NYU

Introduction to Robot Intelligence
[Spring 2023]

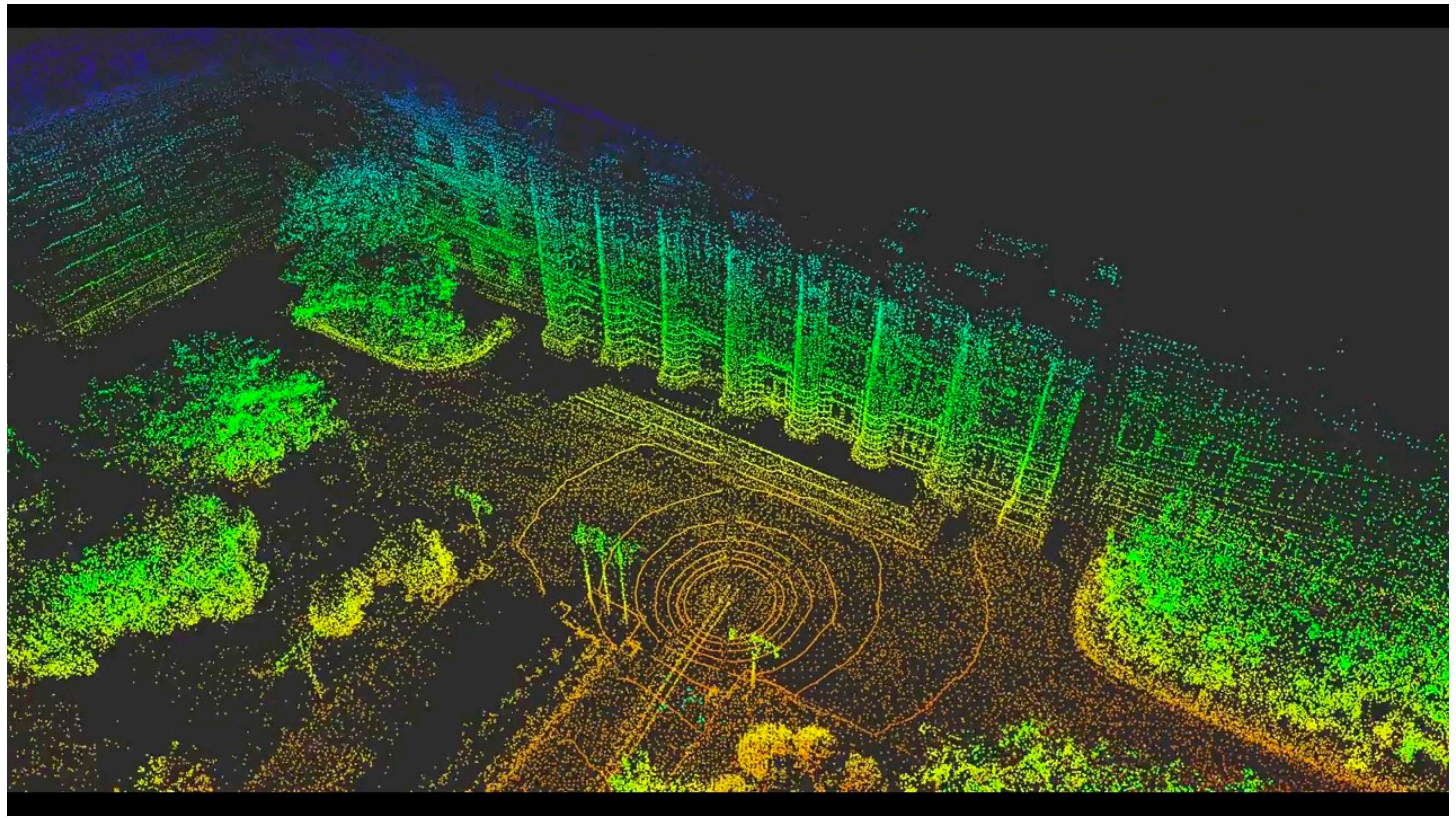
Probabilistic Robotics

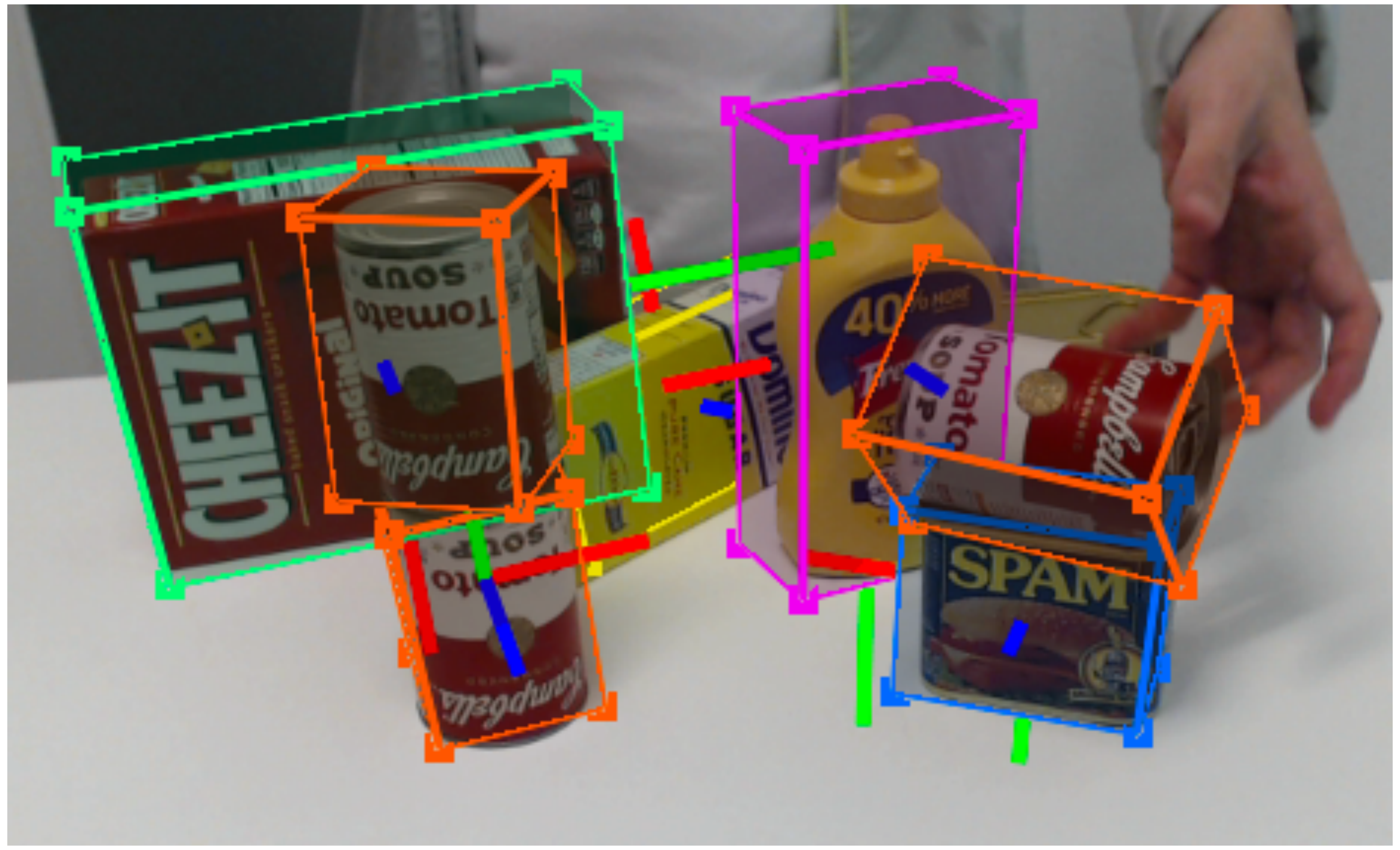
April 6, 2023

Lerrel Pinto

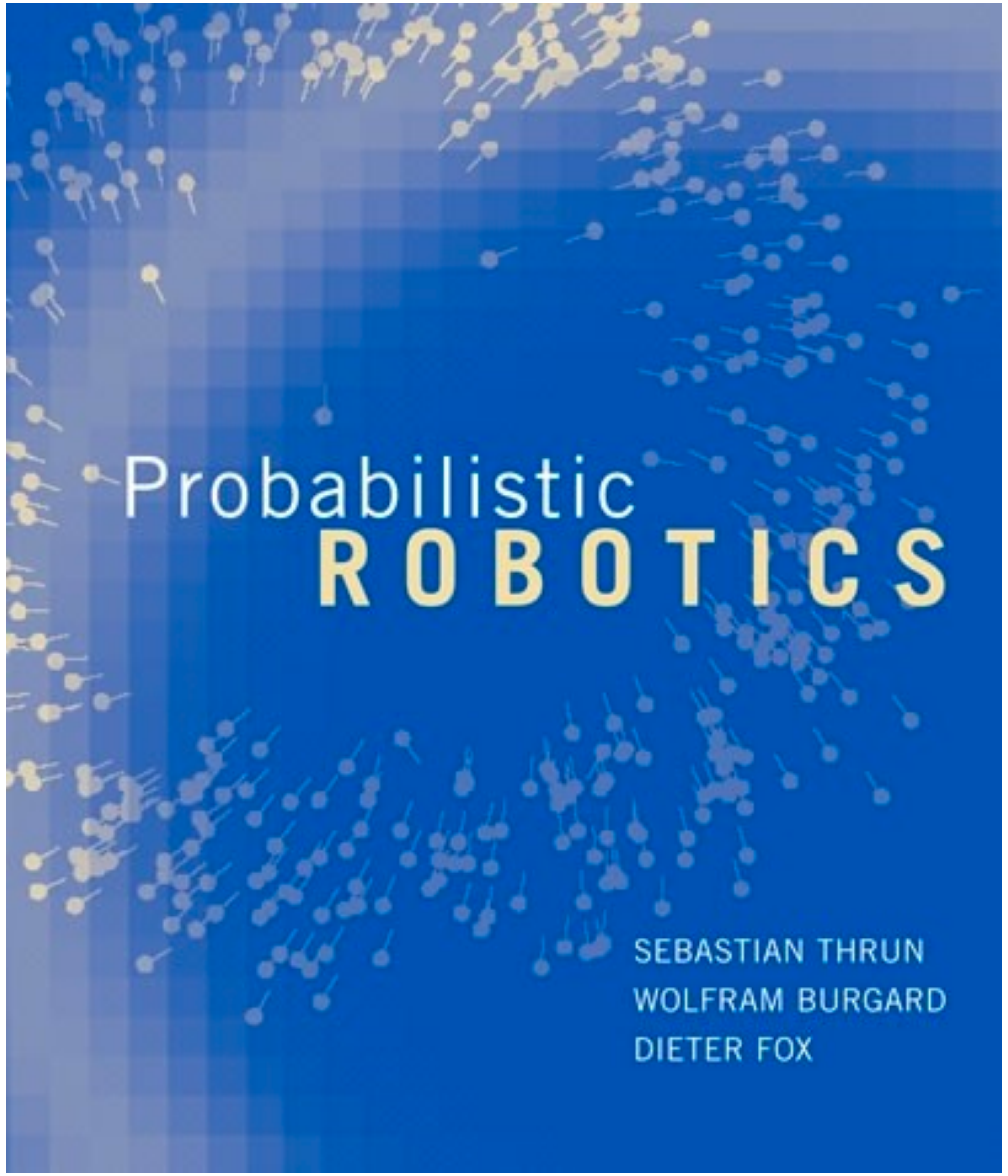
Challenges with sensing

- Dealing with inaccuracies/ noise in the sensor
