ENG4940 Capstone I

Problem Identification, Research, and Requirements Specification Report

---

Environment Sensing Occupancy Integration System

Name:	*Student Number :*
Raven Castaneda	100559932
Eric Dube	100
Brady Ibanez	100367230
Taylor Somann	100502392

Contents

1 Problem Identification

It is the intention of this capstone project to allow for the configuration and implementation of an environment sensing IoT system. The system will be capable of referencing the environment in which it resides and providing diagnostic feedback as to the detailing of specific objects and states that are of particular concern to the situational maintenance it is meant to satisfy. In specific, as a paired grouping capstone project, this system is to be inherently concerned with temperature and humidity detailing, as to allow for the capacity of machine learning oriented HVAC control. It is to be primarily concerned, however, with allocating the capacity of occupancy status provisioning and to be capable of identifying entities to be defined as human occupants within the environment monitored.

By providing the machine capacity of a system to be aware of occupants, and to monitor associated parameters such as occupant location, occupant count, occupant status (in terms of environment stay duration), and so forth, any associated environment control system will be provided a level of insight to their situational control demeanor beyond any other form of direct user controlled environment systemization. In this sense, systems will be allocated capacity for inferential control beyond adherence to static variable coherence, by being provided a degree of environment understanding to a dynamic extent.

This is therefore the precise measure of the problem this project will seek to satisfy: The issue of dynamic IoT system inference as attained through passive user interfacing. By providing the capacity for a system to reference user and occupant detailing dynamically and automatically, system ability to infer situational requirements becomes a possibility, and allows for much more involved system design when considering the requirements of users and environments from a consistent input spectrum.

What should also be defined here is the concept of passive user and environment interfacing. The intended concept here is to relate to system interaction from a completely indirect interaction vantage point. The system itself should be capable of inferring required setting alteration parameters from constant observation through sensor inference, rather than from direct user input. This is something that does not currently exist in an entirely generalized sense in defined IoT devices within the smart home/static indoor environment, but rather within specialized implementation for specific capacity devices.

While systems to a similar extent exist today, they exist through more limited design, coherence, and manifestation. With this in mind, it can be seen how through existing implementations like Lutron lighting [1] and Legrand Industrial building control systems [2], there are potential solutions for occupancy detection and environmental inference. However, these means facilitate only individual case capacity, and do not accommodate for alternatively influencing factors such as pet detection and maintained occupancy count and diagnostics, among an array of other variables that this project will seek to include and detail.

It is felt that the environmental and situational diagnostics that this system is intended to address are vastly required components for the evolution of IoT integration in dynamically intelligent control systems. It is a conceptual component that could benefit not only smart home implementation, but other industries including automotive, health care, and education, should the system be constructed in order to be readily integrate-able and readable by other data requesting manipulating services.

2 Project-related Background and Research Review

Eric is going to research what was discussed in the meeting about house location definition to make a focus for this section.

Brady will find more research.

Add whatever you have with citation and Brady will organize. List Of Raven's Research: https://learn.adafruit.com/pir-passive-infrared-proximity-motion-sensor/how-pirs-work https://maker.pro/raspberry-pi/tutorial/how-to-interface-a-pir-motion-sensor-with-raspberry-pi-gpio https://www.youtube.com/watch?v=1oGN0t - IR Research http://www.canadarobotix.com/ - Means of price checking https://www.hydro.mb.ca/your$_h ome/insulat$ $Insulationformulasforestimationsonheatlosshttps : //www.postscapes.com/wireless - vent - keen/ - MarketComparisons$

3 Design Process

4 Scenarios and/or Use Cases

5 Stakeholder Requirements

Primary stakeholders of this project from the direct perspective of residential environment automation include residents and occupants of the system integrating environment. This includes occupying home owners and tenants. These stakeholders must be considered primary for the fact that they will be the most involved and effected individuals in respect to system interaction and control. The operation of the system and it's purpose entirely revolve around the capacity it maintains to benefit the comfort and convenience of these stakeholders on a daily basis.

These stakeholders require the fulfillment of reliably accurate environment and occupancy detection, analysis, and detailing. From the environmental aspect, it is necessary for the system to include readings of temperature and humidity. A deviation in temperature within 1.0 degree Celsius is shown to have no impact on thermal comfort[3]. Furthermore, from further research, it has been found that temperature readings should not exceed a deviated value of greater or less than 0.5 degrees Celsius to prevent noticeable temperature deviation without active intervention[4]. This standpoint has been taken to adhere to a greater caution factor in system quality maintenance. From the occupancy detection aspect, there will need to be a means of qualifying registered system users (who have inputted as known entities to the system) from general occupants. There should be a 95 percent accurate value provided for general occupant count to compensate for misinterpreted signals confusing human numbers, and a 100 percent accurate value for readings of registered users.

Another main concern and requirement that must be facilitated for these stakeholders is the factor of privacy and anonymity. Because the system will require the capacity to interface with other potential users to augment functionality capabilities, including potential homestead administrators and third party product developers, crucial user details (especially registered user details), should never be shared or made vulnerable to other stakeholder system interaction.

