flashes to be detected by the camera; red cells are IR flashes to be detected by the IR receiver.**

## CURRENT STATUS AND FUTURE WORKS

We evaluated the feasibility of the proposed method by implementing its essential subsystems. Particularly, we implemented the IR receiver and changed the QualiTrack TUIs to send state information using our dual mode method. We also investigated whether the battery operated TUIs allow us to send signals powerful enough to be detected by the IR receiver, considering the distance between the TUIs and the sensor. Our findings show that it is feasible to implement a tabletop using our new method. A next step in this project will be to implement a complete tabletop using the method presented here.

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