- Integrating multiple sensors
- Modeling and mapping the environment

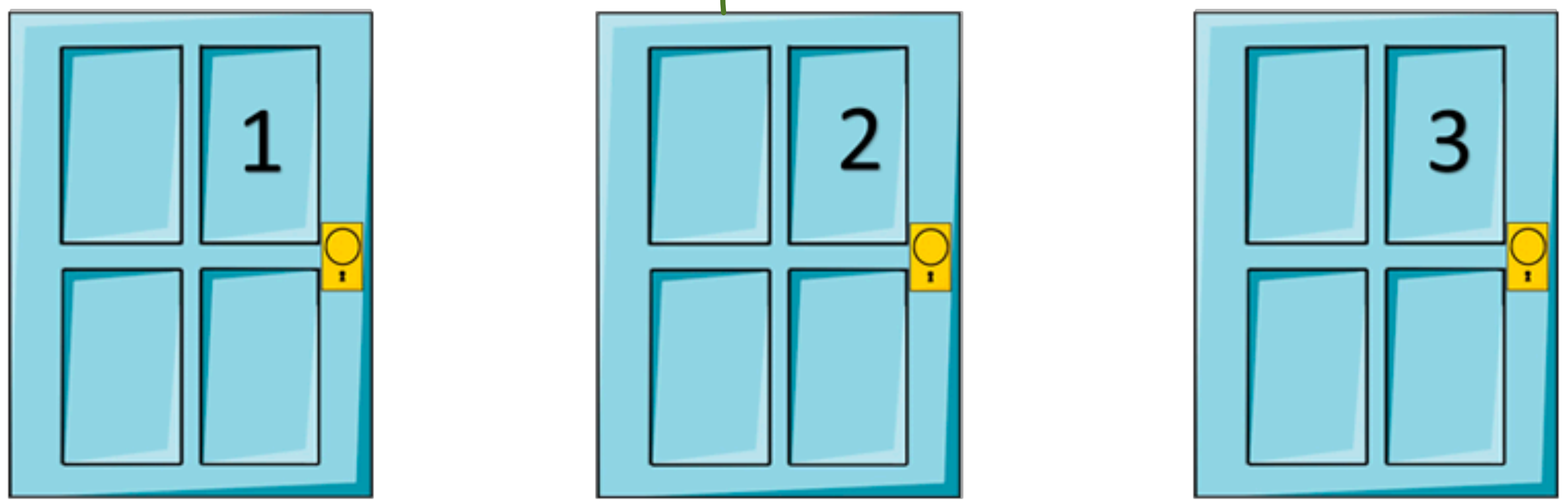




Key difference from previous portions:
Dealing with Stochasticity


Probabilistic
ROBOTICS
SEBASTIAN THRUN
WOLFRAM BURGARD
DIETER FOX

Probability exercises



0 $\quad$ $2/3$ $\quad$ $1/3$

switch

vs.

