CS486C – Senior Capstone Design in Computer Science

Project Description

Project Title: Automated IoT People Counting Infrastructure	
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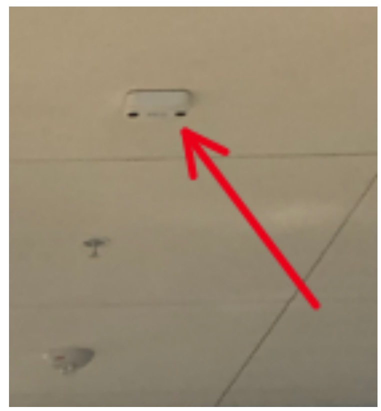
Project Overview:



The Internet of Things (IoT) has fundamentally transformed our everyday technological landscape over the past decade. Embedded in everything from wall switches, to refrigerators, to garage door openers to webcams, these small embedded microprocessors connect to the internet as small wifi or ethernet devices, making them accessible from anywhere at any time. This allows you to control the lights and lock of your home through a "smart home" app, or keep an eye on what your cat is up to from a web app on your desktop at work. In this way, IoT technologies are a cornerstone of our increasingly connected world.

The NAU ITS Internet of Things (IoT) group within ITS is in charge of exploring the potential of IoT solutions to implement a "Smart Campus" and "Smart Building" infrastructure across the NAU Campus. The key concept behind these efforts is the development and installation of a wide variety of IoT devices on campus that monitor and measure a wide variety of metrics, bringing these data streams together into a centralized infrastructure that allows us to better understand the utilization and physical dynamics of our buildings and spaces. Some examples include temperature sensors, room and desk occupancy, and people counting sensors.

One specific example of such a device is shown in the picture to the right: it is a ceiling-mounted sensor that counts people going into and out of a given area. This sort of sensor technology has recently become more important in the COVID era, e.g., the NAU IoT Team implemented the commercial product, SenSource SafeSpace, to create safe distancing areas with maximum people limit in certain locations such as Campus Dining. Similarly we are exploring the use of IoT temperature sensors as part of the NAU HealthCheck initiative based on infrared (IR) sensing temperature detectors. In exploring such solutions, the IoT team often works directly with a variety of microcomputer platforms, such as Arduino, Raspberry Pi, and Jetson Nano. For example, various problem solutions based on image recognition can be explored by pairing a Raspberry Pi and a Pi Camera with software based on Open CV (an open source image processing package); one such problem might be the people counting system.

The Envisioned Product

The project proposed here is based on the simple observation that the SenSource SafeSpace commercial product mentioned earlier is costly; it is not a cost-effective solution that can be scaled across all of the NAU campus. Moreover, as a commercial system, it has limited customizability and a closed codebase, making it impossible to extend or customize to our unique needs. *What is needed is a flexible, open-source IoT solution based on a microprocessor with a simple camera attached that can analyze image data from the camera in real-time to determine the number of people passing by the sensor, and report that information to a central server.* Some key features of this solution would include:

- A secure web-app to serve as the primary user access GUI for the system. Some features of the web-app will include:

- A roles-based user authentication system supporting various user types (admin, staff, student, guest)
    - Ability to easily register new endpoints for monitoring within the system. An endpoint is plugged in, comes online, is registered, and immediately shows up in the GUI.
    - A "dashboard view" that provides a simple overview of all registered endpoints and their status.
    - Allow graphical analysis of traffic past a particular endpoints or within a particular room over a zoomable timeframe.
- Prototype a simple IoT device based on a microprocessor and a camera; **let's call these "endpoints".** Any device can be used for this proof-of-concept, however, the implementation should be clearly portable to similar hardware. We recommend a Raspberry Pi + PiCam as a starting point, due to easy availability.
- An image processing application running on the IoT endpoint device that is able to process/count people that appear in the video stream as accurately as possible. Some detailed functionality here will include:
    - Should be "smart": basic "fast and dirty" image processing should be used where possible, but should also explore AI-based techniques if needed for more complex situations.
    - Ability to count multiple persons in the same image frame.
    - Recognition of direction and/or placement of entrances/exits. To count/track the total people present in a space (say a large room), an endpoint mounted over the door would need to recognize that some are entering and some are leaving.
    - As an endpoints counts people, it reports back to the server at a configurable interval, e.g., every 30 second, every 5 minutes, etc.
- Ability to create "spaces" in the GUI; these represent rooms in which total number of people at any one time is being monitored. Some details:
    - Spaces can be named, e.g., the Dub, Room 90-102, etc.
    - Can attach geolocation information for spaces, e.g., allowing them to be placed on a map.
    - Obviously, some spaces will have a single enter/exit, others will have multiple enter/exits. Thus, it must be possible to associate multiple endpoints to each "space" (one for each entrance/exit); the total people in the room is calculated by tracking total entries/exits of persons.
    - Can create and attach one or more "alerts" to a given space. For instance, the system could be set to send a warning notification when a given space exceeds 100 people, or when more than 10 persons/minute are entering that space.
- Must be designed (e.g. REST interfaces) for future integration into a mobile app, e.g., the NAUgo app.
- Must be an open-source solution suitable for broad distribution for the benefit of other institutions with similar needs.

In sum, the recent COVID-19 crisis has increased the emphasis on monitoring movement of persons (in a maximally anonymous fashion) on our campus and its spaces. Many other large organizations and institutions are facing a similar challenges. Although some commercial solutions currently exist, they are prohibitively expensive and rigid. A strong solution to this design challenge would yield a cheap, effective solution that could be used by organizations all over the world to help their populations stay safe. Not only could the data collected by such a system help enforce COVID-related safety policies, it could also help NAU Faculty and Staff members understand the overall utilization of resources, such as conference rooms and class rooms, and schedule a resource in real time depending upon availability.

Knowledge, skills, and expertise required for this project:

- Knowledge of modern Web2.0 programming techniques, frameworks, and languages required to develop the web app
- Knowledge of back-end server and database technologies, with emphasis on configuration and deployment of IoT server resources.
- Programming skills in Python, C/C++, Android/IoS, html, REST is useful,
- Learn about raspberry pi and camera based image recognition.

Equipment Requirements:

- Raspberry Pi and Pi Cameras will be provided, other hardware will be provided if justified.
- There should be no equipment or software required other than a development platform and software/tools freely available online.

Software and other Deliverables:

- The software applications and endpoint device, as described above, deployed and tested successfully in a typical real-world space monitoring context.
- Must include a complete and clear User Manual for configuring and operating the software.
- A strong as-built report detailing the design and implementation of the product in a complete, clear and professional manner. This document should provide a strong basis for future development of the product.
- Complete professionally-documented codebase, delivered both as a repository in GitHub, BitBucket,or some other version control repository; and as a physical archive on a USB drive