EECS 507: Embedded Systems Research Proposal

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Inspiration: It is a universally known fact that smart systems hold huge potential to augment our daily lives. There is a large push to make everything a smart device (something that has computing power and connectivity). However, as Husain Rahman, the CEO of Jawbone says, "Everything in the world is smart and connected, and everything has an app built to it, but that doesn't mean it's easy for users"[1]. He highlights the idea that having all devices being smart but in their own vacuum hinders the true potential of smart environments due to two main reasons:

- It is difficult to buy and maintain numerous smart devices (extensive setup and management)
- Many devices aren't human-centric (they don't measure human behavior, thus aren't actually very useful)

Noting similar difficulties, Gierad Laput explores in his research "Synthetic Sensors: Towards General-Purpose Computing"[2], the idea of "general-purpose sensing, wherein a single, highly capable sensor can indirectly monitor a large context, without direct instrumentation of objects" as an alternative to the traditional approach of attaching a web of special-purpose sensors around a home.

This idea of general-purpose sensing takes on much more importance when we consider smart-device integration into buildings. Any industrial/office-space building would require immense sensor data not only due to the expanse of such structures but also because they have complex HVAC systems requiring a large number of sensors. KODE Labs[3], a company that integrates building management systems, handles around 24,400 sensor data points for the First National Bank Building in Detroit. The cost of adding a web of ~24,000 sensors in all areas of a building can become inhibitive.

In the interest of exploring human-centric smart systems, we also looked at current solutions for detecting humans in closed spaces. Approaches ranged from RFID tags spread around a room, carried out by Hahnel et al[4] to a company Density[5], which used computer vision. We found these approaches to be intrusive, as they required either meticulous setup or posed privacy concerns. We also-looked at "A Non-Intrusive Approach for Indoor Occupancy Detection in Smart Environments" by Abade[6]. This paper attempted to use general purpose sensing to detect human occupancy but required multiple nodes deployed in a room. This,

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[1] https://www.youtube.com/watch?v=9u6-BL-Fskc
[2] https://www.gierad.com/assets/supersensor/supersensor.pdf
[3] https://kodelabs.com/
[4] https://ieeexplore.ieee.org/abstract/document/1307283
[5] https://www.density.io/
[6] https://www.ncbi.nlm.nih.gov/pmc/articles/PMC6263685/#B10-sensors-18-03953

while being non-intrusive, would still not scale up to a building, which would be our main application space.

Vision: Based on the pain points we found in our research, we wanted to tackle the problem of integrating human-centric sensors into large buildings with minimal intrusiveness. Intrusiveness in this context pertains to set-up difficulty, information privacy and ease of integration into already existing smart system.

So, we want to make a general-purpose style sensor that can does three things:

1) Can be easily installed into a room (plug-and-play style behavior)
2) Can detect the number of humans currently in the room along with base stats for a room (temperature and humidity) without using any sort of camera system or cloud based processing
    a. We expect to do this by running ML on the edge device and using a mix of heterogenous sensors. We will have to study which combination of sensors will be most useful at detecting human occupancy.
    b. Data encryption TBD
3) Can communicate with widely accepted building controls communication protocols
    a. Can communicate using BACNET IP

How will we measure success: KODE Labs is a Detroit-based startup that provides a web/mobile-based platform that tenants and building managers can access, to monitor and control the building management systems. They integrate all the proprietary and niche HVAC/lighting systems that are pervasive in buildings into a user friendly interface. This allows tenants to easily request maintenance, building managers to monitor system health and real-estate owners to track expenses/energy consumption.

They have offered to integrate prototypes of our system in order to automate their building controls. They want to implement such a device in places like conference rooms/offices and utilize them as an input to adjust various building controls. By carrying out a real world deployment, we can assess:

1) The accuracy of our human occupancy as a cost function in a conventional use-case
2) The ease of integration to a company's already existing building management system
3) Fragility of system
    a. Can it really be installed anywhere in the room?