On the Feasibility of WiFi-Based Material Sensing

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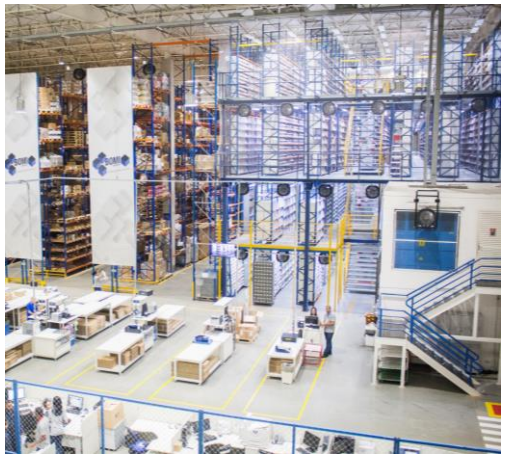
Drones are increasingly useful in obstacle-rich environments.

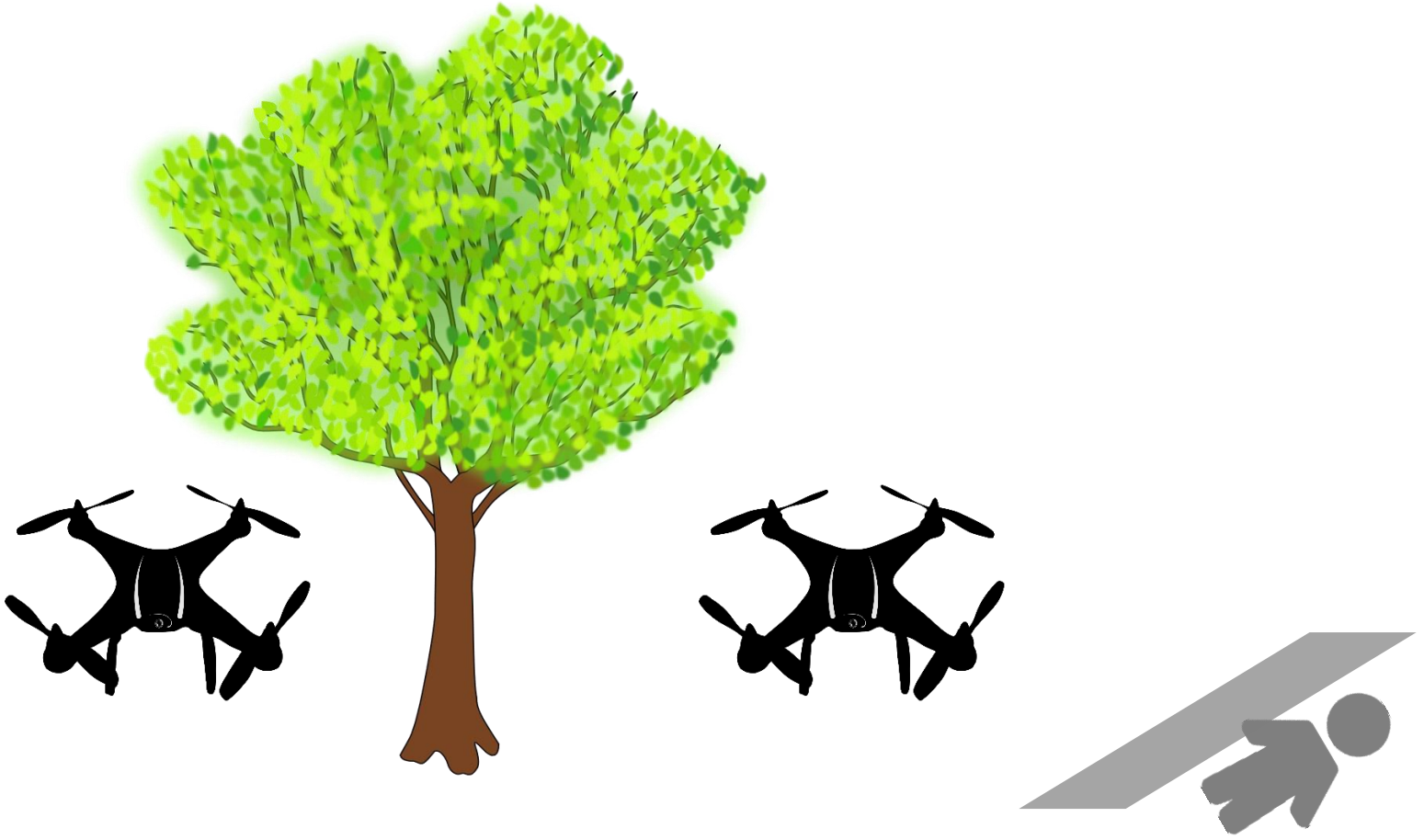
Urban Settings

Disaster Sites



Warehouses

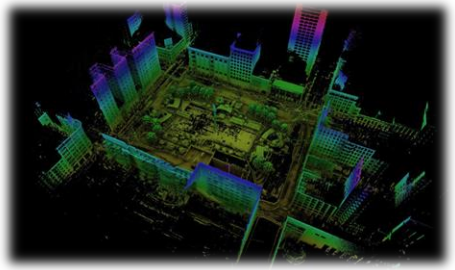
Drones must make obstacle-specific responses to maximize utility



The sensing system must be infrastructure-free and contained entirely on the drone.

