

# “Robot” localisation with HMM based forward-filtering

This task is essentially corresponding to task 15.9 in the course book, with a more detailed specification of the sensor model. The task relies on the explanations for matrix based forward filtering operations according to section 15.3.1 of the book.

Hence:

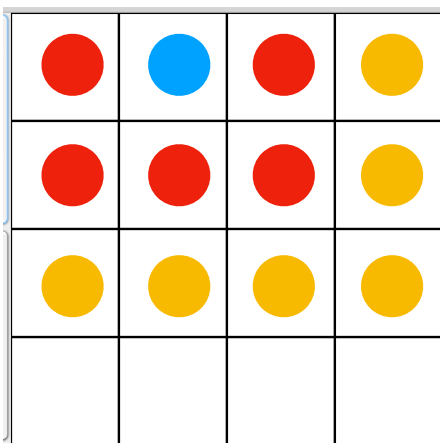
If you do not have access to this particular edition ([Artificial Intelligence: A Modern Approach](#), 3/e, by Stuart Russell and Peter Norvig, ISBN-10: 0132071487) and thus have difficulties in figuring out what to do, please contact me (Elin) at [Elin\\_Anna.Topp@cs.lth.se](mailto:Elin_Anna.Topp@cs.lth.se) before attempting to solve the task!

## In short

You are assumed to work with robot localisation based on forward filtering with a Hidden Markov Model.

## In detail

You are supposed to implement an HMM to do forward filtering for localisation in an environment without any landmarks. Consider the (in the book) previously mentioned vacuum cleaner robot *in an empty room*, represented by an  $n \times m$  rectangular grid. The robot's location is hidden; the only evidence available to you (the observer) is a noisy sensor that gives a direct, but vague,



approximation to the robot's location. The sensor gives approximations  $S = (x', y')$  for the (true) location  $L = (x, y)$ , the directly surrounding fields  $Ls$  or the “second surrounding ring”  $Ls2$  according to the specifications below. Here,  $n_{Ls}$  is the number of directly surrounding fields for  $L$  (this can be 3, 5, or 8, depending on whether  $L$  is in a corner, along a “wall” or at least 2 fields away from any “wall”) and  $n_{Ls2}$  is the number of secondary surrounding fields for  $L$  (this can be 5, 6, 7, 9, 11, or 16, depending on where  $L$  is located relative to “walls” and corners).

In the example in the figure, the blue spot marks  $L$ , the red spots are the in this situation possible 5 positions in  $Ls$ , and the yellow dots mark the 6 possible positions in  $Ls2$ .

The sensor reports

- the true location  $L$  (blue) with probability 0.1
- any of the  $n_{Ls} \in \{3, 5, 8\}$  existing surrounding fields  $Ls$  (red, here  $n_{Ls} = 5$ ) with probability 0.05 each
- any of the  $n_{Ls2} \in \{5, 6, 7, 9, 11, 16\}$  existing “secondary” surrounding fields  $Ls2$  (yellow, here  $n_{Ls2} = 6$ ) with probability 0.025 each
- “nothing” with probability  $1.0 - 0.1 - n_{Ls} \cdot 0.05 - n_{Ls2} \cdot 0.025$ .

This means that the sensor is more likely to produce “nothing” when the robot's true location is less than two steps from a wall or in a corner (there are also other possibilities of setting up the sensor model, but you should stick to this model for the implementation).

