Activity Recognition for Energy Efficiency

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***Abstract*—This report is about the project for energy efficiency by detecting activity recognition. Often in offices, conference rooms, etc. people forget to turn off the lights and other electronic devices when these are not in use. This leads to unnecessary wastage of electricity. The project is an effort to reduce the unnecessary consumption of electricity and thus conserve considerable amount of precious energy. We have designed a model which checks for activity like talking, movement, etc. using microphone in the conference room. If some activity is detected then the simulated room lights and AC are controlled. The AC is controlled on the basis of simulated temperature and humidity sensor values. The AI Agent also schedules meetings from a centralized server by accepting requests from multiple clients. By observing the results, it has been found that above proposed model gives accurate results when activity takes place within 2 meters of the microphone sensor.**

***Index Terms*—K-Means, Nearest Neighbor Rule, Fuzzy Logic, Energy Efficiency.**

1. Introduction

Energy wastage is a big concern nowadays. With increasing technology, consumption of electricity is increasing and in turn wastage of electricity is also increasing. K-means clustering algorithm, nearest neighbor classification and fuzzy logic are used to implement the project. Conference rooms are targeted in the project for energy consumption as in a professional setup, there are mostly big conference rooms with multiple ACs, Fans and lights with one or two projectors and microphones. These devices use a huge amount of electricity. If after the meeting, the devices are not turned off then it causes a big wastage of energy. Any software system cannot detect the presence of people in conference rooms and hence it can not decide whether lights, fans and ACs are required at the time or not.

To achieve the goal of minimizing energy consumption in conference rooms, we have analyzed a conference room continuously for some appropriate time duration. The duration for analysis is selected such that in that duration, the meeting is on and off multiple times. This is done to get accuracy in clustering. K-means clustering is a method of vector quantization that is popular for cluster analysis in data mining. The K-means clustering algorithm partitions n observations into k clusters in which each observation belongs to the cluster with the nearest mean. In our case, k is 3. When the test data comes, it is classified into one of the clusters and according to that, particular action is performed. Above all, the model also tries to save energy while meeting is going on. When AC is turned on, after some time the temperature gets low. The temperature sensor and humidity sensors are applied for continuously sensing the temperature and humidity. These two sensors data is used to control the climate of the conference room when some activity is going inside based on Fuzzy Logic.

We have implemented energy efficiency for the following observed scenarios of activities, like meeting:

1. Many times meeting is over before the schedule time of ending.

2. Many time it happens that meeting was scheduled, but it did not happen.

3. Many time it happens that meeting room is used for some other purposes which are not scheduled like maintenance.

2. Motivation

There are several motivations behind implementing the project. Reducing energy consumption reduces energy costs and results in a financial cost saving to companies and consumers if the energy savings technique does not take any great cost. Air conditioners are responsible for emission of a huge amount of greenhouse gases. Thus reducing energy use (mainly AC) is also a solution to the problem of reducing greenhouse gas emissions. According to the International Energy Agency, the improved energy efficiency in buildings, industrial processes and transportation could reduce the world's energy needs in 2050 by one third, helping in controlling global emissions of greenhouse gases.[1]

3. Methodology

The methodology in detail is as follows:

3.1. Scheduling the Meeting:

The conference rooms in any organization may be booked by many individuals. We are calling those individuals as authorized clients. There is a centralized program/agent running on the server which allows authorized clients to book the date and slot of the meeting. The agent maintains the centralized database which is used for its operations. When a client wants to book the meeting slot, it logins on the agent. If that user is not authorized, then the agent will not allow the client to book the meeting slot. In case of successful login, the client is able to book the slot. If a client wants to book an already booked slot, then the agent will send a message to client indicating that the slot is already booked with the user name who booked it. In case the meeting is adjourned the user can delete the meeting scheduled by him/her.