not switch

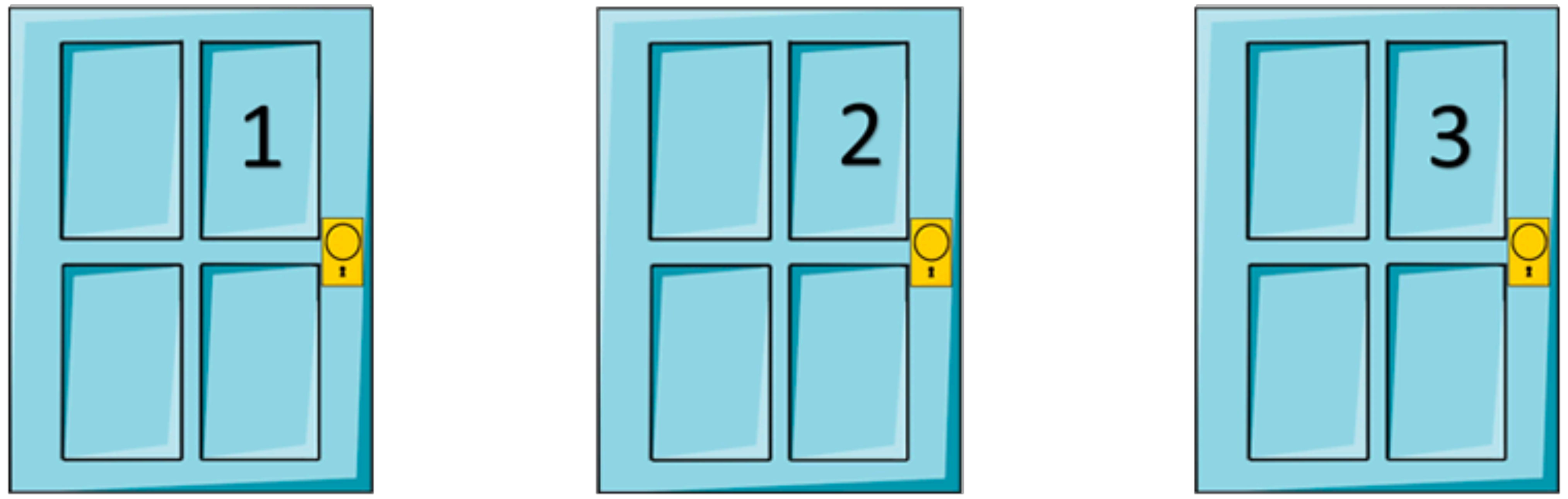
$2/3$? $\leftarrow P(\text{winning} \mid \text{switch}) >$

? $\leftarrow P(\text{winning} \mid \text{dont switch})$

$1/3$

$\Sigma p = 1$

Monty Hall Problem



Suppose you're on a game show, and you're given the choice of three doors: Behind one door is a car; behind the others, goats. You pick a door, say No. 1, and the host, who knows what's behind the doors, opens another door, say No. 3, which has a goat. He then says to you, "Do you want to pick door No. 2?" Is it to your advantage to switch your choice?

Blindfolded walk to wall

Does a positive test mean I am positive?

