Design of Smart Diffuser System using the Sensor Network and Machine Learning Techniques for Energy Efficiency and Human Comfort

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MOTIVATION

- Although the main function of the Heating, Ventilation and Air-conditioning (HVAC) system in commercial and residential buildings is to maintain comfortable indoor conditions, provide safety and acceptable indoor air quality, this has not been the case.
- Often, the HVAC system works at capacity to satisfy the one occupant who represents the "worst case" within that zone.
- The downside to HVAC systems is the associated high-power consumption.
- According to the building energy data book of the US Department of Energy (DOE), about 50% of the energy consumption in buildings is directly related to space heating, cooling and ventilation as shown in Figure 1.
- Achieving a level of individualized optimum comfort control within the same room or space in buildings is not possible today.
- Most organizations only use between 45% and 65% of their office space.

➢ **Residential Sector Energy Consumption**

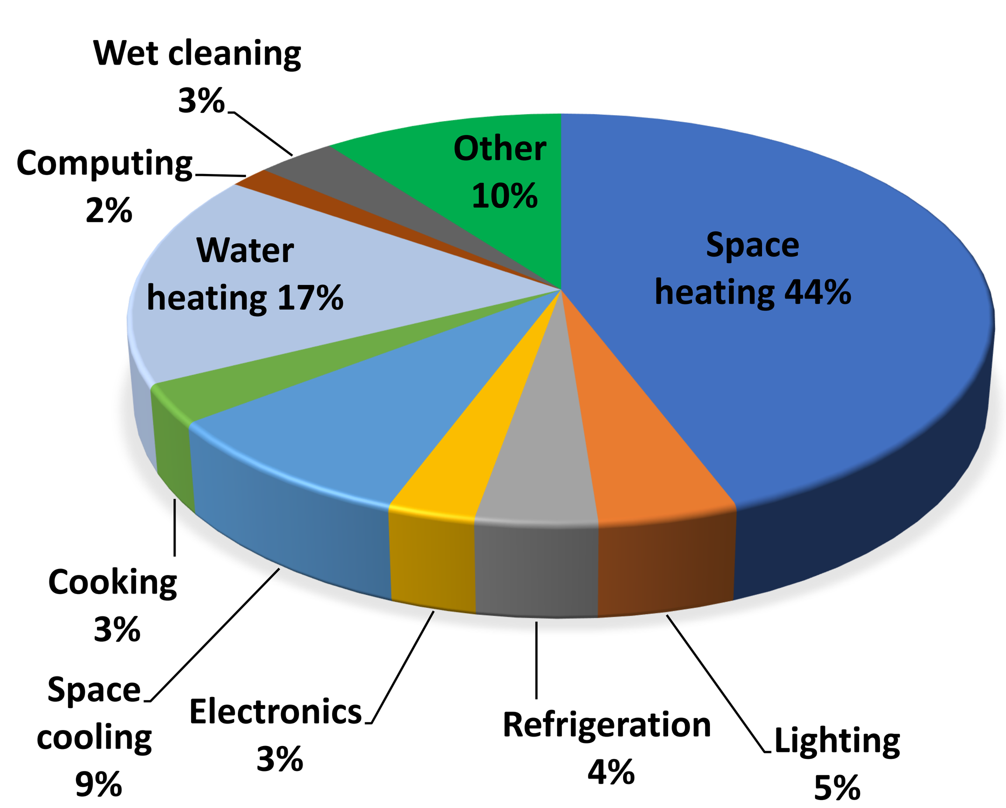

Figure 1. 2015 Residential Energy End-Use Splits

OBJECTIVES

- Collection of multi-sensor readings in a tabular database format with the corresponding time-stamp of infrared images.
- Development of Machine Learning based AI models and big data Analytics for HVAC energy control utilizing Infrared Occupant Detection (IROD) and Smart Diffuser Sensor Network (SDSN).
- Calibration of sensors.
- Retraining of Machine Learning models for improved models.