Further primary stakeholders who are not subject to first person interaction with the active system include individuals involved in the maintenance and construction of system controlled environments. Such stake holders consist of non-occupying home owners, residential property administrators, as well as property developers and constructors. These stakeholders, while not experiencing direct effect of the system during active operation, are subject to effects in terms of either existing system status diagnostics and/or system implementation.

It is necessary that these stakeholders be aware of both proper system installation practices, as well as system failures. This first item is important for the reason that without an appropriate means of installation, either facilitated by themselves or a third party installer, it can not be assumed that system integration will allow for proper operation, and thus will result in inaccurate and faulty operation. These stakeholders will also require information concerning any faulty operation within a system that might occur after installation for the reason of vested interest in both the system installed, as well as the residence in which the system is operating. In particular, faulty temperature readings alternative to expected reading values can be indicative of a malfunctioning HVAC system, which could lead to residence damage. These notifications must be free of fault and inaccuracy such that false alarms be avoided entirely.

Developers of the configuration and creation of the system are as well primary stakeholders. Their requirements involve the assurance of system reliability and operability, which is defined and guaranteed through initial testing practices outlined in the Project Plan section.

Secondary stakeholders include third party developers who may come to deal with integration of the system as a subsystem within other systems they create themselves. Requirements in this regard entail the ability to interact with sensor read values of the environment. This then leads to the requirement of available sensor interpreted readings, since these stakeholders will require the insight of the system primarily as a means of elevating the implementation of their own systems. In order to achieve this, it will be necessary that the means of sensor interpretation be provisioned through a central location connected to the internet. This location will require security authentication, meaning third party stakeholders should not be able to access an operating instance of the system without authentication satisfaction as constructed by registered user acceptance. This can be done through the creation of a public API allowing third party developers the ability to write general functionality for the system that does not have access, however, until a system user provides it.

The one requirement to maintain above others is that of privacy for direct system interactors. This is for the fact that the requirements of all non direct interactors with the system will require access to some capacity, but that the provisioning of this access could compromise direct users who will be exposing much more sensitive personal information. It is for this reason that the satisfaction of another requirement will have to be reconsidered should it compromise the occupant's system security and privacy requirement.

Refer to the table provided below for a concise summary of the identified stake holders and their corresponding requirements. Note that requirements will be defined with an identifying variable reference (ex. R1 for the first identified requirement) for use in later sections:

Stakeholder Requirements

Occupants and Tenants	Primary	• R1: 95% accurate occupancy detection • R2: 100% accurate registered user detection • R3: Non-deviant temp readings greater or less than 0.5°C • R4: System occupancy count reliability • R5: System security, and privacy • R6: The ability to accept third party product interaction requests
Administrators and Developers	Primary	• R7: Installation documentation and references • R8: Accurate system failure notification
Third-Party Developers	Secondary	• R9: A public API for auxiliary product creation

6 Definition of Acceptance Tests

Since it is the intention of this project to implement hardware and software interfacing, it will be necessary to include testing designed for both included hardware to correctly and accurately reference the environment aspects intended to be characterized, as well as for software configuration to be able to accurately respond to the hardware provided data sets. For the purpose of detailing these tests in this section, hardware testing will be acknowledged first.

This system will be primarily concerned with referencing linear, instantaneous capturing of environment data. As such, the hardware will need to provide static references throughout elapsed time. This is intended for the most part in order to reduce processing capacity requirements within sensors, and will also help to reduce the detail required in hardware testing. In this way, sensors will merely have to be tested for singular event accuracy.

For temperature sensor (thermometer) testing, analog reference of a given temperature within an environment will be initially taken. Simultaneous reference provided by the configured thermometer sensor will be compared. A passing value from the sensor will adhere to a deviation of recorded temperature no greater or less than 0.5 degrees Celsius compared to the analog thermometer. A similar testing protocol will be adhered to for humidity testing in reference to relative humidity.

For occupancy testing, the test practice parameters will adhere similarly to those mentioned above, where comparative measures are provided merely through first person human recordings. The sensor must be able to detect human presences with 95% accuracy to achieve a passing value. Occupancy sensors must also be able to detect registered users and provide a boolean reference variable value asserting the registration status of the user. The existence and accuracy of this variable must be referenced during testing and correlate to the perceived status of the recorded occupant. Hardware testing only need correlate to sensor accuracy for the static variables for which they provide representation.