Current infrastructure-free sensing solutions cannot enable this.

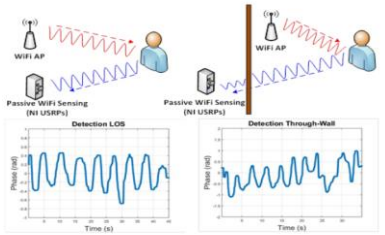
Obstacle Type Identification



Vision-based
(LIDAR, Infrared,…)

?

Non-Line-of-Sight Sensing



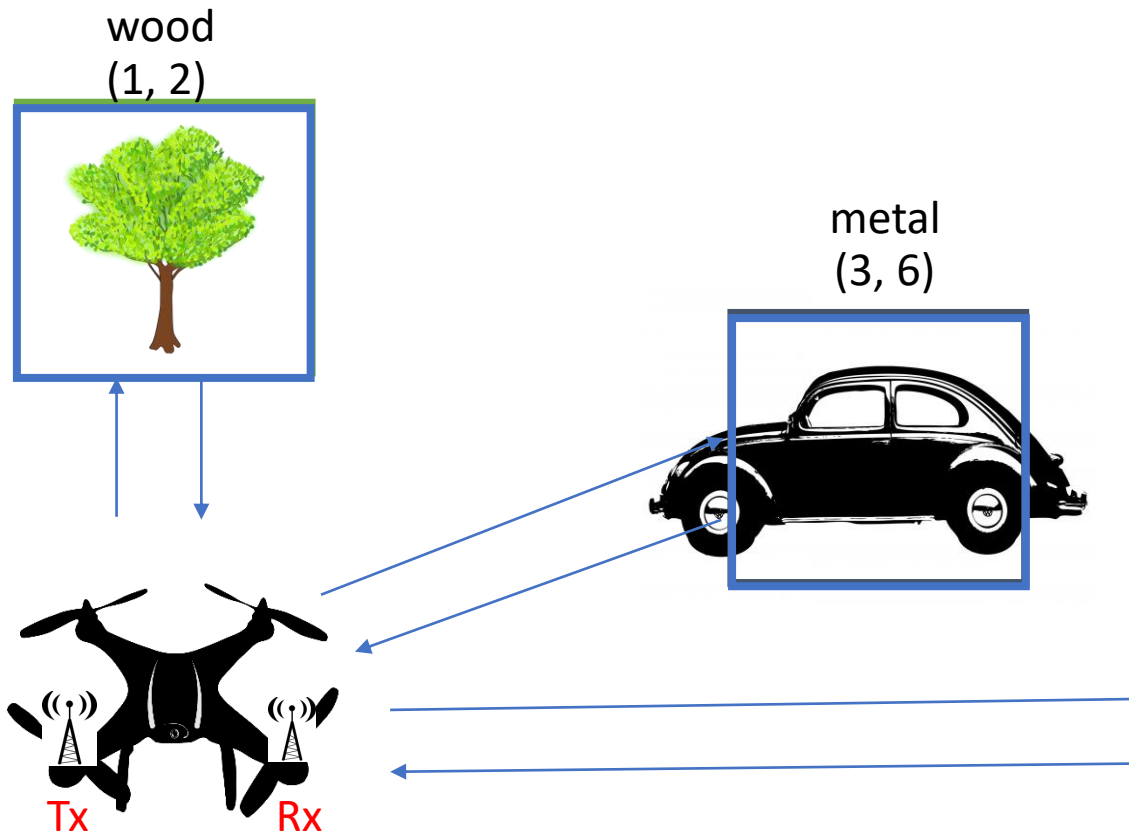
RF-Based
(WiFi, RADAR,…)

IntuWition

A complementary WiFi-Based sensing system that can detect material of obstacles in line-of-sight and non-line-of-sight settings.

- Uses existing WiFi radio already on many drones
- Does not assume infrastructure
- Applies beyond drones – vehicles, product testing, disasters, etc.