$p(\text{a person having covid}) = 0.1$ — $X=1$

$p(\text{testing positive} \mid \text{person has covid}) = 0.8$ — $Y=1$

$p(\text{testing negative} \mid \text{person has covid}) = 0.2$

$p(\text{testing positive} \mid \text{person doesn't have covid}) = 0.1$

$p(\text{testing negative} \mid \text{" " " "}) = 0.9$

$P(X=0) = 0.9 \quad P(X=1) = 0.1$

$\rightarrow P(Y=1 \mid X=1) = 0.8$

$P(Y=0 \mid X=1) = 0.2$

$\rightarrow P(Y=1 \mid X=0) = 0.1$

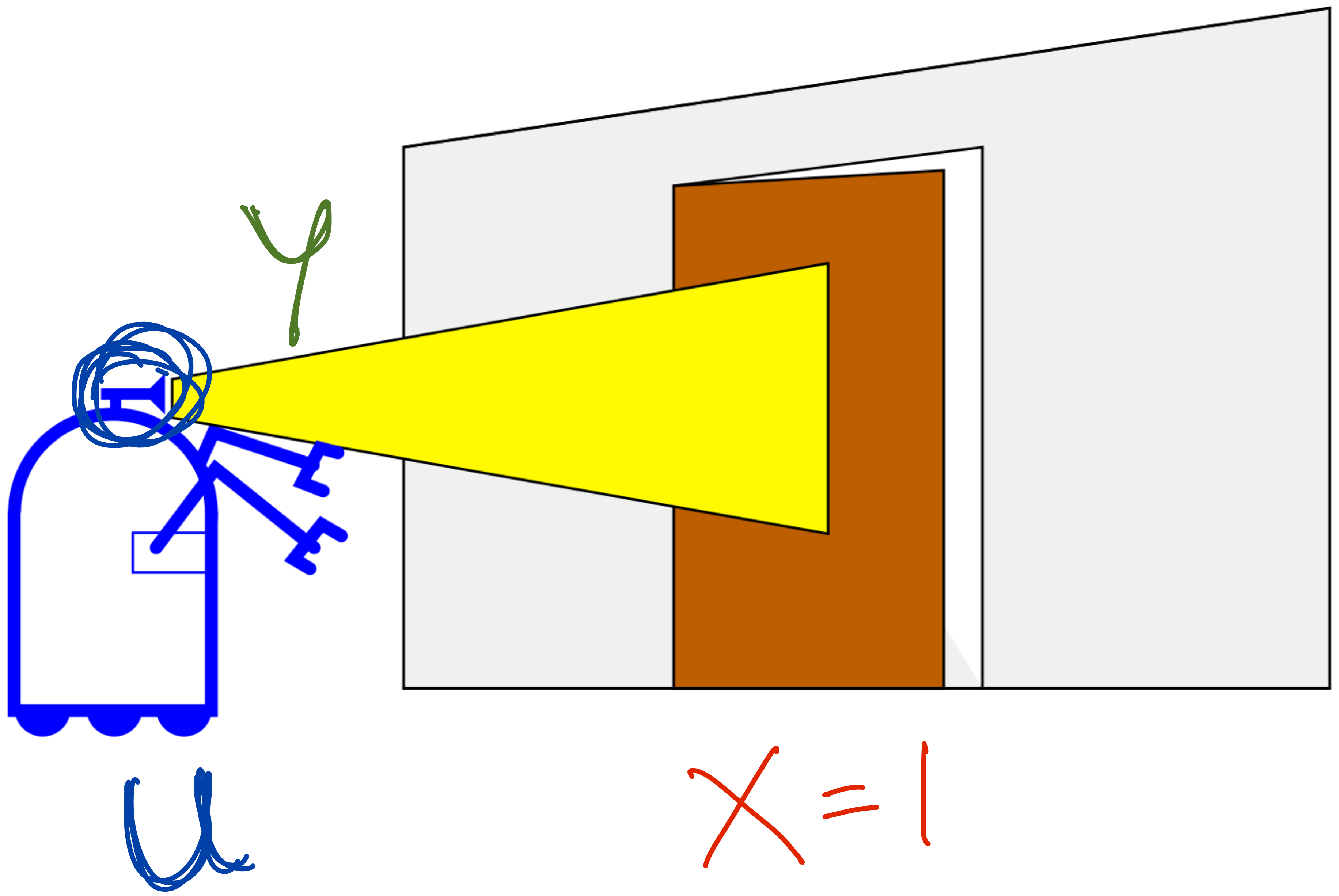
$P(Y=0 \mid X=0) = 0.9$

$$? \quad P(X=1 \mid Y=1) = \frac{P(Y=1 \mid X=1) \cdot P(X=1)}{P(Y=1)}$$

$$P(Y=1) = P(Y=1 \mid X=1) \cdot P(X=1) + P(Y=1 \mid X=0)\, P(X=0) = 0.8 \times 0.1 + 0.1 \times 0.9 = 0.17$$

Q: $p(\text{person has covid} \mid \text{testing positive}) = 8/17$

Is the door open?



$p(x=1) = 0.9$

$p(y=1 \mid x=1) = 0.8$

$\vdots$

$p(x=1 \mid y=1) = \frac{8}{17}$

$p(x=1 \mid y=1, u=1)$

$p(x=1 \mid y=1, u=0)$

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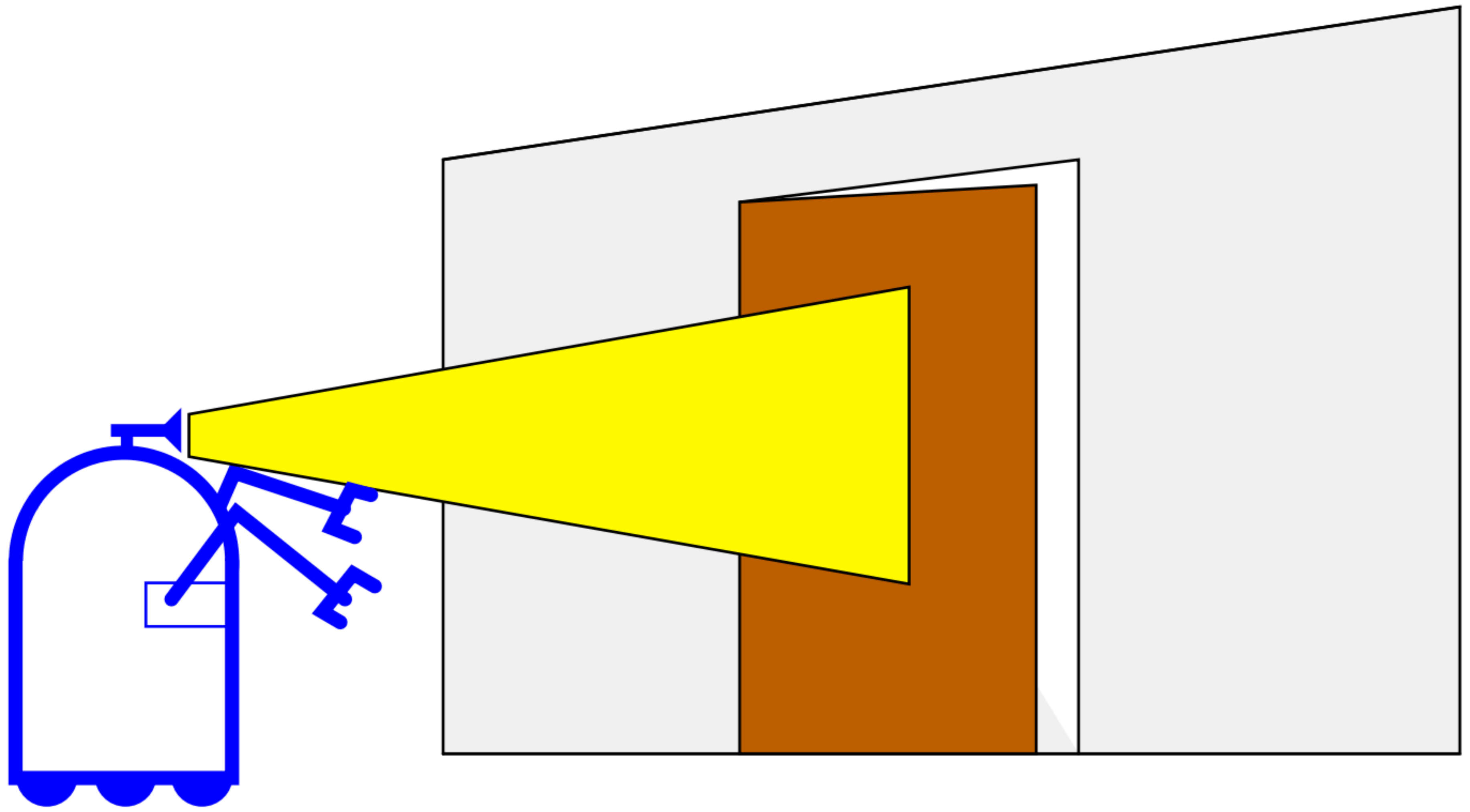
Is the door open?



