Introduction:

Motivation:

Buildings amount to nearly 40% of total energy consumption, it is time that the building sector plays a key role in climatic policy. With limited access to renewable energy resources, it is a challenge for Singapore to reduce the energy consumption of building and provide comfort to its occupants [1]. It is noted that the HVAC systems account for 40% of the total energy consumed by the buildings. Since improvising the HVAC system can reduce the energy cost considerably it is becoming more attractive [2]. While energy cost reduction is important, the indoor environment quality(IEQ) is equally important to improve the productivity of the occupants. IEQ collectively refers to the Indoor Air Quality, Lighting Quality, Acoustic quality, Thermal Quality and Comfort of Human Beings in the building space. In today’s scenario where people most of the time reside indoors, IEQ becomes important for the health and throughput of work of the people.

IEQ can be affected by a variety of factors such as temperature, relative humidity, particle concentration, gaseous and biological pollutants, acoustic comfort, lighting intensity and color and number of occupants. The most important part of IEQ remains to be Thermal comfort and Air Quality. Thermal Comfort has some major standard like the ASHRAE 55-2017 based on the field studies of different countries across the world and EN-15251, which is European standard for Indoor environment parameters. These standards have a measurement for the thermal comfort based on the air speed, temperature and relative humidity in the form of a psychrometric chart. These charts give a relation between Dry Bulb Temperature and Humidity ratio and range of comfort zone for the air speed, metabolic rate and clothing level of individuals. Like the Thermal comfort, Air quality has also great impact on the IEQ. In the past few decades, rapid industrialization in the Asian countries and large-scale usage of closed environments for workspace has resulted in interests towards study of Indoor Air Pollutants. These closed sealed environments could lead to wide variety of diseases and hence has become a point of research to reduce these pollutants. Most common indoor pollutants include Carbon-di-oxide CO2, Carbon-monoxide CO, Volatile organic compounds (VOC’s), Dust (PM 2.5 and PM 10) which impact the Indoor Air quality. These components of air can cause sensory irritation even if they fall below a specified level. But if they go beyond a threshold level over a long period of time can cause major harm to health leading to variety of disease. Hence, the IAQ is much more complex in the form of controlling the pollutants as there is no direct way of controlling the level of pollutants. All the factors of thermal comfort and IAQ are to be controlled by the Air conditioning and mechanical ventilation system (ACMV) and hence this form the major part of the IEQ. The other parameters that fall into the scope of IEQ include lighting and acoustics. The lighting comfort can be controlled linearly with color temperature and intensity of light varying linearly. The acoustic comfort is the one that depends on the noise levels within the room. As the general preference of occupants is less noisy environment, the unwanted noise arising due to equipment present in the room is to be reduced. The flooring and ceiling of the indoor environment must be surfaced with an absorbent material to reduce the noise further arising due to other factors like walking around or speech.

IEQ has direct effect on the occupants involved and the occupants have individual preferences of the components of IEQ. The occupants form the active agents of the system and the control and office equipment form the passive agents. The active agents have individual feedback about the about the environment that the passive agents learn from and have control on the environmental variables. The multi-agent feedback is essential for the goal of IEQ to be established as the comfort of the occupants are essential part of the IEQ.

Aim:

The goal of this project is to integrate the multi-agent capability into the controlling of Indoor Environment Quality and take coordinated decisions based on the sensor values. As the project had more focus into building theoretical models of the room FEC2, National University of Singapore, the mathematical model was constructed for that specific room and its physical properties where considered to model it mathematically. The indoor air quality, the thermal comfort lighting was all modelled for the room which was a fully controlled environment. This was done as it is difficult to develop a universal control strategy for all residential and commercial buildings and rooms. This project involves development of computational models and experiments for a closed computer lab like environment. The project also involves in development of sensor arrays consisting of a variety of IEQ sensors that involve in the multi-agent aspect of the project. The sensors sense the constituents of air, thermal properties, lighting and sound and help in taking coordinated decisions for achieving a better IEQ index. IEQ index was also modelled based on the Singapore’s Building and Construction Authority standards for Indoor Air Quality in Commercial and Residential Buildings and Environmental Authority, USA standards that where modelled earlier.

To achieve the aim, the following challenges where tackled during the course of the project:

1. Development of mathematical model for the wall: The basic element of the system that can be assumed to be
2. Development of mathematical model for the room: This involved multiple parameters that must be taken for the system to be as close as the real one. Various level of approximations are taken due to monetary and time restriction in the project so to be modelled and approximated to the experimental room.
3. Development of sensors array: The development of libraries for sensor array consisting of sensors that have different communication protocols with the edge processor that communicates with a central server present in the room.
4. Model fitting by approximations: The HVAC system present in the room couldn’t be controlled so the system needs to be approximated. The room is not a completely sealed environment as hence the leakage of air from the external environment into the room must be approximated.
5. A GUI environment was developed for the occupants of the room to have their preferred settings of their environment.

Literature Review:

Researches over the past decade have shown that majority of the people spend 80% of their time indoors which leads to increase standard of living but also demands the other requests to be satisfied [4]. The future focuses on the occupant comfort and energy consumption aspect of the building. This implies the primary problem for the building operators are the indoor environment quality and energy consumption of the building. The indoor environment quality which is directly affected by factors like Indoor Air Quality, Thermal comfort, Lighting comfort and acoustic comfort. Indoor Air quality and thermal comfort are affected by building material, construction material, level of air-conditioning which influence the health of occupants directly and influence their productivity. To improvise the comfort level of occupants it is essential that its occupants also form part of the feedback loop. The sensors help in taking coordinated decisions and improvise the IEQ index. Energy consumption of buildings depend significantly on controlling the Indoor air quality, temperature, humidity and lighting and it also depends on the building design and operation. Reducing energy consumption and improvising IEQ index is the ideal goal of futuristic buildings. According to [5], the studies have shown that the cost of poor indoor environment is higher than the energy consumption in the same building as poor IEQ results in poor productivity of the occupants. Thereby improvising IEQ is the approach for energy minimization and also better comfort for the occupants.