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3D Tracking via Body Radio Reflections

The main objective of this paper lies in **tracking motion using radio reflections off bodies**.

The main motivation behind this work revolves around the question - can we see through walls using wireless signals?

The authors claim that WiTrack (Wireless Tracking) achieves centimeter level tracking from just reflections off people's bodies. WiTrack works behind walls and does not require an individual to hold/wear any devices (like the previous methods).

Some applications of this work can be in (1) gaming, (2) gesture control, (3) helping first responders, (4) elderly health monitoring, etc. In order to define the problem, the authors look at localizing a person :

With a transmitter and a receiver in a room, the authors proceed to transmit a wireless signal towards a wall. While most of the signal would get reflected off the wall, a part of the signal would pass through the wall - which is of interest to us. This signal would then bounce off the individual behind the wall and would again come back to the receiver. In order to calculate the position to localize the person, they try to find the distance (measured by speed of signal * reflection time). Since the speed is a constant, the time is the unknown that needs to be calculated.

In order to find the reflection time, the authors do the following experiments :

Exp 1 : Transmit short pulse and listen for an echo - This however is not feasible since the subsampling rate needs to be of the scale of nanoseconds which may not be feasible for a receiver since it would be costly. Along with that, the Multi-Ghz samplers would introduce noise to an already weak signal.

Exp 2 : Frequency Modulated Carrier Wave (FMCW) - The interesting part of an FMCW signal is that for a change in time (T to T+ΔT), the frequency too would change from (F to ΔF). Since the signal is generated by the user, from the ΔF, the value of ΔT can be found out from the relation, reflection time = ΔF / slope.

In order to find ΔF, we subtract (through a mixer) the Tx and Rx signals and then find the fourier transform of the subtracted signal. Plotting, there is a single high spike at a particular frequency ΔF which is what is needed. From ΔF, the reflection time can be found out from which the distance can be found out.

However, there exists an issue of multipath reflections which could give us multiple spikes due to different objects around a room such as furniture. For this, the authors propose taking **multiple readings from which static objects can be eliminated by subtracting** and the person who is moving can be found. The authors again found that there existed two spikes for a single person who was in the other room. They concluded that this was due to Dynamic multipath - when there happens to be a reflection from the person and then bounces off an object in the room and is then received. To take care of this, the authors only consider the first of the two spikes since it is a direct reflection rather than the second spike which would have arrived from the reflection off an object.

Next using these reflection times, in order to localize the person, the authors propose using another receiver which would then create two ellipsoids - one with each receiver and the common transmitter and the intersection of the two would **pinpoint the person in 2D while using a third receiver would help in 3D**.

For the implementation, the authors built an FMCW front end with frequencies ranging between 5.5-7.2 Ghz. The authors claim that the frequency range is approved b the FCC regulations for consumer electronics and that the power transmitted (0.75mW) is 100x lesser than a WiFi access point. For the ground truth, the authors used VICON Infrared cameras to map the person in 3D.

The authors ran a set of experiments to see how well the system performed.

1. **Through wall localization accuracy** - Plotted CDF vs Localization error : Had a localization error of 10cm (X axis), 13 cms (Y) and 21 cms (Z).
2. **Accuracy of pointing gesture** - Plotted CDF vs Localization orientation : Had an orientation median error of 11 degrees.
3. **Fall detection for elderly** - Elevation vs Time plot : The authors show that the waveforms vary for different activities such as walking, lying down, sitting down and falling down.

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

Questions :

1. What if the person is stationary? The system will fail since the authors propose subtracting the measurements. How do the authors propose resolving this issue?

2. In the results for the fall detection v/s other tasks such as lying on ground, the author uses a plot and says the lying down is less drastic. What if the person who falls down falls down and tries to gain balance from a nearby object and finally falls down thereby making it less drastic?

3. The authors also claim an accuracy of 97% for fall detection. There is however no mention of how many times the experiments were performed nor is there any mention of how many times each activity was performed or even the ratio of the activities performed.

4. What if we need to track multiple people? The system would fail in such a scenario.

5. WiTrack claims that it transmits at 100x lower power than a WiFi AP. How are the authors sure that there is no form of long term risk to an individual?

6. What is the range of a single set of transmitter and 2/3 receivers? Would it cover the entire house? If not, won't movements cause multiple readings at different points?

7. Why does the localization error sometimes decrease with an increase in the distance from the transmitter?

8. WiTrack will not work when a person tries to do gestures while walking. How can this be resolved?

More details about the paper

Adib, F., Kabelac, Z., Katabi, D., & Miller, R. C. (2014). 3D tracking via body radio reflections. In 11th {USENIX} Symposium on Networked Systems Design and Implementation ({NSDI} 14) (pp. 317-329).