IntuWition comprises two major parts:

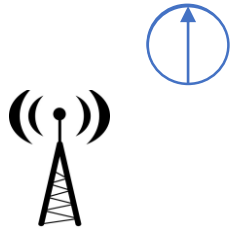


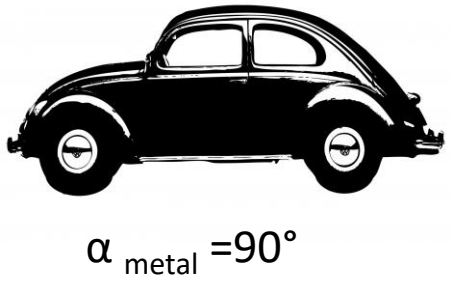
1. Localization
2. Material Sensing

Radar Polarimetry can measure material-specific responses

$\alpha_{wood} = 180°$

Different α values can be used to distinguish materials

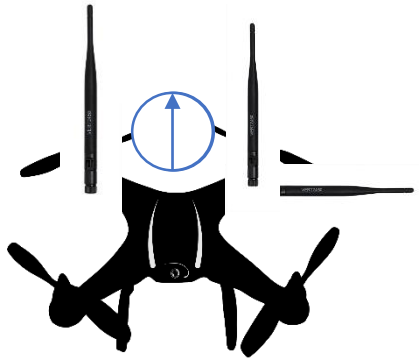


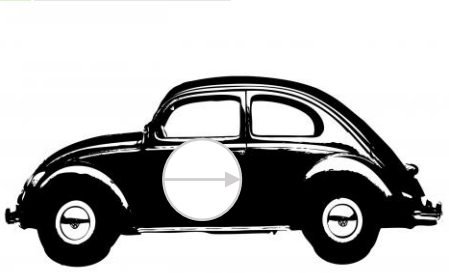


$\alpha_{metal} = 90°$

To bring Radar Polarimetry to WiFi, a vertically polarized signal must be transmitted and received

