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EE 597 IoT Review 12

08 November 2020

FingerIO: Using Active Sonar for Fine-Grained Finger Tracking

The main objective of this paper is to do **Finger tracking for near device interaction with no finger instrumentation and no line or sight**.

Applications include making anything a drawing surface, go beyond a tiny screens, interactions with occlusions.

There are existing approaches such as doppler radar (Google Soli for example). Two key flaws in previous works is that, we need Ghz of bandwidth to accomplish centimeter level resolution and this is not practical. The other problem is we need radio to transmit signals which requires extra area on devices.

The authors claim that their method **FingerIO** achieves an accuracy of **0.8 cm** on Galaxy S4 smartwatch and **1.2 cm** on a prototype smartwatch.

To do FingerIO, the authors faced two issues :

1. How to transform mobile devices into active sonar systems?

The authors leverage the fact that there exists speakers on the phone which can emit sound signals and also that there are microphones on the phone which can receive the reflected signals. The time for the echo to arrive back at the phone changes as the finger moves. The sampling rate on mobile phones is 48 Khz which mean that each sample can have a resolution of distance resolution of 0.7 cms. But since the phone has two microphones, the authors claim that the two can be combined to achieve sub centimeter level resolution.

2. How to achieve sub-centimeter level tracking accuracy?

The key is to accurately identify when an echo arrives at the phone. The authors begin by **transmitting a chirp which has a high auto-correlation to obtain the time of arrival**.

The authors conclude that the closest moving echo is the one which corresponds to the echo which can be used for tracking. In practice, the authors obtained accuracy of 3 cm. This however is still a lot.

To solve this, they looked at WiFi which has a TxR and RxR which figures out when a message starts to successfully decode it. The authors then ideate about using **OFDM (Orthogonal Frequency Division Multiplexing)** to find out the phase to get the exact echo arrival time.

Putting it all together,

1. Transmit 18-20Khz OFDM symbols every 5.92 ms (time taken for the signal to reach 1m in distance and get reflected back - which is the maximum distance the authors are interested in the problem).
2. Use correlation to get a coarse timing estimate within 2-3 samples.
3. Correct error using OFDM phase to obtain sub centimeter level accuracies.

For evaluation, there were 10 users doing 3 repetitions for a total of 30 measurements.

a) **Phone** : The accuracy was 0.8cm with a 50x100 cm grid.
b) **Smartwatch** : The accuracy was 1.2cm with a 25x50 cm grid.

However, there were a few points that needed more clarity :

Questions :

1. The authors claim that the results for the smartwatch is not the same as the phone since the system was not optimized for noise performance. They however, do not talk about optimizing noise performance for the phone!

2. Since the system is still based on a plane, how this would work in a 3D tracking is a question that needs to be answered.

3. There is no mention of users in motion and how it would it would affect the accuracies or if it will work?

More details about the paper

Nandakumar, R., Iyer, V., Tan, D., & Gollakota, S. (2016, May). Fingerio: Using active sonar for fine-grained finger tracking. In Proceedings of the 2016 CHI Conference on Human Factors in Computing Systems (pp. 1515-1525).