INFRARED THERMAL COMFORT REVIEW

Table 1. Studies on Advanced Infrared Sensing Techniques for Thermal Comfort Models

Reference	Input variables: Subject Feedback	Input variables: Hardware	Deficiency/Drawbacks
(Ghahramani et al.,2016)	7 scales of thermal votes – (Much Too warm/ uncomfortably warm/ Comfortably warm/ Comfortable/ Comfortably Cool/ Uncomfortably Cool/ Much Too Cool	Glass frame fitted with four infrared sensors(MLX90614), Two electrical heaters, AC system, Temperature/ Humidity sensor (Aosong AM2302 and Arduino Uno	Method still required physical contact to the occupant which indicates intrusiveness.
Wang et al. (2017)	9 – perceptions (hot/ cold/ dry/ humid/ humid/ glare/ dark/ draft/	Sensors (Temperature and Humidity, CO_2 concentration, globe temperature, air speed, sound level, motion sensor and electricity meter	Applicability of thermal cameras in the real operational settings was limited as occupants cannot move around at will.
(Pavlin et al., 2017)	ASHRAE 7-point thermal sensation scale	Lepton infrared camera, Raspberry Pi 2, DHT11 sensor, ultrasonic sensor HC SR04, Resistance Temperature detector, Globe Thermometer, Capacitive Hygrometer	Low-resolution thermal camera extracted crude measurements of the forehead.
(Han et al., 2017)	5 – point scale thermal votes (comfortable/ slightly uncomfortable/ /uncomfortable, / very uncomfortable/ intolerably uncomfortable	Infrared camera, a computer, HMI on a cellphone, a control software, a ventilation fan, a fan coil unit, and a dehumidifier	The scenario of occupants moving in the room was not considered.
(Cosma and Simha, 2018)	3 – point scale thermal comfort votes (cold discomfort/ comfort / warm discomfort)	A depth sensor and color camera combination (Kinect 2), a thermographic camera (Flir lepton) and a point IR sensor (MLX90614)	Remote sensing platform could only mainly see upper part of the body. Thermographic camera significantly had a lower image resolution.
(Metzmacher et al., 2018)	N/A	FLIR A35 thermographic camera, Microsoft Kinect, PT100 platinum resistance. thermometers, DT85	Temperature sensor was affixed to the skin which makes method invasive.
(Burzo et. al., 2018)	3 – point scale thermal comfort votes (cold discomfort/ comfort / warm discomfort)	FLIR SC6700 Thermal camera, Flir One camera	Manual detection of thermal faces.