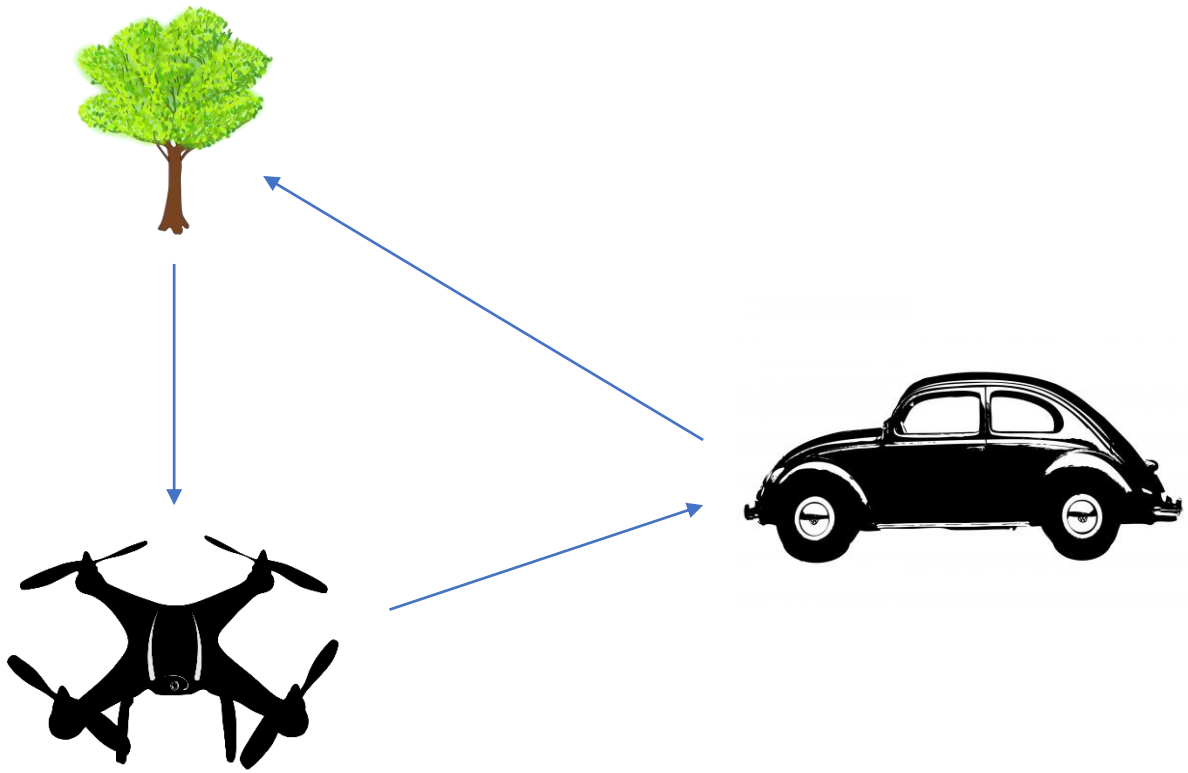
$\alpha_{wood} = 180°$



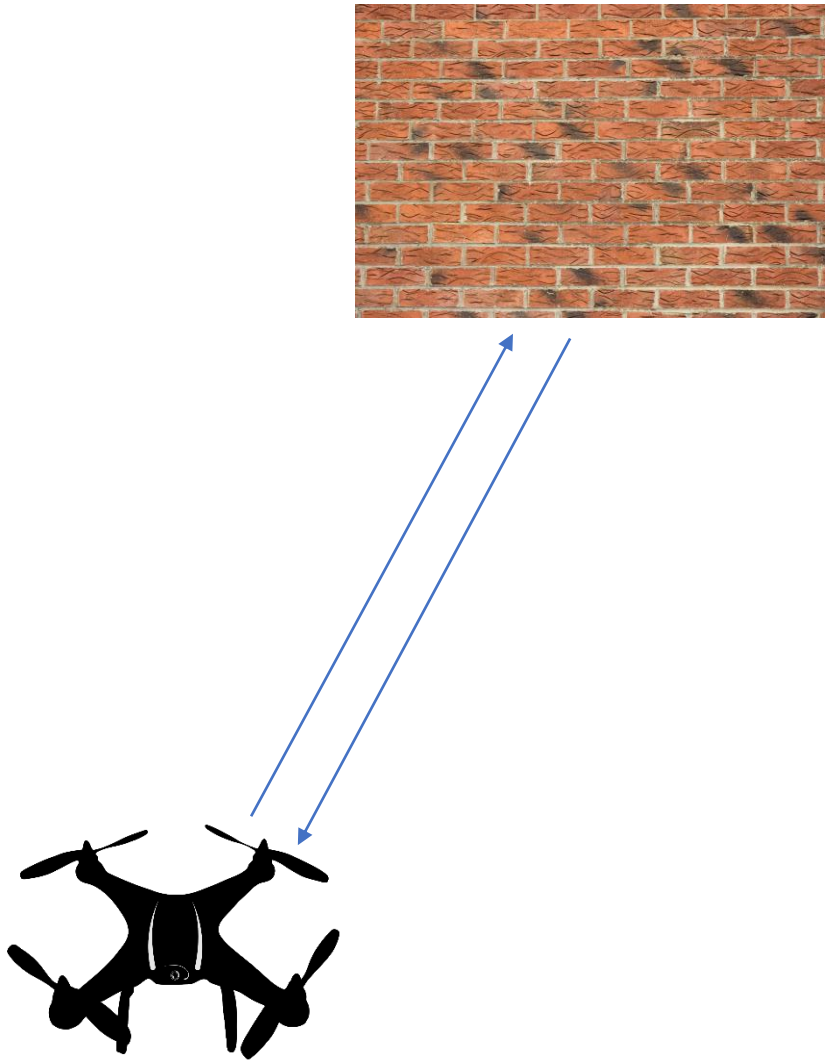


$\alpha_{metal} = 90°$

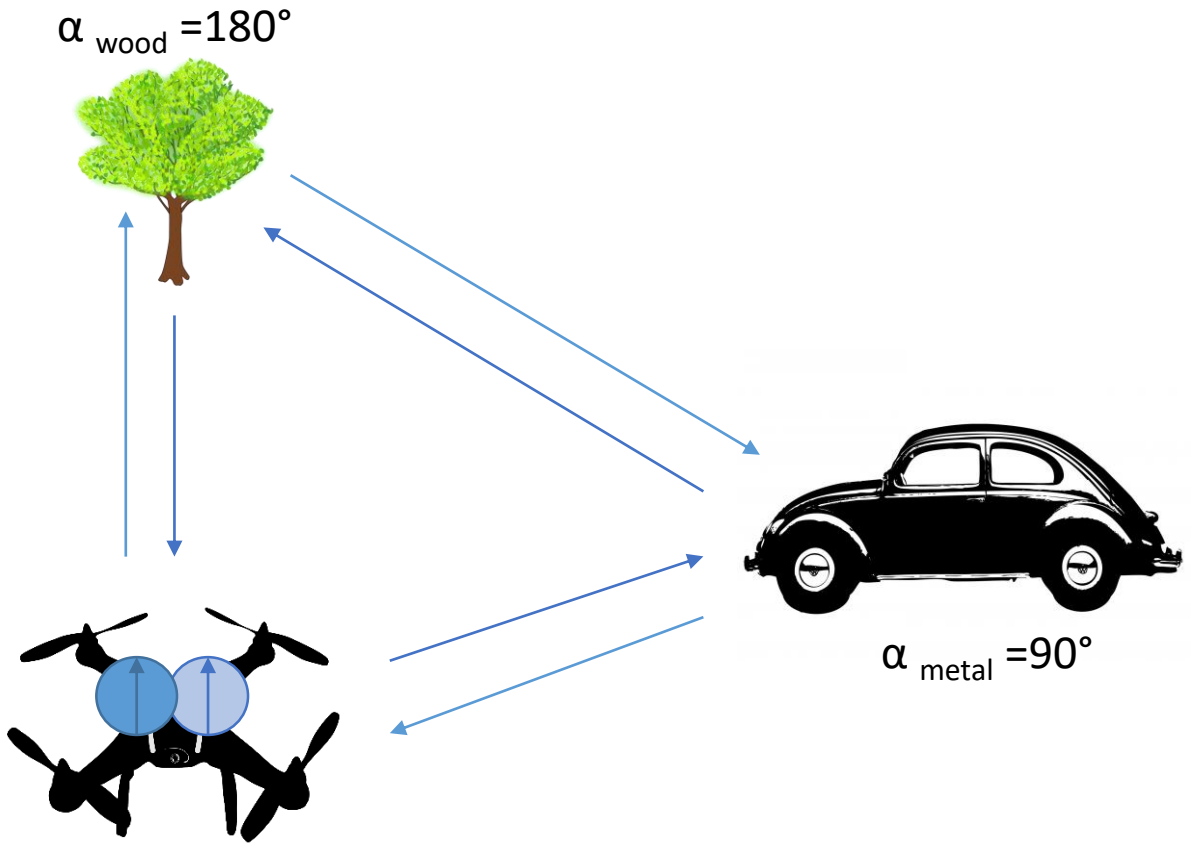