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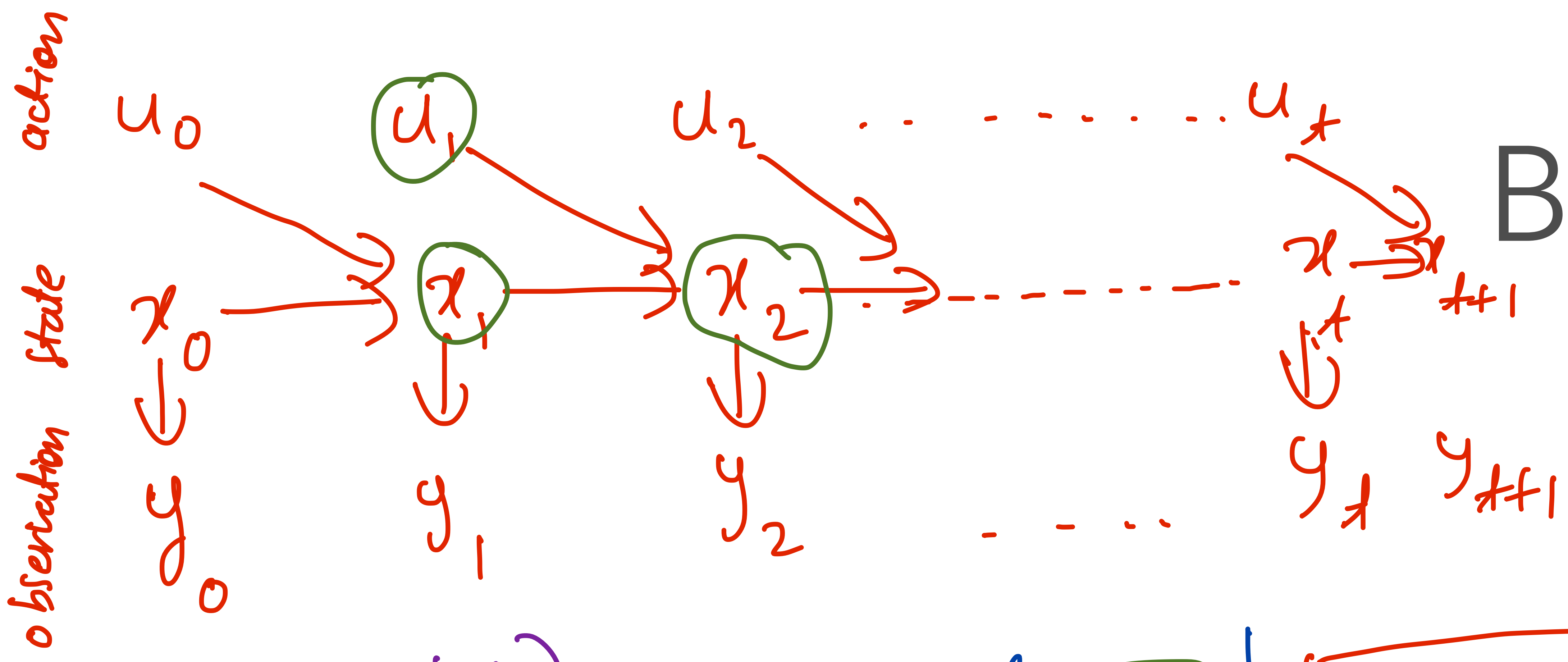
Bayes Filter



$p(y_2 | x_2)$

$$p(x_t \mid u_0, u_1, \ldots u_t, y_0, y_1, \ldots y_t)$$

$$= \frac{p(y_t \mid x_t, u_0, u_1, \ldots, u_t, y_0, y_1, \ldots y_{t-1}) \cdot p(x_t \mid u_0, u_1, \ldots u_t, y_0, y_1 \ldots)}{p(y_t \mid \boxed{})}$$

red terms independent from $y_t | x_t$

$$= \eta \, \underbrace{p(y_t \mid x_t, \cancel{\ldots})}_{} \cdot \underbrace{p(x_t \mid u_0, u_1 \ldots y_0, y_1 \ldots y_{t-1})}_{}$$

$$= \eta \, p(y_t \mid x_t) \sum p(x_t \mid u_0 u_1 \ldots u_t \, y_1 \ldots y_{t-1}, x_{t-1}) \cdot \boxed{p(x_{t-1} \mid u_0 u_1 \ldots y_0 \, y_1 \ldots)}$$

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Bayes Filter

Belief(x_t)

$$p(x_t \mid u_0, u_1, \dots u_{t-1}, y_0, y_1, \dots y_t)$$

$$= \eta\, p(y_t \mid x_t) \cdot \sum p(x_t \mid u_0, u_1, \dots u_{t-1}, y_0, y_1, \dots y_{t-1}, x_{t-1})\; p(x_{t-1} \mid u_0 u_1 \dots u_{t-1}, y_0, y_1, \dots y_{t-1})$$

$$Bel(X_t) = \eta\, \underbrace{p(y_t \mid x_t)}_{\text{Measurement}} \underbrace{\sum_{\text{states}} p(x_t \mid u_{t-1}, x_{t-1}) \cdot Bel(X_{t-1})}_{\text{Prediction}}$$

0	1.0	0
	X	
0	0.1	0.9

$Bel(x_{t-1})$

0.1	0.9	0.0	0.1	0.0

$Bel(X_t)$

0.01	0.18	0.81	0.01	0.09

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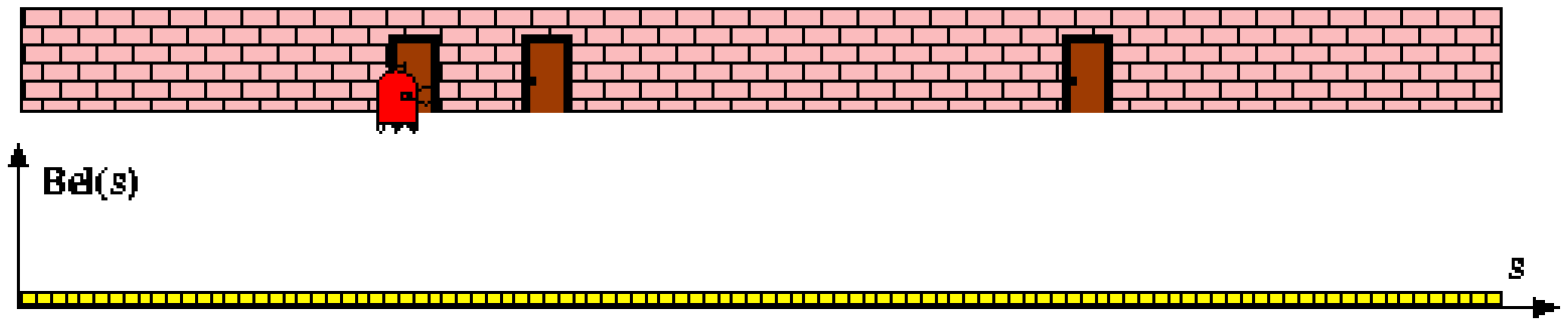