SENSOR INSTALLATION AND DATA COLLECTION

➢ **Preliminary Work**

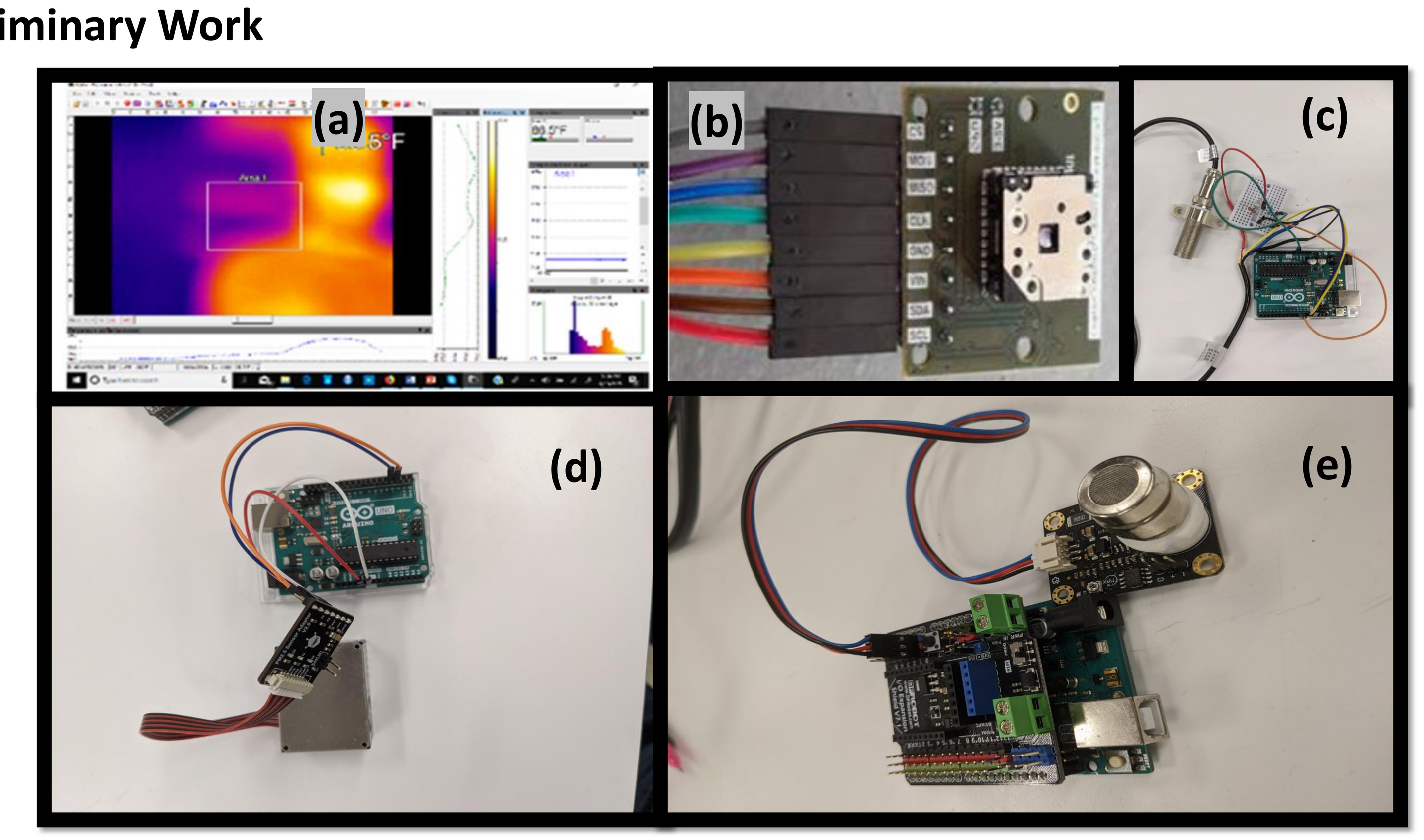

Figure 2. (a) Optrix Connect Software: Optrix PI 160 captures accurate, calibrated and noncontact temperature data in every pixel of each image.
(b) Lepton camera connection.
(c) Temperature and Humidity sensor and Arduino Uno connections.
(d) Air Quality Monitor and Arduino Uno connections.
(e) CO_2 sensor and Arduino Uno connections.