Challenge #1: Multi-Bounce



Vs.



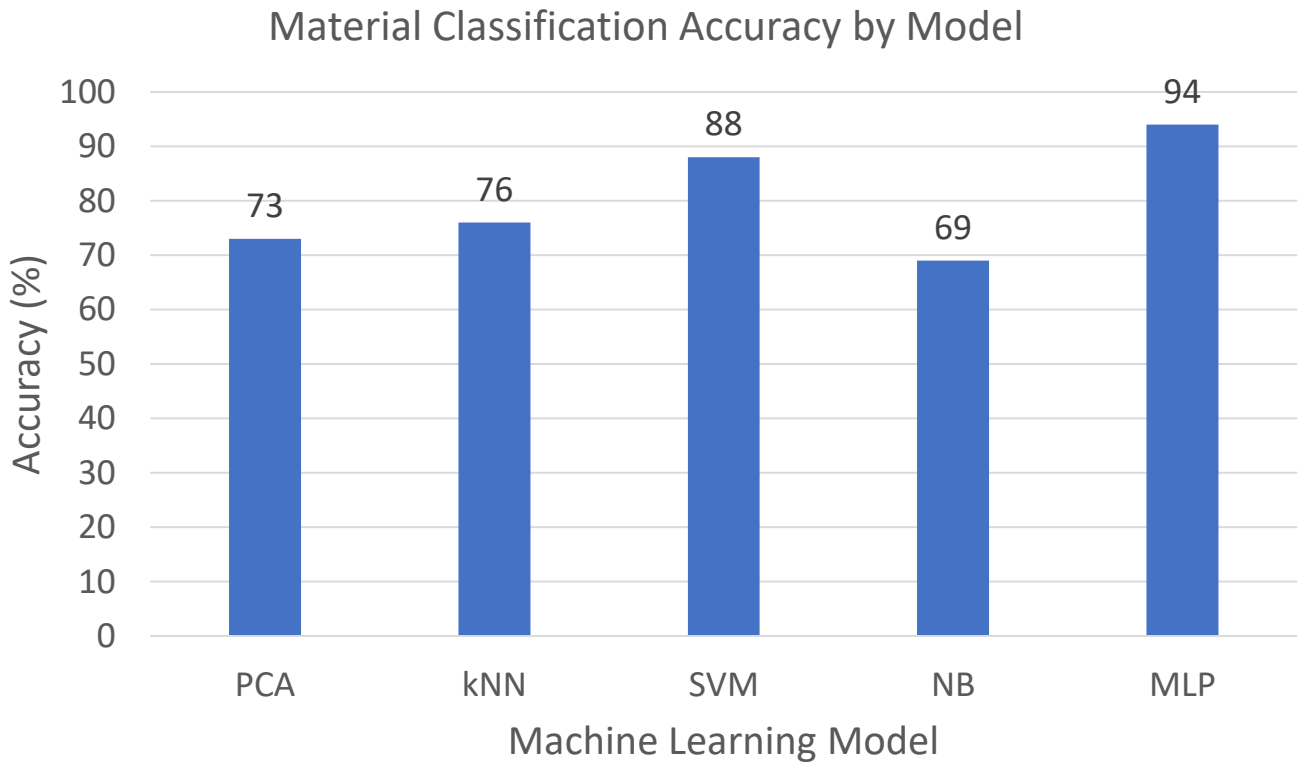
Since the α values of multi-bounce are related to the single-reflection, these can be removed