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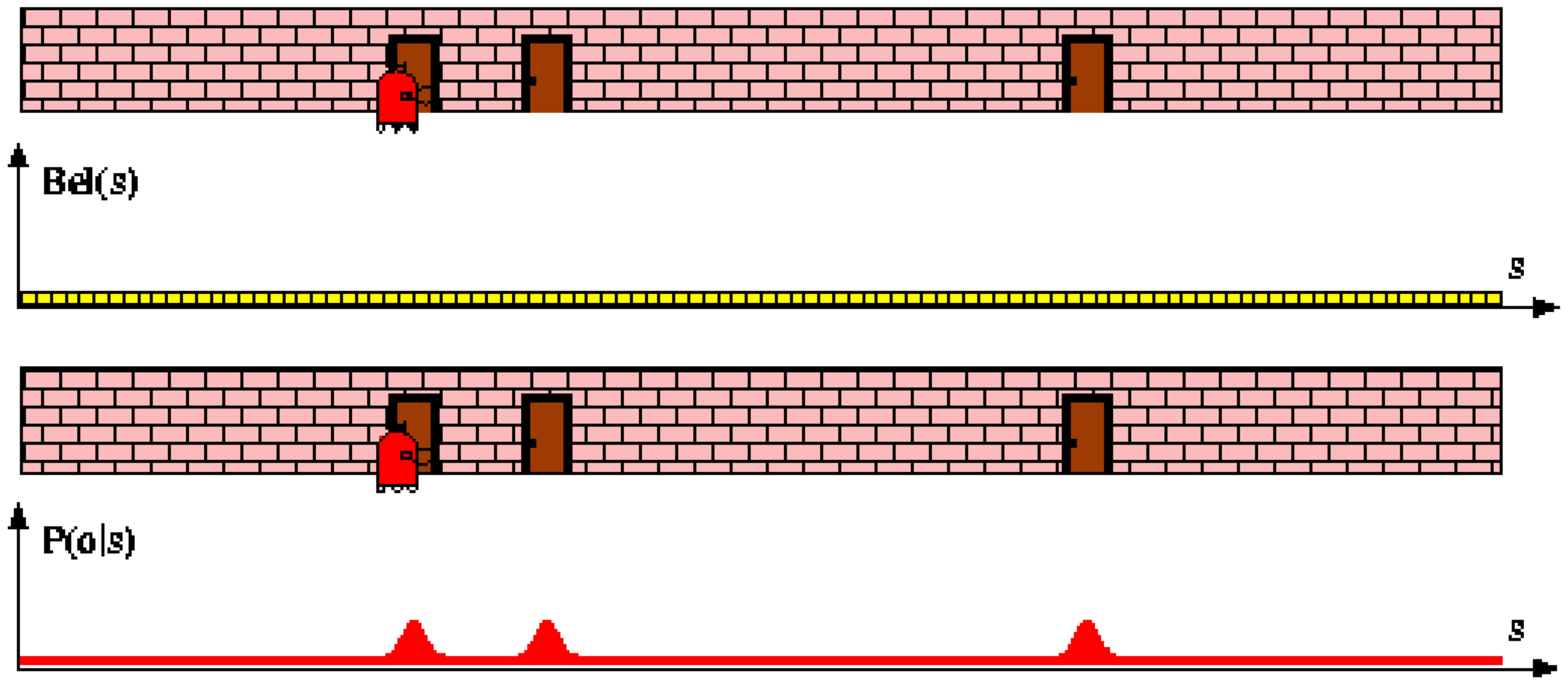

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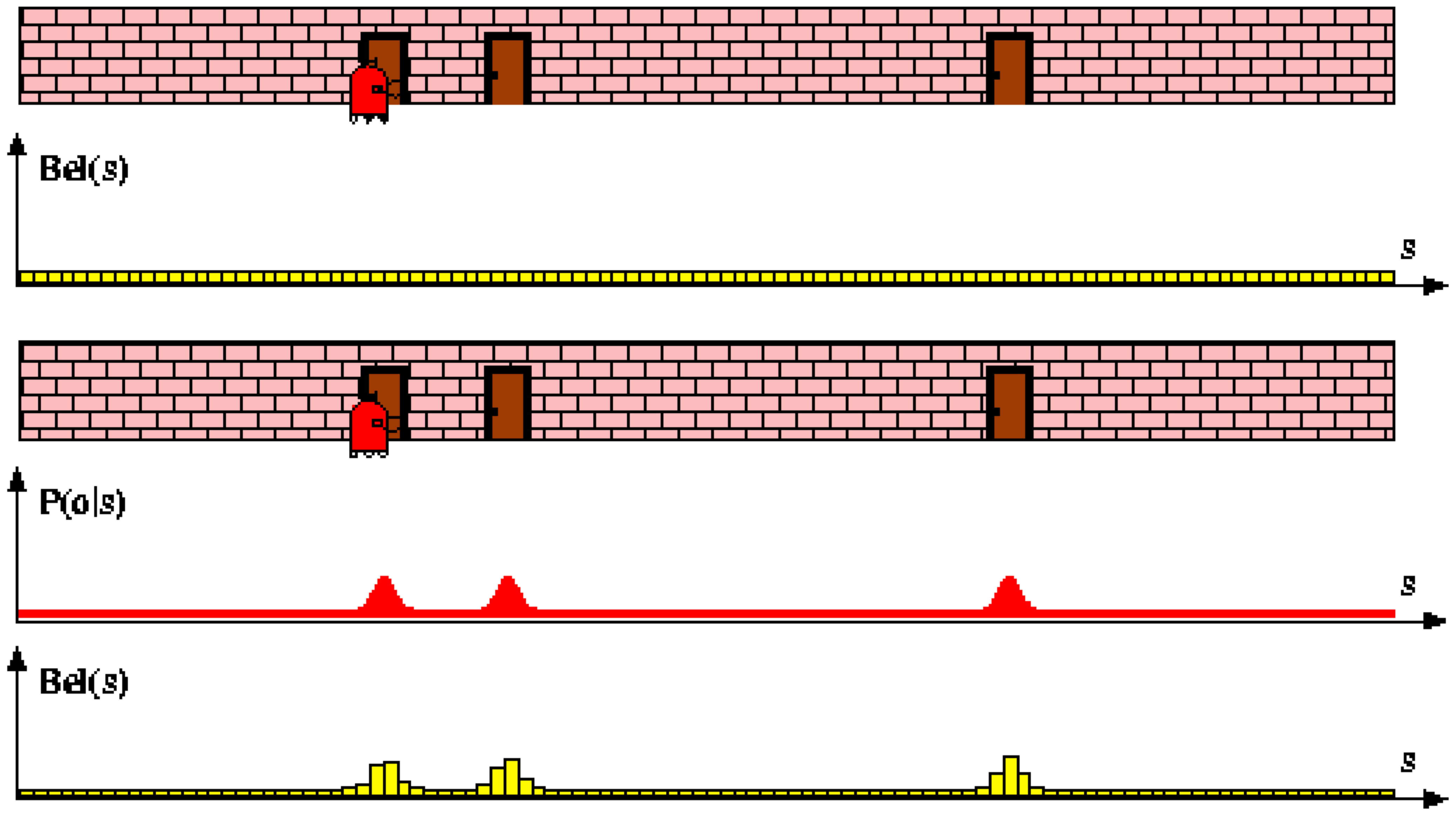

