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On the Feasibility of Wi-Fi Based Material Sensing

The main objective of this paper lies in proposing a system called **IntuWition** which **uses existing WiFi radio on drones to detect material of obstacles in line-of-sight and non-line-of-sight settings**. The authors also list other applications of **IntuWition** in urban settings such as delivering packages, finding survivors, disaster sites, warehouses, etc.

The authors explain that **IntuWition** consists of two major parts :

1. Localization
2. Material Sensing

The drone has a pair of transmitter and receiver which transmits a signal and receives it back to localize the coordinates of the materials. The next step is to label the materials.

The sensing paradigm is inspired by polarimetry. Polarimetry can measure material-specific responses.

The system transmits a vertically polarized signal and the signal rotates upon reflection by an angle alpha. This alpha value is different for each material. (Example : Metals from a car could be 90 degrees while wood from a tree may be 180 degrees.)

Since there are multiple signals received at the RxR, the authors decide to step away from it spatially and prefer to use Time of Flight. This is why localization is seen.

The authors faced a few challenges in this project.

1. Multi-bounce : Suppose we have a tree and a car with wood and metal material respectively, there could be a possibility that the signal sent to a car may reflect towards the tree and the tree's reflection my be sent to the drone. The drone might assume that the object in question is a tree rather than a car. Need more clarity - For this, the authors inform that the alpha values of multi-bounce are related to the single-reflection which can be removed/ignored.

2. Several variations in material : Trees v/s book shelves have different shapes, etc. To group them together, the authors use machine learning models to classify the material type. They used 5 methods - PCA, kNN, SVM, NB and MLP where MLP had the best accuracy of 94% and NB had the least with 69%. The authors claim that MLP performed the best since it extracts the deeper features that are specific to the material. The authors also claim that the ML models account for location, texture and so on - needs clarity.

IntuWition overview : Have a TxR and RxR which transmit signals. This is followed by localization which gives the RxR power and the location points which is then fed to the MLP classifier which tells the material.

Testing : Tested across materials such as metals and wood, systems such as drones and cars. The authors inform that across 5 classes (copper, aluminum, human, plywood and birch), the best accuracies are for Birch (97.1%) while the worst is for Copper (90.5%) which is good accuracy.

The second set of experiments were done on objects such as chair and shelf and the authors claim that the results are encouraging (all around 80%+).

There are some limitations such as

1. The signal cannot be detected if it is too weak or has had too many multi-bounce effects,
2. The materials that have similar polarization characteristics cannot be distinguished, etc.

Thus, in a nutshell, IntuWition is a system that explores sensing the material and location of objects using WiFi radios. The authors claim that the applications can be in drones, vehicles, disaster response, etc. The authors claim that future work can include having more objects, on-board processing and sensor fusion.

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

Questions :

1. Can we make use of Computer vision based techniques for identifying materials along with WiFi?
2. How would the thickness of birch change the confusion matrix results vs wood?
3. How would the materials such as table which may have metallic components such as rods change the results?

4. How do the authors plan to improve the identification of some materials which may have similar characteristics?

More details about the paper

Zhang, D., Wang, J., Jang, J., Zhang, J., & Kumar, S. (2019, October). On the Feasibility of Wi-Fi Based Material Sensing. In The 25th Annual International Conference on Mobile Computing and Networking (pp. 1-16).