Algorithm looks for alpha and locations that are consistent with physics of multi-bounce, to eliminate them as spurious (details in paper)

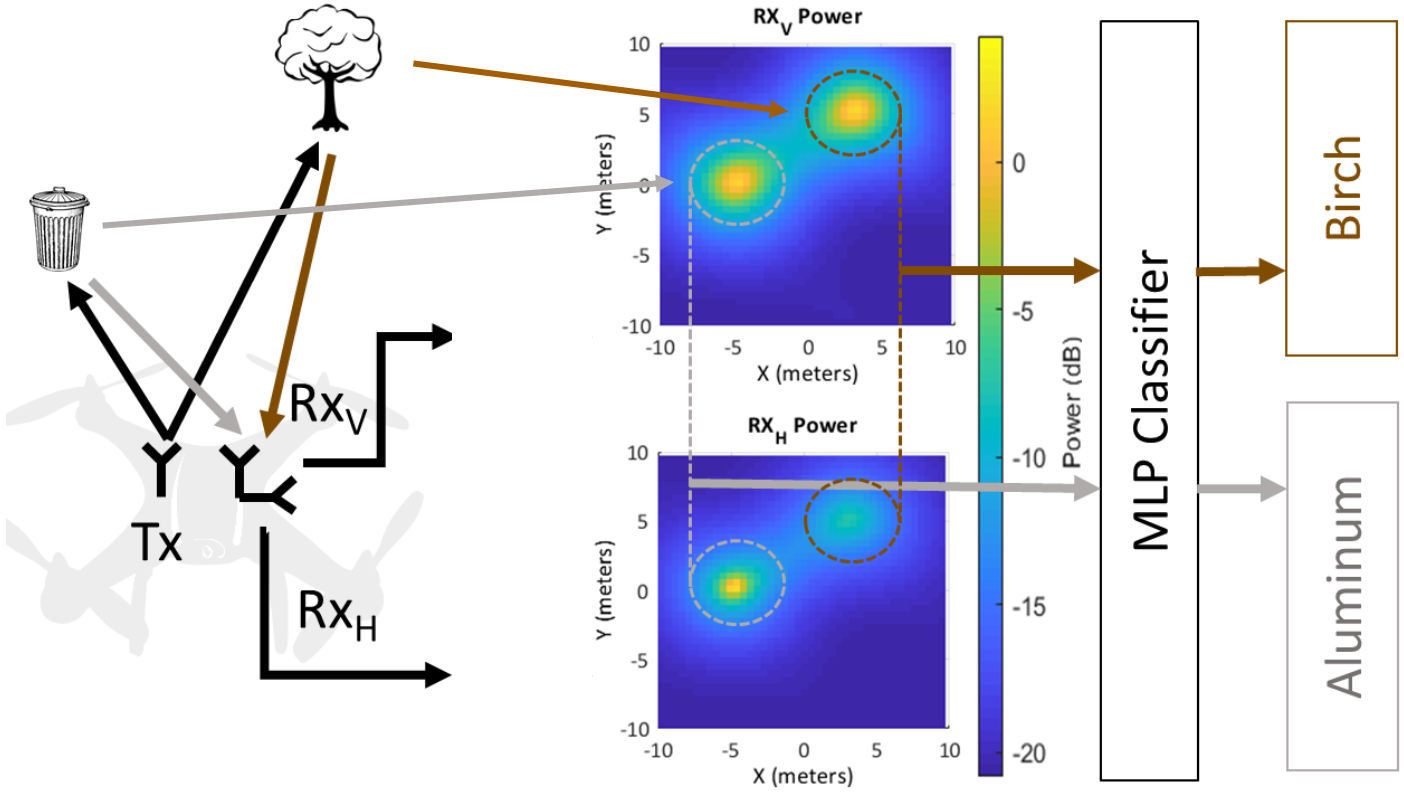
Challenge #2: Several Variations in Material

