3D Tracking via Body Radio Reflections

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The Problem Definition:

With advancements in technology, the research and development in the field of 3D tracking have become quite vast. Many software applications have been popularized over years, which aim to track the 3D motion of a user precisely and then perform certain tasks like analysis of body parks, gesture tracking (for smart homes, etc.), fall detection, etc. Most of these solutions depend on with the smart device on the user or in their vicinity (for indoors) or the user carrying a smartphone (basically a GPS receiver) for outdoors. Not only this, but most of these solutions require a lot of calibrations and empirical data to be stored or rely on Machine learning algorithms or even go to an extent where the user might feel his/her privacy being invaded (like using the microphone on the user's phone to detect the signatures around him). This paper presents the idea of solutioning tracking the 3D motion of the user without any calibration, empirical data, or even without any device on the user's body. Moreover, it doesn't even require the user to be in close vicinity of the setup device named WiTrack.

Key Idea:

The solution WiTrack works on the idea of using antennas (one transmitter and multiple receivers) to analyze the radio signals reflected off from the user's body to detect the 3D motion of the user. Basically, it bridges the gap between the RF-based localization systems which locate a user through walls and occlusions, and human-computer interaction systems like Kinect, which can track a user without instrumenting the body but requires the user to stay within the direct line of sight of the device. The three major challenges that the user faces while transforming this idea into practical are: Measuring Time of Flight (TOF), Detection, and cleaving multipath. The paper tried to tackle these challenges and implement/analyze three applications: 3D tracking of human motion through a wall, Elderly Fall detection, and controlling applications by gestures.

Important Details:

1. The ground truth is evaluated using VICON, which required a non-flexible setup and has a dependency on IR sensors and cameras.
2. The antennas used are directional in nature and their placement is known.
3. The antenna structure is T shaped as all the antennas should be arranged in one plane facing the wall in order to localize the user behind the wall.
4. ADCs (Analog-to-Digital converters) cannot be used for measuring the Time of Flight (TOF), as they are high-power, expensive, and have low bit resolution.
5. The idea of eliminating the dynamic multi-path is based on the observation that, a direct signal reflected from the human to our device has traveled a shorter path than indirect reflections.

6. To eliminate noise while filtering the reflected signals (being received at the receiver's end) optimization techniques like outlier rejection, interpolation, and filtering (Kalman Filter) are used.
7. Over 100 experiments each lasting per minute, were performed with eleven human subjects (2 females and 9 males) between the age of 22 to 56 years.

My Thoughts and Criticism:

The paper indeed presents some great work in the field with relevant observations and proofs. The paper provides an unbiased view of the critics, loopholes, and future work, which demonstrates a great mindset. It can be observed very clearly that the author has tried to be open about his ideas and thought process on the possible limitations of the work done.

A few of the assumptions and scenarios that led me to further questions and thinking are:

1. The application of WiTrack to detect elderly fall detection won't be effective if the user is moving very fast. As mentioned in the paper the Fall is identified as a sudden fast change. However, fast motion and jumps can also give us a sudden fast change.
2. WiTrack works for only one person not on multiple people in the same space.
3. WiTrack relies on the fact that the user won't be completely static and there will be slight motion in the user's body, but in real-time, the user can be completely static (like without motion and not due to breathing).
4. WiTrack cannot distinguish between body parts and hence pointing angle or gesture pointing can be inefficient.
5. To better rule-out multipath, the WiTrack relies on the assumption that with time there needs to be a training data set that can determine the static distance from the reflectors, but reflectors can also be non-static over time (for example moving an office chair)
6. For the pointing angle application, the user needs to stand first (i.e. be static: instead of walking) while performing the pointing gesture but in real life, the user might not be able to apply these. Also, there can be multiple, continuous gestures performed at one time.
7. The experiment is performed in a limited space with no tests done on the kids and pets, which is highly possible in real time.
8. If not handled well, privacy can be an issue with WiTrack.

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