Comp 9418 Assignment 2 Report

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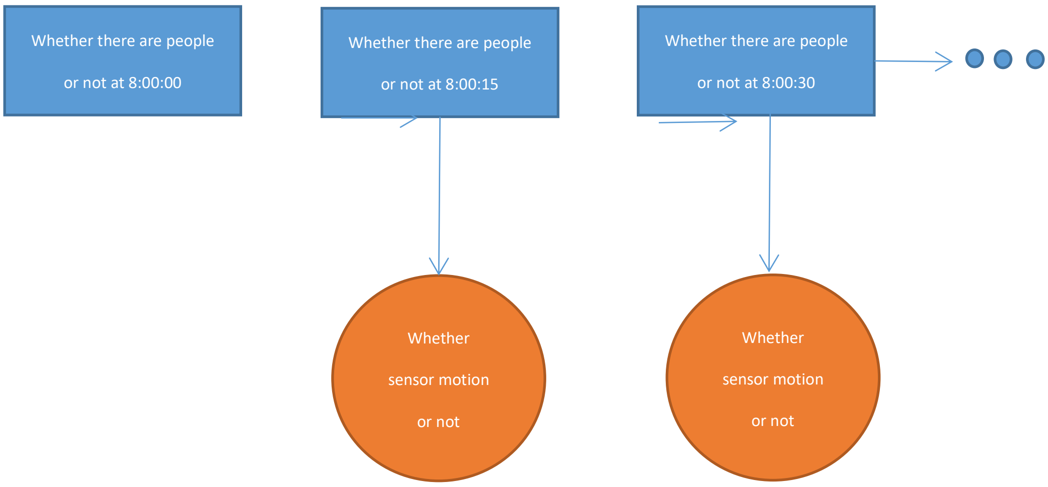
In this assignment, we use two models to predict the light states in the building. The first one in Hidden Markov Model and the second one is Naïve Bayes Model.

1 Hidden Markov Model

1.1 Assumption

Assuming all rooms are independent, and the sensor is only related to the room it is in.
According to the Markov chain, we find the probability of whether there is anyone in each room at each moment. If there are people in the room, then turn on the light. Otherwise, turn off the light.
Assuming that the state of the number of people in each room is Markovian. The state of the lights in the room at a certain moment is related to whether there are people, and the number of people in each room at the next moment is related to the number of people at present. This feature is consistent with the Markov property of the Markov chain.
We can construct the Markov model for each room like this:



1.2 Transfer table

The time t to t+1 for each room
Firstly, we assume that there are two states for each room (people in room, no people in room). The state space is (E1, E2). 'E1' means there is no people in the room and 'E2' means there are

people. According to the data, we can get the frequency distribution of the state space of the number of people with. Then, using the frequency distribution, we can obtain the frequency table of state transition for each room.
For example, the frequency table of state transition in room one shown as below:

People	E2	E1
E2	1284	77
E1	77	962

This table shows that the number of transitions from state ‘E2’ to state ‘E2’ is 1284. The same for other state transitions.
Divide the frequency of each state transition by the frequency of the state before the transition to get the transition probability table.
For example, the transition probability table for room one shown as below.

Transition Probability	E2	E1
E2	0.943	0.057
E1	0.074	0.926

So, the transfer table can be obtained by the transition probability table.
For example, the transfer table for room one is:

$$P(r1) = \begin{bmatrix} 0.943 & 0.057 \\ 0.074 & 0.926 \end{bmatrix}$$

The time complexity for transfer matrix is O(n^2), and n represents the length of state space.
Second, we should get the emission matrix.

1.3 Emit table

In terms of emit table, it describes the relationship between observation and the state of lights in each room. In this case, the observation is the state of sensor in each room. However, we can use the state of people (whether there is anyone) to indicate the state of light in one room.
The matrix can be represented in the following:

Whether there are some people or not

	on	off
motion		
No motion		

Whether sensor motion or not

Finally, we use Markov chain to compute the probability of turning on the lights and the probability of turning off the lights, respectively. Compare these two probabilities and follow the larger one.