Solution: Devise machine learning models

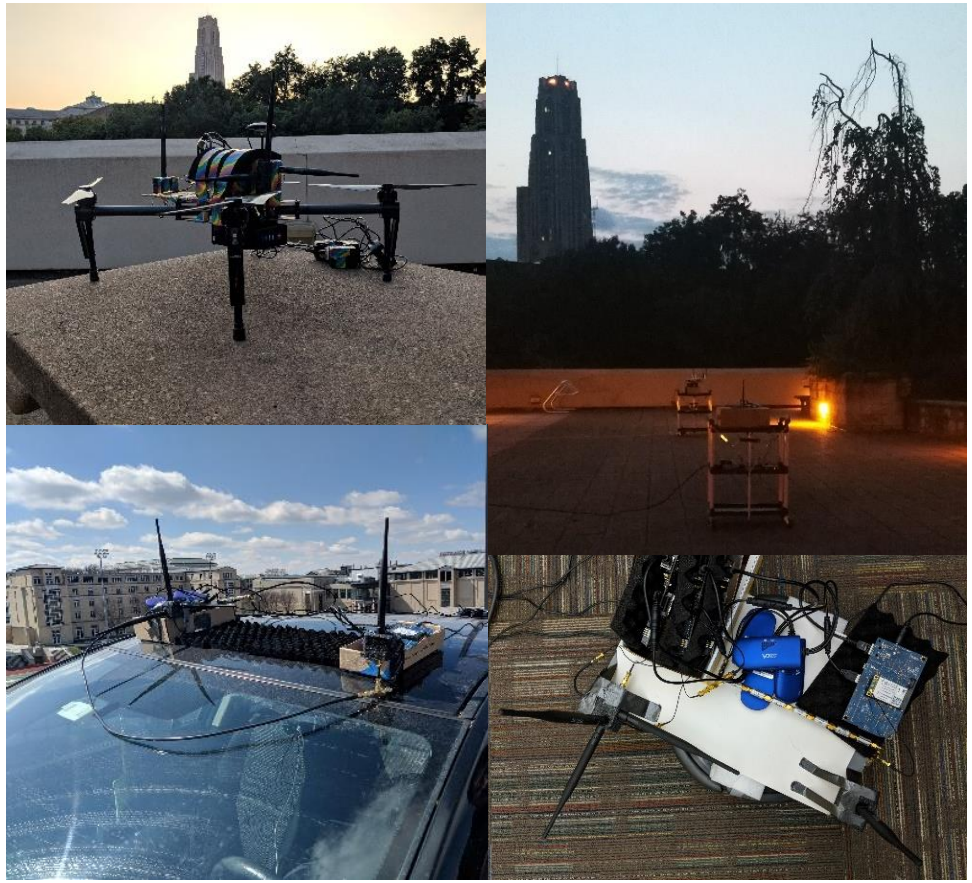


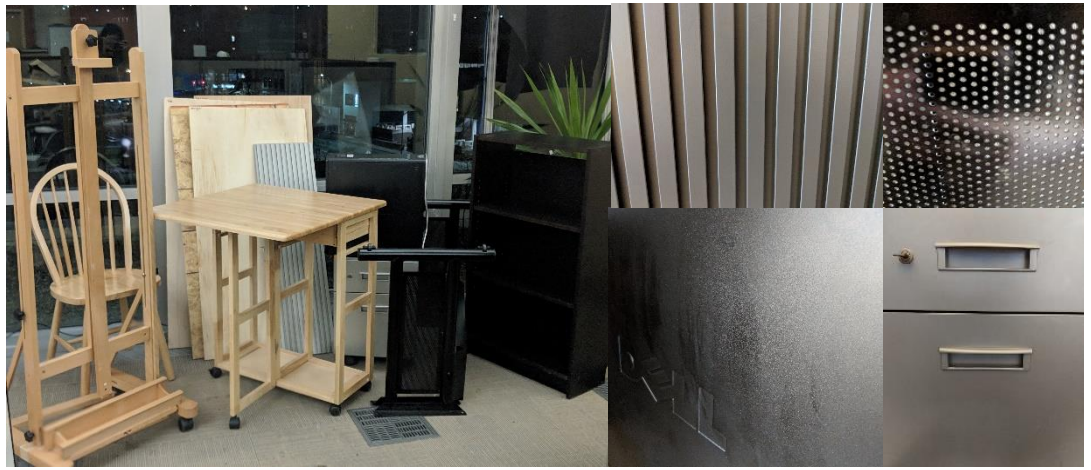
ML model accounts for additional challenges: location, texture – details in the paper.

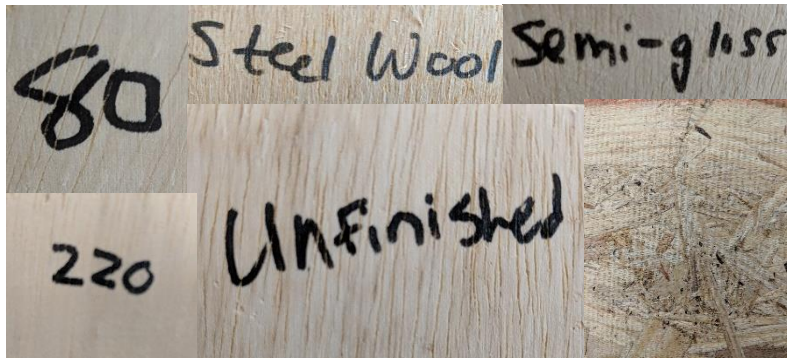
IntuWition's System Overview:



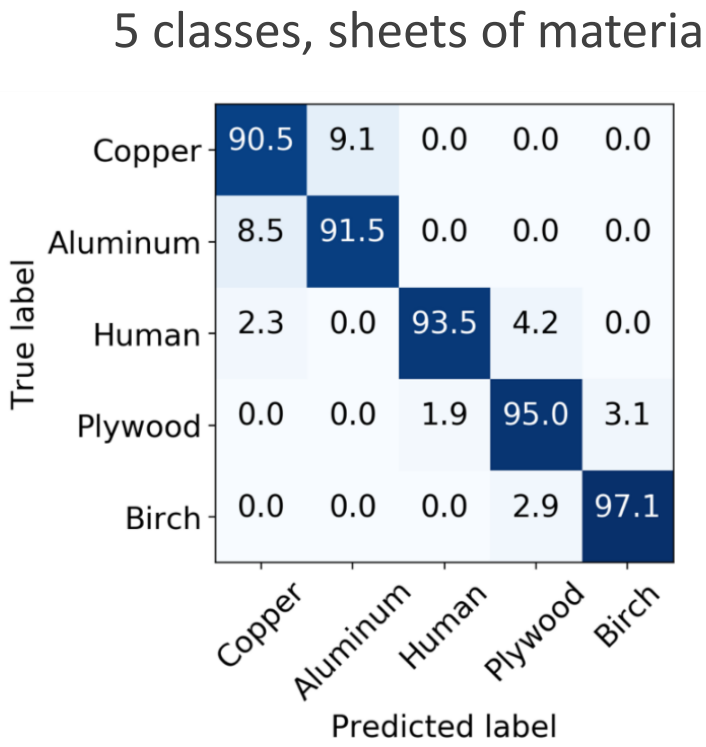
We tested polarimetry as a material identification feature across a variety of materials and platforms.



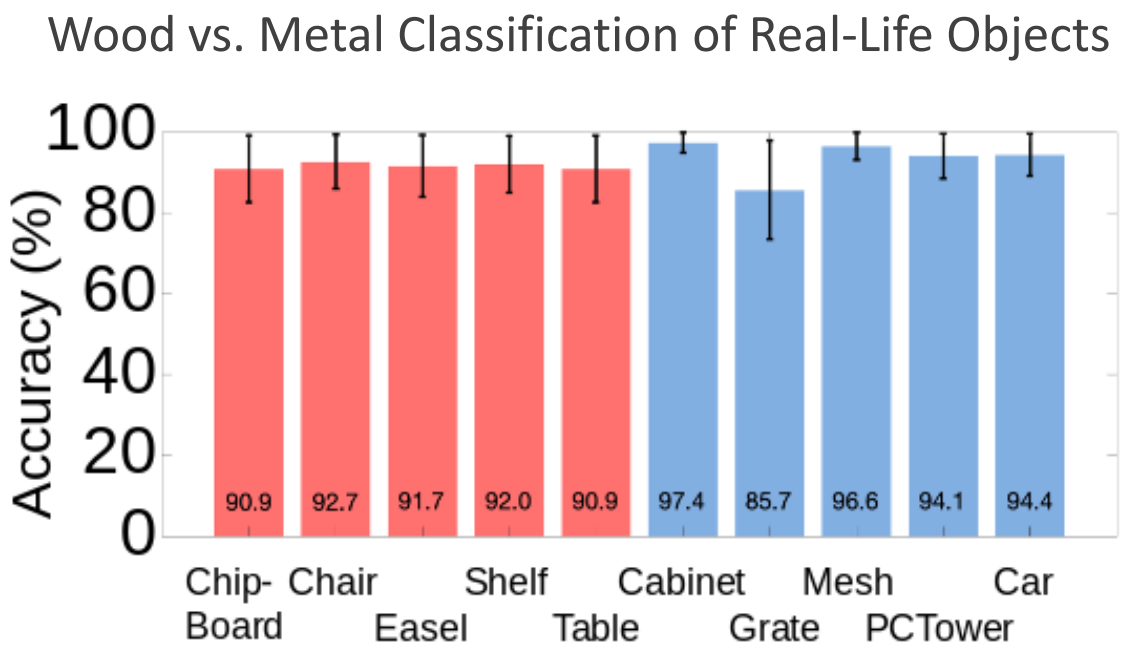




Our system showed high classification rates for five classes of materials.



Further, our system also worked well for classifying real-life objects as wood or metal.



Limitations

- Can’t detect signal when too weak, too occluded, or too many multi-bounce effects
- Cannot distinguish materials of similar polarization characteristics
- May respond excessively to surface characteristics (e.g. clothing)

IntuWition is a system that explores sensing the material and location of occluded objects

- Uses COTS WiFi radios
- Our evaluation demonstrates promising accuracy in material classification
- Applies broadly beyond drones: vehicles, disaster response, product testing, etc.
- Future work includes more objects, on-board processing, and sensor fusion

www.witechlab.com/intuwition