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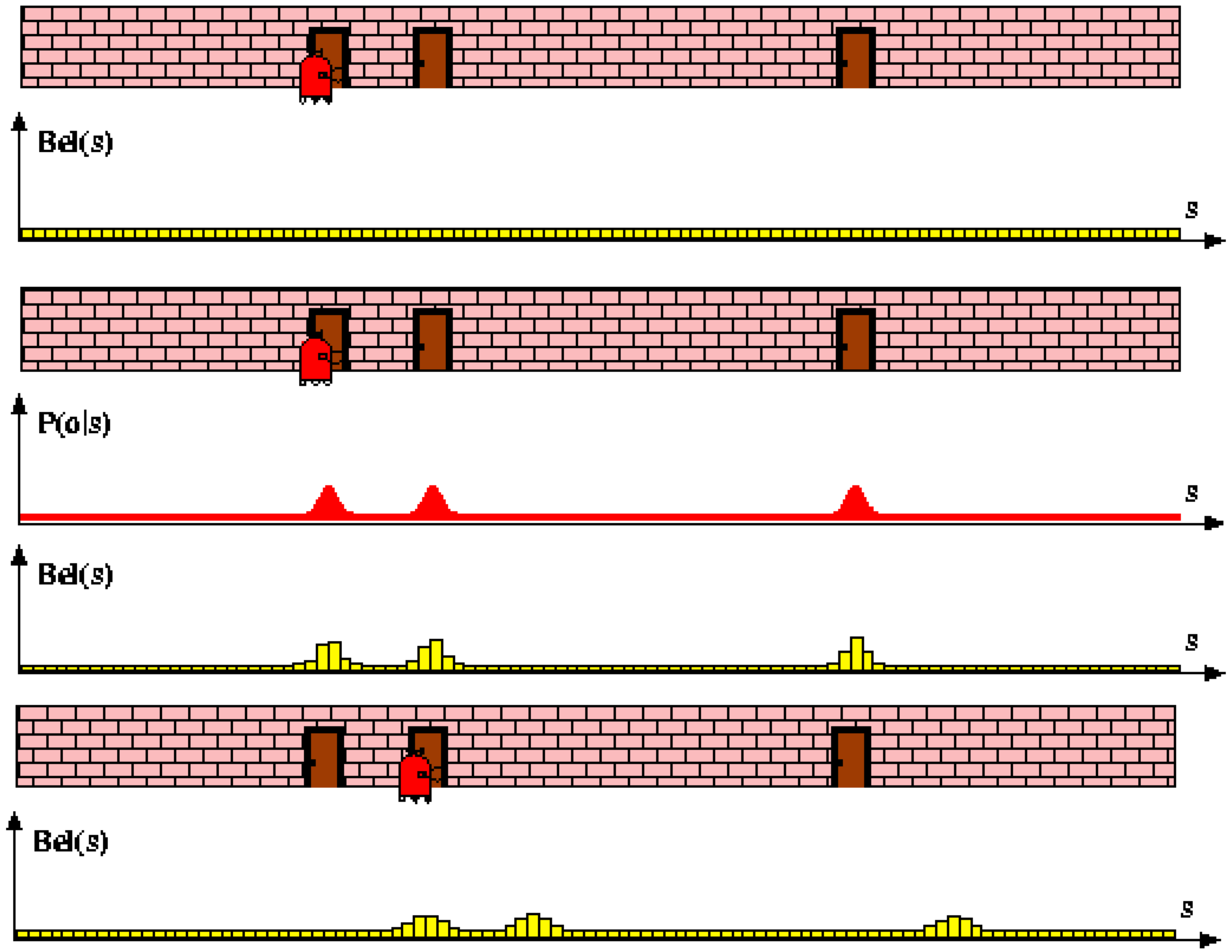

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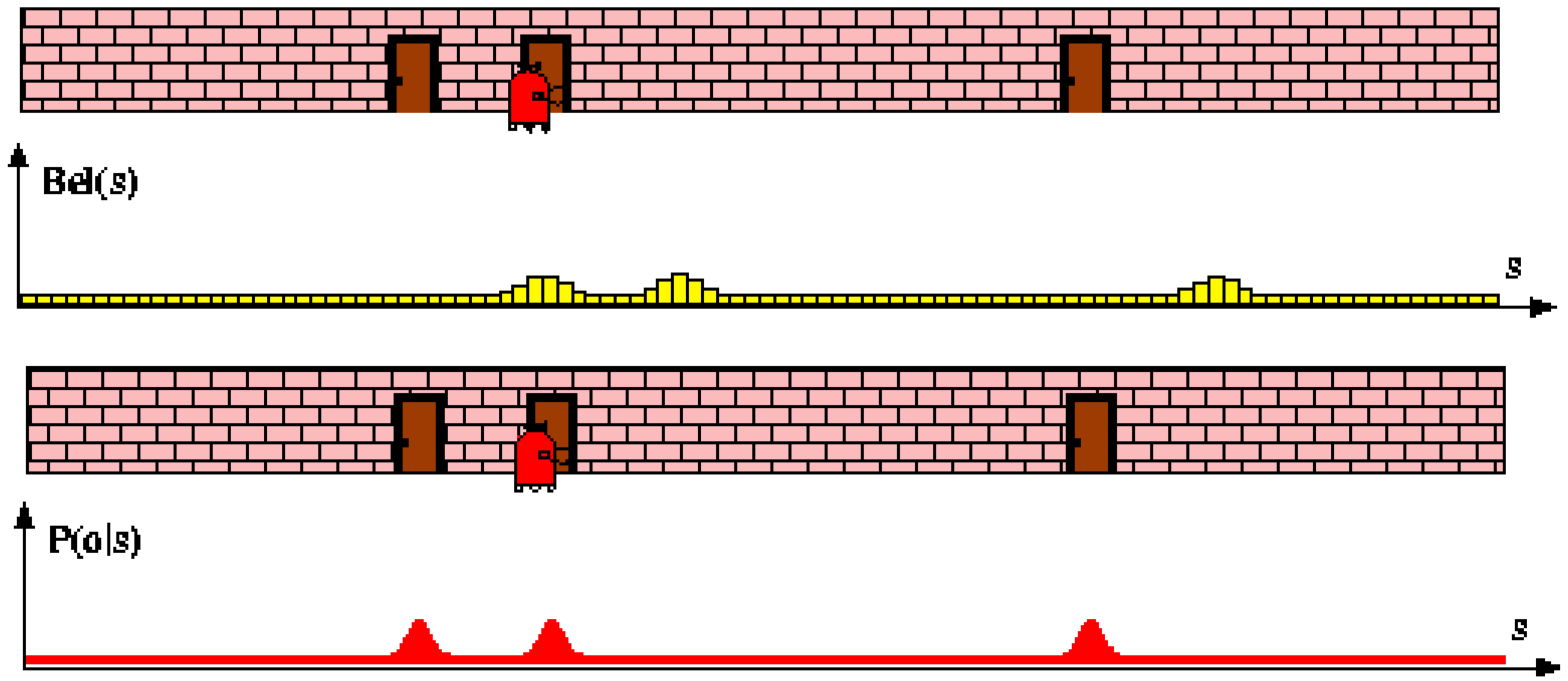