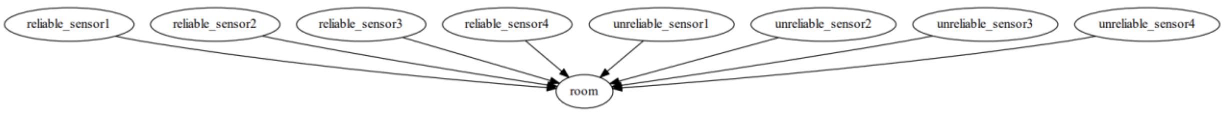
1.4 Model Disadvantage

(1) This method does not consider that the rooms are dependent. It only considers the changes in individual rooms.
(2) This method can only predict the state of lights of rooms with sensor because we assume that whether the sensor motion or not is only related to the actions of the people in the same room.

2 Naïve Bayes

2.1 assumption

In this method, we assume all rooms and all sensors are independent to each other.
For each room, all sensors are its parents, and we build a Naïve Bayes model to predict the state of it.

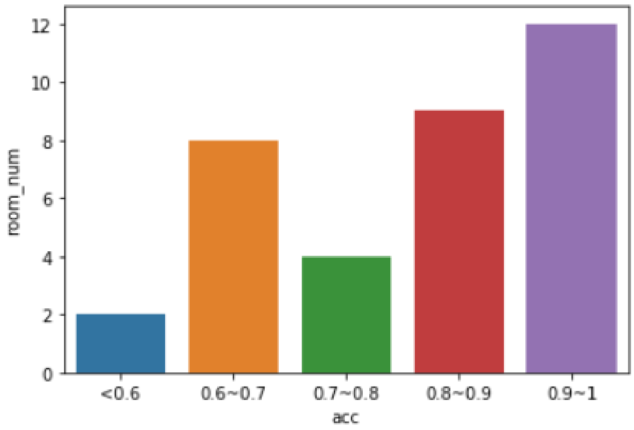


Given that each sensor only has two states (“motion” and “no motion”), we choose Bernoulli Naïve Bayes as our model. It calculates the prior probability of turning on the light or not. Then it figures out the conditional probability of whether there are some people in the room or not, the condition is the state of sensors.

2.2 Model training

To avoid overfitting, we select 80% of the data as our training set.
Because we assume all rooms are independent and we do not care about how many people move between them, the states of each room are “people in the room” and “no people in the room”. We label them as 1 and 0.
After training the model, we try to predict the rest 20% of the data. The result shows below:

R1	R2	R3	R4	R5	R6	R7	R8	R9	R10	R11	R12
0.91	0.84	0.63	0.70	0.97	0.84	0.78	0.95	0.71	0.82	0.59	0.94
R13	R14	R15	R16	R17	R18	R19	R20	R21	R22	R23	R24
0.74	0.61	0.66	0.97	0.67	0.62	0.68	0.87	0.85	0.87	0.90	0.94
R25	R26	R27	R28	R29	R30	R31	R32	R33	R34	R35	
0.97	0.85	0.69	0.98	0.97	1.0	0.97	0.84	0.58	0.61	0.84	



The average accuracy is 0.812. The results show that the model works well when faced with data that has not been encountered before. Therefore, we decided to use the predicted result as the main basis for judgment whether turning on the lights or not and add other conditions to modify the result.

Because robots give us the exact number of people in the room, we turn on the light when robots say there are some people in the room. However, when we try to use door sensors to increase the model, the result become worse. So, we decide to abandon door sensors.

Given the fact that the cost of turning off the light when someone in the room is much higher than the cost of turning on the light when no one in the room. We did not directly use the prediction results but let the model output probabilities.

Intuitively, when the probability of turning on is close to the probability of turning off, we should turn on the light. Only if the former probability is four times greater than the latter one, we turn off the light.

Then we use this model to predict the example simulator. The result in the example test is around 60000, which is much better than using HMM model. And it takes 21 seconds to go through one day.

3 Model Comparison

Model Name	Cost	time
HMM	Around 79000	4s
Naïve Bayes	Around 60000	21s

When we feed data to models, HMM uses two matrix multiplications, however Naïve Bayes needs to call the model of each room. So, the time cost of NB is much higher than HMM.

On the other hand, NB's accuracy is much better than HMM and the final cost is lower.

So, we choose NB as our final model.