Poster: Enabling Hands-free Drawing on WiFi Devices

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ABSTRACT

We present the high-level design of WiDraw, the first 3D hand motion tracking system using COTS WiFi cards, proposed in [3]. WiDraw can track hand gestures without a priori learning or requiring the user to hold any hardware. It can be implemented on existing mobile devices using only a software patch. WiDraw exploits the Angle-of-Arrival values of incoming WiFi signals at a WiFi device and enables hand trajectory tracking in both LOS and NLOS scenarios. WiDraw's high tracking accuracy allows the users to send arbitrary input to their WiFi devices, opening up a whole new class of applications in human-computer interactions.

Categories and Subject Descriptors

C.2.1 [**Network Architecture and Design**]: Wireless communication; H.5.2 [**User Interfaces**]: Input devices and strategies

Keywords

Wireless; Motion Tracking; Gesture Recognition; Angle-of-Arrival

1. INTRODUCTION

In this paper, we introduce WiDraw [3], the first hand motion tracking solution that can be enabled on existing mobile devices using only a software patch. Different from existing hand tracking solutions using wireless signals, such as [1] and [2], WiDraw utilizes the Angle-of-Arrival (AoA) values of incoming wireless signals at the mobile device to track the detailed trajectory of the user's hand in both LOS and NLOS scenarios, without prior learning and without requiring the user to touch the device or hold any hardware. The intuition behind WiDraw is that whenever the user's hand blocks a signal coming from a certain direction, the signal strength of the AoA representing that direction will experience a sharp drop. Therefore, by tracking the signal strength of the AoAs, it is feasible to determine when and where such occlusions happen and determine a set of horizontal and vertical coordinates along the hand's trajectory. The depth of the user's hand can also be approximated using the drop in the overall signal strength. By estimating the hand's depth, along with horizontal and vertical coordinates, WiDraw is able to track the user's hand in the 3D space.

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2. DESIGN OVERVIEW

WiDraw periodically probes neighboring WiFi devices and computes their AoA values based on the received ACKs. 3D AoA values can be obtained if the user device's antennas are arranged in a special pattern. However, a laptop or tablet is usually equipped with a linear antenna array, which can only report 2D AoA values – the mapping of 3D AoAs to the plane where the linear antenna array reside in. We observed that a 2D AoA value achieves its maximum if the signal incidents the mobile device along its antenna array. To estimate 3D AoAs, we ask the user to rotate the mobile device to look for the maximum values of 2D AoAs. Thereafter, WiDraw can compute 3D AoA values based the geometrical relationship between the initial and maximum 2D AoA values in 3D space. Note that such a calibration procedure only needs to be conducted once initially.

To determine the hand's initial depth, we track the average of the RSSI values of all incoming signals from the neighboring transmitters. We found that, on average, the drop in the aggregate RSSI is higher if the user's hand is placed closer to the receiver. This happens because when the hand is closer to the receiver's antenna, a larger number of incoming signals from different transmitters are blocked. Therefore, we calculate the drop in the average RSSI value when the user's hand first appears near the receiver and then use the relationship between depth and average RSSI drop to estimate the hand's depth. Given the depth value, WiDraw can estimate the user hand's horizontal and vertical coordinates when an AoA attains a minimum value in signal strength. We refer the readers to [3] for the details of tracking depth change and calculating horizontal and vertical coordinates.

3. EXPERIMENTAL RESULTS

We demonstrate the feasibility of WiDraw by building a software prototype on HP Envy laptops, using Atheros AR9590 chipsets and 3 antennas. Although the tracking granularity of WiDraw depends on the number of AoAs along the hand's trajectory, we show that by utilizing the AoAs from up to 25 WiFi transmitters, the WiDraw-enabled laptop can track the user's hand with median error less than 5/10 cm in 2D/3D scenarios. Experiments with 10 different users demonstrate that WiDraw can be used to write words and sentences in the air, achieving a mean word recognition accuracy of 91%.

4. REFERENCES

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