0.00	0.00	0.00	0.00	0.025	0.050	0.050	0.050	0.625	0.500	0.500	0.625
0.00	0.00	0.00	0.70	0.025	0.025	0.050	0.050	0.625	0.625	0.500	0.500
0.00	0.00	0.00	0.00	0.025	0.050	0.050	0.050	0.625	0.500	0.500	0.625
0.00	0.00	0.00	0.00	0.025	0.050	0.100	0.050	0.500	0.325	0.325	0.500
0.00	0.00	0.00	0.00	0.025	0.025	0.050	0.100	0.500	0.500	0.325	0.325
0.30	0.00	0.00	0.00	0.025	0.050	0.100	0.050	0.500	0.325	0.325	0.500
0.00	0.00	0.00	0.00	0.025	0.050	0.050	0.050	0.500	0.325	0.325	0.500
0.00	0.00	0.00	0.00	0.025	0.025	0.050	0.050	0.500	0.500	0.325	0.325
0.00	0.00	0.00	0.00	0.025	0.050	0.050	0.050	0.500	0.325	0.325	0.500
0.00	0.00	0.00	0.00	0.025	0.025	0.025	0.025	0.625	0.500	0.500	0.625
0.00	0.00	0.00	0.00	0.025	0.025	0.025	0.025	0.625	0.625	0.500	0.625

In the three figures above you see a grid visualisation (each cell  $(x, y)$  has four headings, representing a bundle of four states with DIFFERENT probabilities to be reached from a specific state, but with the SAME probability to have caused a certain sensor reading) of one row of the transition matrix and the diagonal of one observation matrix. The images show the following:

Left: The transition visualisation shows the probabilities to go from  $(0, 0, \text{EAST})$  (cyan) to any other state, i.e. only two states,  $(0, 1, \text{EAST})$  and  $(1, 0, \text{SOUTH})$  are possible and have a probability larger than 0.

Middle: Here, you see the probabilities for each respective state  $(x, y, h)$  to have generated the (cyan) reading  $r = (1, 2)$ .

Right: These are the probabilities for each respective state  $(x, y, h)$  to have generated “nothing”.

**Hint 2:** Even though a sensor reading of “nothing” normally means to do the forward step without update, i.e. it boils down to mere prediction in theory, you should use the information given in the known sensor model as stated above, i.e. a sensor reading of “nothing” is slightly more likely to get when the robot is close to a wall. Thus, even a “nothing” reading from the sensor should entail a proper prediction + update step.

**Evaluate** your implementation!

**Hint 3:** In terms of robot localisation it is often not relevant to know how often you are 100% correct with your estimate, but rather, how far “off” your estimate is from reality on average / how often. You could measure the distance between true location and estimate by using the Manhattan distance (how many robot steps off), or the direct Euclidean distance (looks nicer, but would not help a robot that can only move straight too much).

**Hint 4:** Assume a grid size of preferably  $8 \times 8$  (at least, however,  $5 \times 5$ ) to base your evaluation on. If you use Java and an  $8 \times 8$  grid, you should observe something like 30-35% of correct estimates rather quickly, roughly 100 steps should already get you there safely - note that this is only given as a reference for you, see hint 3 about evaluation of tracking systems. The average Manhattan distance (i.e. the number of “robot-steps” necessary to get from estimated to true position) should then be somewhere between 1.6 and 2.0. It is quite common to observe a checker-board pattern in the visualisation (see to the right, where the darker colours stand for higher, lighter for lower probabilities, grey is the highest one found, black is the true location and cyan marks the current sensor reading).

0.0000	0.0000	0.0000	0.0000
0.0000	0.0124	0.1127	0.0136
0.0000	0.1187	0.0289	0.3025
0.0000	0.0192	0.3222	0.0698

You can find a zip-file with a Java-based tool for visualisation of **your** transition model, **your** sensor model and your estimation (including some sort of user's guide) included in this archive! Feel free to use other programming languages (C++, Matlab, Python are ok as well) or tools, but if

you choose Java, please make use of the visualisation - it presumably helps us a lot to understand your implementation in case you need help!

**Note:** If you use the viewer tool, make sure that the viewer only shows what you actually use in your calculations, i.e. implement the transition and sensor model independently from the visualisation and just give to the viewer what the viewer asks for **as extracted data FROM your models!** A common mistake seems to be to set up two models, one for the visualisation and one that calculations are done with, if those differ, the inspection of models will look correct, but the program will produce incorrect results.

If you experience difficulties with understanding the task, setting up the models, getting the implementation to work, etc, please, CONTACT us well BEFORE the deadline!

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