FingerIO: Using Active Sonar for Fine-Grained Finger Tracking

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The Problem Definition:

With IoT and wireless scaling up more and more innovations are being made for easy accessibility for human beings. The idea is to make the use of almost all devices simple for the user by providing them with the best devices which can learn their normal/regular movements and interpret their instructions. The paper introduces one such idea named FingerIO, which is a more novel approach to fine-grained finger tracking without any instrumentation on the figure. The idea is different from all other ideas already in the market as other ideas focus more on the coarse-level gesture.

Key Idea:

FingerIO works on the idea of transforming the device (the mobile phone/watch which is transmitting and receiving) into an active sonar system that transmits inaudible sound signals (of Frequency between 18-20kHz) and tracks the echoes of the finger at its microphone. It does this without any instrument or line of sight. To improve for sampling errors in the received signals the paper relies on the property of Orthogonal Frequency Division Multiplexing (OFDM) with cyclic suffixes, in which the sampling error identifying at the beginning of the signal, translates linearly into phase changes in the frequency domain. Then these changes can be extracted from the microphone using an FFT.

Important Details:

1. FingerIO achieves a frequency of 0.8-1.2cm accuracy on Galaxy S4 and smartphone prototypes.
2. 2 microphones of the phone are used to receive the reflected echoes from the finger. The author also claims that with 3 microphones we can also track the 3D motion of the finger.
3. To estimate the arrival time of the echo and consider the error in the received samples, a correlation technique is used to get the coarse time estimate.
4. The issue of clock synchronization is handled with the introduction of OFDM signals.

My Thoughts and Criticism:

The paper presents some good work with relevant observations and theoretical proofs. The author has tried to be very open about his ideas and thought process on all the factors and observations.

However, a few of the assumptions and scenarios that led me to question/confusion are:

1. In order to expand the application of this idea it should be extended to detect non-continuous finger motions because usual human writing is not a continuous motion. Although the paper mentions this can be achieved by introducing 3rd microphone but

in that case, normal phones have 2 microphones so that means we are introducing some additional piece of the device as part of this FingerIO (technically).

2. It is assumed that the phone and user are static in all the evaluations. But in real-life, that might not be the case (always).
3. Tacking multiple fingers on the surface can be a big challenge as we are currently relying on the echos from the fingers, and nothing is mentioned about the segregation of these echos if they're coming from multiple figures.
4. FingerIO, technically is just a concept and relies on 3rd party device for computation and data collection. This can introduce more device-specific issues in the experiment if someone has a cheap Samsung phone the microphone might not filter out the noise and hence you receive a lossless, unfiltered response. But in the case of a smartphone like the iPhone or a higher version of Samsung we can surely see that the microphone does filter some of the noise. This aspect of the experiment is not assured and might lead to poor performance.
5. Power consumption is left as part of future works, which I believe should be analyzed again considering we are depending on the 3rd party tool.
6. Will the speed of the movement of the finger impact the analysis and claims? Because not all users write at the same speed.
7. How do we authenticate the user to maintain privacy concerns?