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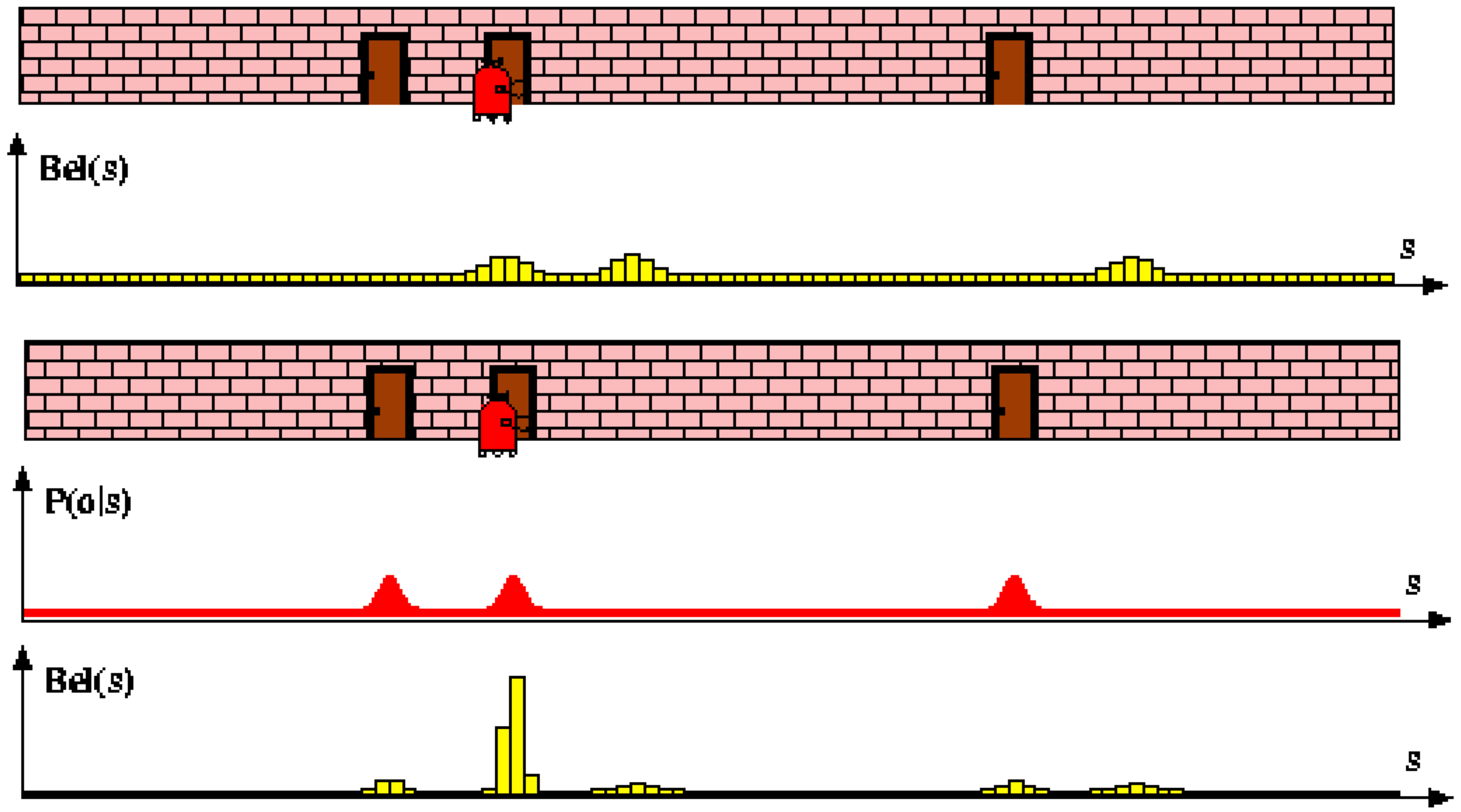

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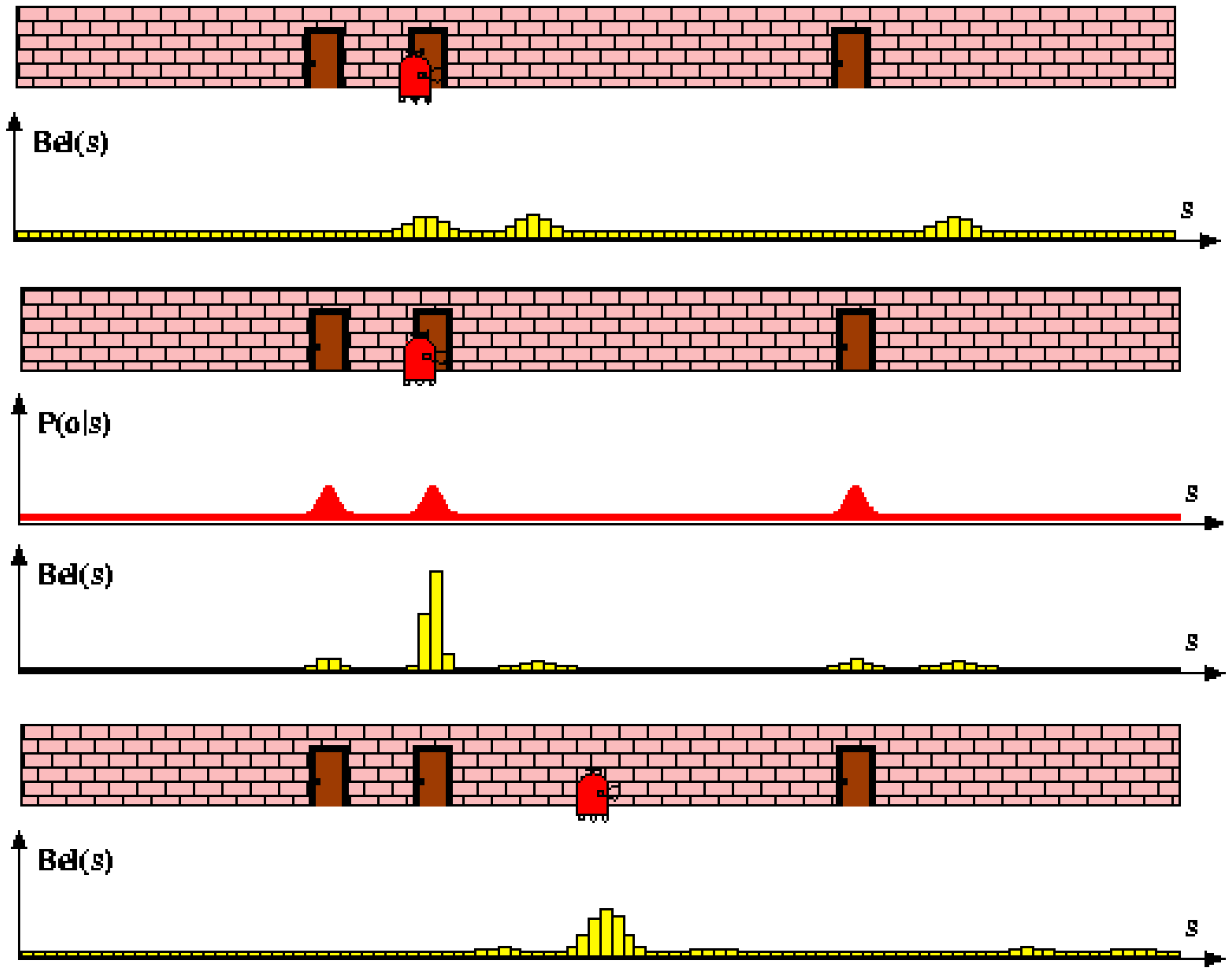

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