In reference to software testing, a perspective concerning a recorded comparison schema must be most prudently adhered to and maintained. It should be the active ability of the data set configuring software component (the thermostat/hub) to allow for data maintenance and manipulation from the sensors to illustrate a workable set. In terms of temperature, software inference of the environmental data points provided by the sensors should be manifested as a table of points correlating to the time at which they were attained. For this reason, it must be possible to confirm temperature and humidity data update times within a set period. Updates must be attained accurately within 5 minutes intervals and reflect appropriately the temperatures and humidity recorded at those times. The five minute interval was determined for temperature reading particularly for being in adherence to the time span utilized in a 2016 study of occupant thermal comfort [5]

In terms of occupancy referencing by software, updates must be provided per noticed alteration per sensor. For this reason, continuous reading would be ideal, however, to save processor capacity and usage within sensors, it is instead decided that update intervals can expand to the 5 second range. This can be the case for all sensors except for occupancy volume sensors at residence entry and exit points which cannot afford any delay. This would be to prevent inaccurate current live occupancy for the entire environment monitored by the system. In order to test this, variable values for overall occupancy and individual space occupancy must be maintained and referenced in comparison to physically perceived values.

Since software implementation cannot wait for hardware implementation prior to functionality testing, it has been decided as well that simulation testing must also play a role in ensuring sound software operation. Thus a corresponding simulation test for each hardware correlated test will also be conducted prior to hardware integrated testing practices. Simulation must generate random values of registered user variable with predefined profiles as well to test appropriate integration of registered user object profiles.

Security testing will be included and executed through a means of active affirmation through attempts made by requesting third-party interfaces to access sensitive data. A passing test will be attained when it is confirmed that sensitive data is not viable through the API.

Refer to the table provided below for a concise summary of the intended acceptance tests to be conducted. Note that acceptance tests will be defined with an identifying variable reference (ex. T1 for the first test) for use in later sections:

Acceptance Tests

Test Name	Description
T1 - Confirm temperature reading	Ensure that sensor reading correlates within $\pm 0.5°C$ of analog reading.
T2 - Confirm humidity reading	Ensure that sensor reading correlates within 5% relative humidity analog reading.
T3 - Detect non-registered users	Ensure human occupancy detection within 95% accuracy.
T4 - Detect registered users	Ensure registered user occupancy with 100% accuracy
T5 - Confirm temperature relay	Ensure hub component receives temperature reading from sensor at 5 minute intervals.
T6 - Confirm humidity relay	Ensure hub component receives humidity reading from sensor at 5 minute intervals.
T7 - Confirm human detection (non-entry point sensor)	Ensure hub component receives occupant count++ accurately within 5 seconds of change.
T8 - Confirm human detection (entry point sensor)	Ensure hub component receives occupant count++ accurately within 1 second of change.
T9 - Simulate T7	Used solely for application functionality confirmation.
T10 - Simulate T8	Used solely for application functionality confirmation.
T11 - Confirm registered user detection	Ensure system is capable of registered user recognition in practice.
T12 - Simulate registered occupant	Randomly assign registered user boolean variable in same testing format as T9 and T10 once succesfully completed.
T13 - Confirm security integrity	Attempt to access data through API implementation

7 Traceability Matrix

This traceability matrix illustrates a means for gauging stakeholder requirement satisfaction. It is believed that through the completion of the defined acceptance tests that an idea of the extent of satisfaction of the requirements will be provided. The following matrix outlines which tests will satisfy acceptable performance of the systems ability to maintain the requirement referenced:

Traceability Matrix

Requirements	———	**R1**	**R2**	**R3**	**R4**	**R5**	**R6**	**R8**	**R9**
Test Cases	**Totals**	5	3	2	9	1	5	1	1
T1	2			X			X		
T2	1						X		
T3	2	X			X				
T4	2		X		X				
T5	2			X			X		
T6	1						X		
T7	2	X			X				
T8	2	X			X				
T9	2	X			X				
T10	2	X			X				
T11	2		X		X				
T12	2		X		X				
T13	5				X	X	X	X	X

It is acknowledged that no current acceptance test exists for the installation documentation and references requirement within the traceability matrix. That has been considered, and should it be deemed necessary, it could be completed through customer user surveying. This is for the fact that it will be a necessary outcome of first hand installation experience that will help provide necessary detail for creation.

8 Project Plan

9 Contribution Matrix

References

[1] YouTube. Lutron Occupancy Sensor. [Online]. Available: https://www.youtube.com/watch?v=fyUyC5S1YTc

[2] LegrandIndustries. WIRELESS CEILING MOUNT PIR OCCUPANCY SENSOR. [Online]. Available: https://www.legrand.ca/aboutus/legrand/overview.aspxandhttps://www.legrand.ca/wattstopper/sensors/wireless-occupancy-sensor/eopc-100.aspx

[3] *Ergonomics of the thermal environment — Analytical determination and interpretation of thermal comfort using calculation of the PMV and PPD indices and local thermal comfort criteria*, Std. ISO 7730:2005(en), 2005-11. [Online]. Available: https://www.iso.org/obp/ui/#iso:std:iso:7730:ed-3:v1:en

[4] L. Jones, "Thermal Touch," *Scholarpedia*, vol. 4(5):7955, 2009. [Online]. Available: http://www.scholarpedia.org/article/Thermal_touch

[5] B. Pavlin, "Real-time monitoring of occupants' thermal comfort through infrared imaging: A preliminary study," *Buildings*, vol. 7(1), 2017. [Online]. Available: https://www.mdpi.com/2075-5309/7/1/10/htm