MACHINE LEARNING PROCESS FLOWCHART

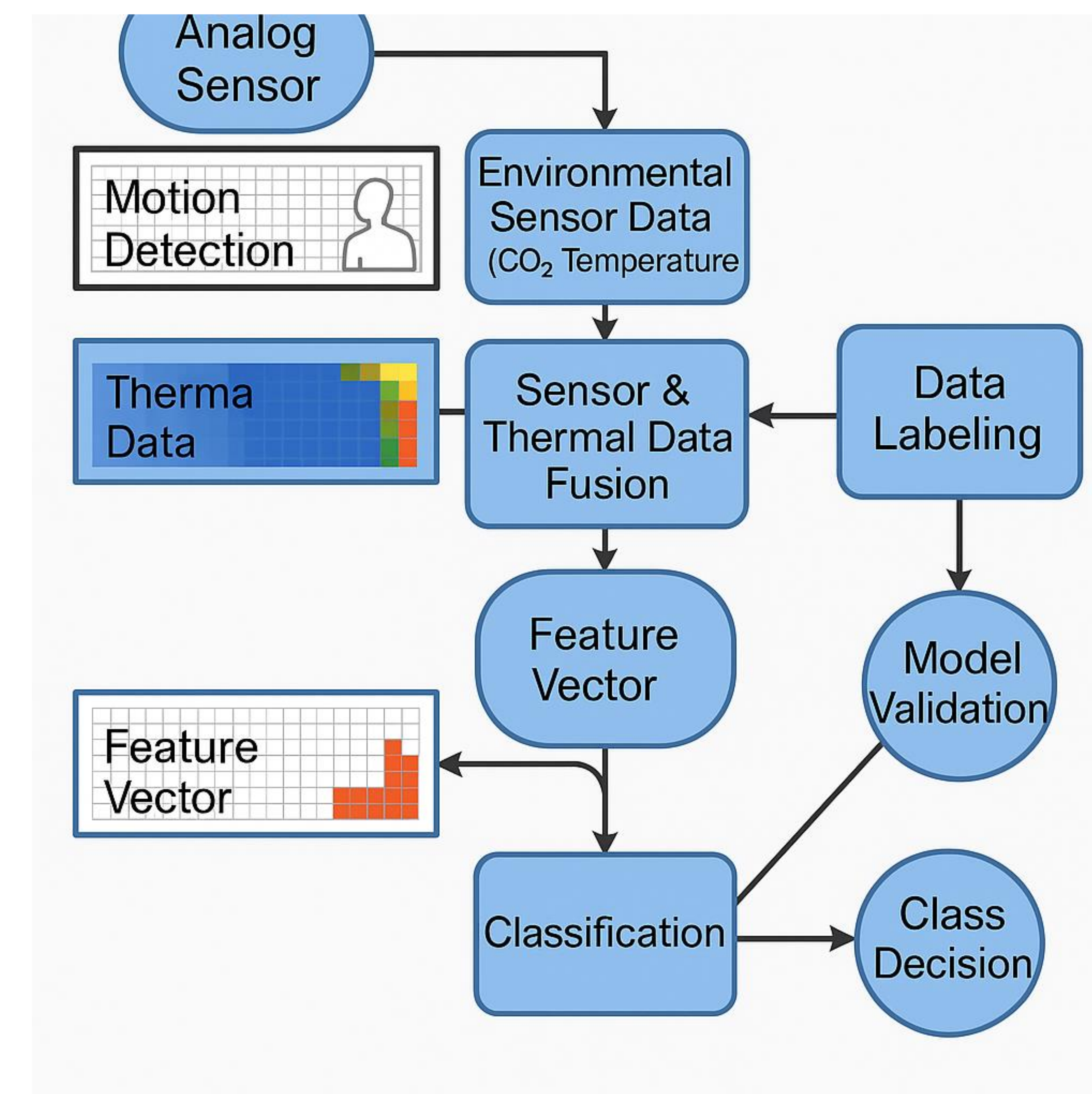

Figure 3. Machine Learning Process Flow Chart

CONCLUSION

- This research distinguishes itself from the references reviewed in Table 1 by eliminating the conventional thermostatic control and developing a Machine Learning Model utilizing Big data Analytics by fusing the analog signals and thermal images from various sensors in the network to control the HVAC system.
- The preprogrammed microprocessors with Machine Learning models , measure and respond to room changes in heating and cooling changes.

KEY REFERENCES

- ASHRAE. Standard 55-2013. Thermal Environmental Conditions for Human Occupancy, 12; ASHRAE: Atlanta, GA, USA, 2013
- Ghahramani Ali & Castro, Guillermo & Ahmadi-Karvigh, Simin & Becerik-Gerber, Burcin. (2018). Towards unsupervised learning of thermal comfort using infrared thermography. Applied Energy. 211. 41-49. 10.1016/j.apenergy.2017.11.021.
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