3.2. Training the Model

For training purpose, we have continuously sensed a conference room for the duration in which meeting is turned on and off multiple times. When the training gets over, we get 3 types of clusters:

- First Cluster: It indicates that there is very little noise in the room (Meeting OFF)
- Second Cluster: It indicates that there is some noise in the room indicating moderate activity (Meeting ON)
- Third Cluster: It indicates that there is very much noise in the room which implies heavy activity (Meeting ON)

This training process should be carried out before the energy efficiency module is activated. The output of the training process is the codebook consisting of the centroid among the samples present in a cluster: C1,C2 and C3. This training process basically ensures that we get a idea what are the decibel levels in the room when there is no meeting ongoing indicated by value of C1. This value will vary from room to room according to the environment and presence of external disturbances like generators,servers in the room leading to some noise. Thus this model is genric and can be implemented in any room in any place.

3.3. Detecting Activity:

After the training is over, the trained model is applied for detecting the activity inside the conference room. There are two states in the system: Meeting ON and Meeting OFF.

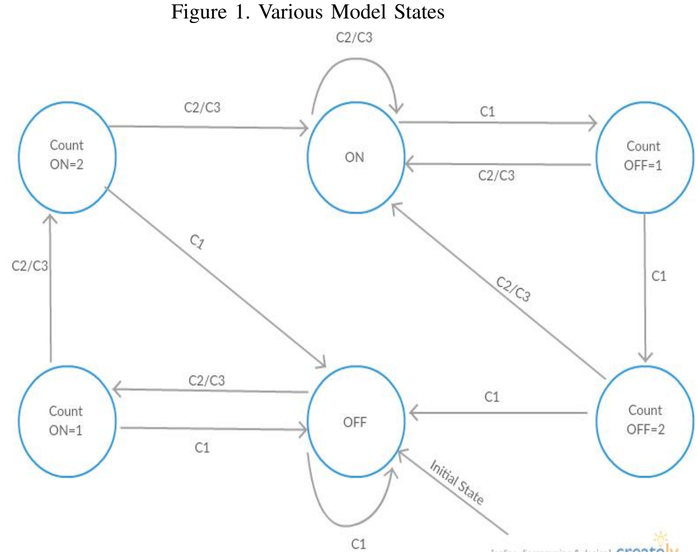
A microphone in the conference room is always on. It continuously records the sound in the room and at a specific interval, the classification algorithm is used to classify it into one of the three clusters. Nearest neighbor rule method based on the centroid of the test data is used for classification here. Three consecutive classification results will tell the current state of the system. For example: If the initial state is Meeting OFF and then three consecutive classification are mapping into cluster 2 or cluster 3, then the current state will be Meeting ON.

The following diagram shows various states of model at different inputs

TABLE 1. TEMPERATURE

Fuzzy Set	Range (degree C)
Very Low	15-20
Low	20-25
High	25-30
Very High	30-40

Figure 1. Various Model States



3.4. Controlling the Air-Conditioner

To control the AC while meeting is going on, we are using knowledge based Fuzzy Logic. The fuzzy sets which define the linguistic terms(Very Low, Low, High, Very High) for Temperature are shown in table 1.

The fuzzy sets which define the linguistic terms(Dry, Comfortable, Humid, Sticky) for Humidity are shown in table 2 .

The fuzzy sets which define the linguistic terms(Off, Low, Medium, Fast) for the output AC Compressor Speed are shown in table 3.

Rules we have defined for AC Compressor Speed control are:

Rule 1: If Temperature is Very Low and Humidity is Dry then Compressor Speed = 0

Figure 2. Membership Function of Temperature

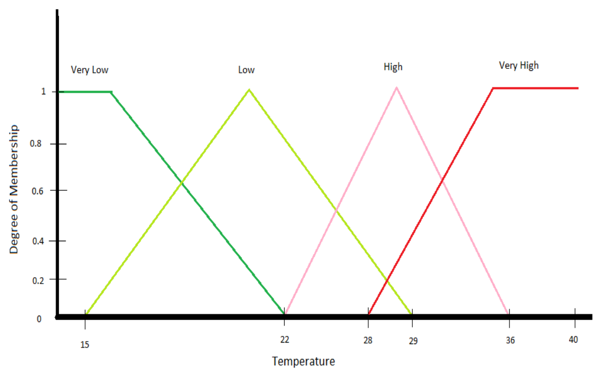


Figure 3. Membership Function of Humidity

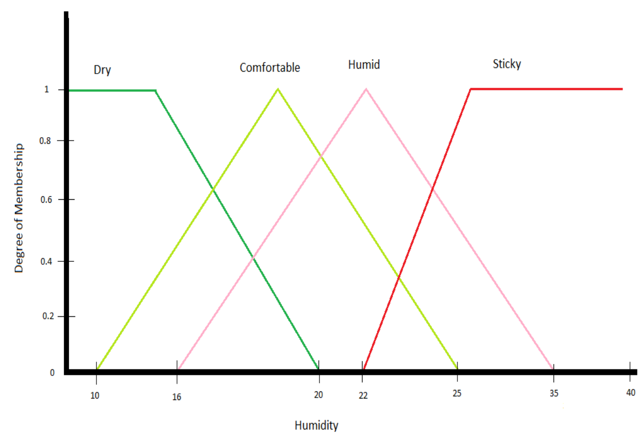


TABLE 2. HUMIDITY

Fuzzy Set	Range(in g/m3)
Dry	10-15
Comfortable	15-20
Humid	20-25
Sticky	25-40

Rule 2: If Temperature is Very Low and Humidity is Comfortable then Compressor Speed = 0

Rule 3: If Temperature is Very Low and Humidity is Humid then Compressor Speed = 0

Rule 4: If Temperature is Very Low and Humidity is Sticky then Compressor Speed = 0.3333

Rule 5: If Temperature is Low and Humidity is Dry then Compressor Speed = 0

TABLE 3. COMPRESSOR SPEED

Fuzzy Set	Value(in g/m3)
OFF	0
Low	0.3333
Medium	0.6667
Fast	1

Rule 6: If Temperature is Low and Humidity is Comfortable then Compressor Speed = 0

Rule 7: If Temperature is Low and Humidity is Humid then Compressor Speed = 0.3333

Rule 8: If Temperature is Low and Humidity is Sticky then Compressor Speed = 0.6667

Rule 9: If Temperature is High and Humidity is Dry then Compressor Speed = 0.3333

Rule 10: If Temperature is High and Humidity is Comfortable then Compressor Speed = 0.6667

Rule 11: If Temperature is High and Humidity is Humid then Compressor Speed = 1

Rule 12: If Temperature is High and Humidity is Sticky then Compressor Speed = 1

Rule 13: If Temperature is Very High and Humidity is Dry then Compressor Speed = 0.6667

Rule 14: If Temperature is Very High and Humidity is Comfortable then Compressor Speed = 1

Rule 15: If Temperature is Very High and Humidity is Humid then Compressor Speed = 1

Rule 16: If Temperature is Very High and Humidity is Sticky then Compressor Speed = 1

These rules are of Sugeno(Zero-Order TSK) type. We have simulated the sensor data for Temperature and Humidity in a room. This data is used to calculate the AC Compressor Speed for climate control in the room. For this we calculated the firing strengths of each of our Sugeno type Rules and used them for Inference. We used Product Method to calculate the firing strengths. For inference we used the following formula:

$$Y = \frac{\sum_{i=1}^{N} wiyi}{\sum_{i=1}^{N} wi}$$

where, wi is the firing strength of rule i
yi is the output of rule i
N is the number of rules
Y is the final crisp output which is the weighted average of all the rule outputs.
So we get the AC Compressor Speed which is suitable for the room.

4. Results

The K-means clustering algorithm with the K=3 converged after 35 iterations for data collected in a room. Initial centroids of the clusters were 500, 1500 and 5000 units respectively based on the assumption that the speaker should be at an average of 1 meter away from the mic. Their values are can be shown by the following Table 1:

The following table shows that silence in the room amounted to a noise which has a centroid at around 442 units of amplitude. The distortion increases monotonically with iteration number as the centroids move more and more away from the initial values. There is a huge displacement of the centroid of cluster 3 which shows that the signal for training our model captured by the systems microphone mainly had noise with a large amplitude.
The results of the classification algorithm are shown below with mainly 3 cases in 3 instances.
1. Centroid value of 163.667325 units for sound captured in complete silence for a interval of 20 seconds. It has a distance of 278.4513329765493 units from the centroid of cluster 1 and hence the data was being mapped to silence zone.
2. Centroid value of 993.5479375 units for normal talking sound captured at a distance of about 1 meter from the microphone for a duration of 5 seconds for a interval of 20 seconds. It has a distance 551.4292795234508units from the centroid of cluster 2 and hence the data was being mapped to moderate activity zone.
3. Centroid value of 7591.0624625 units for normal talking sound captured at a distance of about 1 meter from the microphone for a duration of 15 seconds for a interval of 20 seconds. It has a distance 2776.0661303069173 units from the centroid of cluster 3 and hence the data was being mapped to heavy activity zone.

Thus our model was successfully able to distinguish sounds of varying intensity and detect activity in the room.

TABLE 4. RESULTS OF K-MEANS CLUSTERING ALGORITHM

Iteration No.	Avg Distortion	C1 centroid	C2 centroid	C3 centroid
1	2.3625	226.9551	2235.2215	7234.2078
5	4.3089	314.0867	3642.3603	10076.8547
10	5.4456	397.7910	4420.1616	11346.6578
15	5.8735	428.6161	4689.2679	11787.3118
25	6.0815	441.1021	4806.0673	11999.1074
35	6.0967	442.1186	4814.9963	12014.3425

TABLE 5. RESULT OF CLASSIFYING VARYING SOUND DURATION

Duration of sound	Centroid of the data	Classification result
0 (Silence)	163.667325	Cluster 1
4 seconds	596.05739375	Cluster 1
8 seconds	993.5479375	Cluster 2
12 seconds	3031.9053625	Cluster 2
20 seconds	7591.0624625	Cluster 3

This simple classification algorithm was initiated after a duration of 1 minute and carried out for 3 minutes. If results of 3 consecutive runs mapped the room data into cluster 1 we concluded that there was no activity in the room and the simulated AC as well as the lights were turned off. Similarly if 3 consecutive runs mapped data to cluster 3 we concluded that there was reasonable activity in the room and proper actions (turning the AC climate control by fuzzy logic and Lights on) were simulated.

5. Limitations and Future Scope

This model may not yield accurate results in the following scenarios:
1. When activity producing low sound like reading books is ongoing, the model may turn off the lights and AC assuming that the room is empty.
2. This model uses a single microphone to capture sound which might not lead to good results. **3.** The prototype used for this model can be further improved by using occupancy sensor combined with microphone to detect activity. Also additional appliances like projectors, fans which are used in a typical conference room can be controlled by interfacing with the prototype.

6. Conclusions

So it can be seen that the method to conserve energy in office rooms is fairly efficient when sound is captured close to the microphone. The efficiency can be further increased by:

1. Using more than one microphones stragetically positoned in different corners of the meeting room. In this case the training model will consider each sample as a value consisting of n tuples (t1,t2,t3,...,tn) where n=number of microphones the room.

2. Using better quality microphones. For the prototype which has been implemented in this project, in built microphones of the system has been used. To further increase the efficiency such that even small noises can be detected inside the room external microphones can be easily interfaced with the system.

Thus, this model is more suitable for rooms where activity in the form of talking takes place more frequently like lectures in the classrooms, brainstorming sessions, meetings, debates and will yield accurate energy efficiency schemes for these scenarios.

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