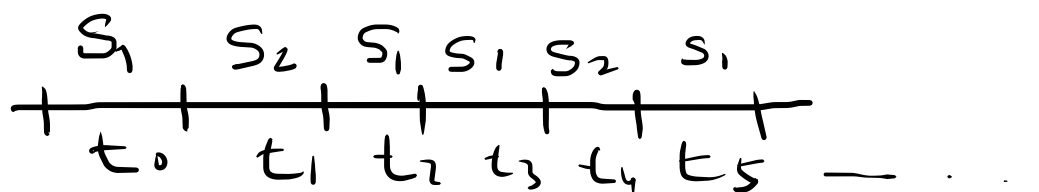# HIDDEN MARKOV MODELS

- Analysis
- Prediction

Time series data $\longrightarrow$ the data that changes w.r.t to regular time intervals

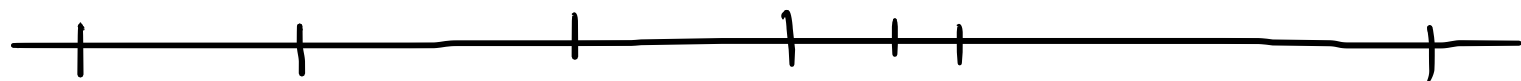$$S_1 \quad S_2 \quad S_1 \quad S_1 \quad S_2 \quad S_1$$

$$t_0 \quad t_1 \quad t_2 \quad t_3 \quad t_4 \quad t_5 \quad \text{---} \quad \ldots$$

- Speech Recognition

- Handwriting Recognition

Handwriting

- Writing text is also time based

"Hidden markov model is a sequence model"

[CRF
  LSTM $\longleftarrow$

1st Order Markov Chain

(S) —0.8→ (S) —→ (S) —→ (R) —→ (R) —→ (S) —0.2→ (R)
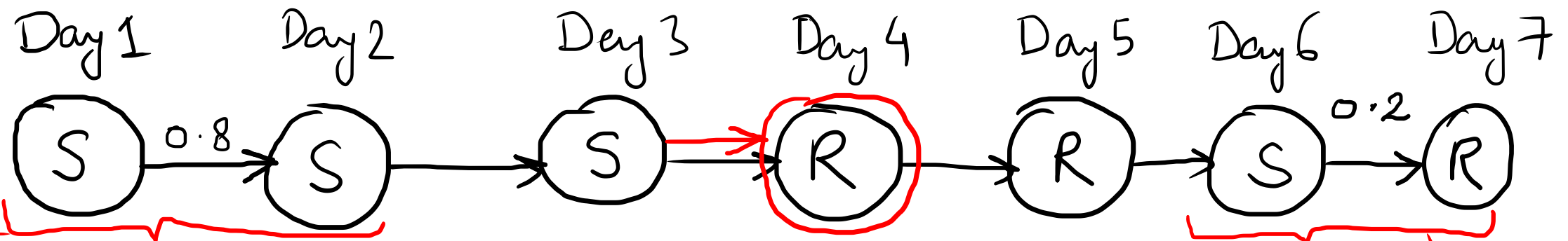
Markov Assumption

$$P(S_{t+1} \mid S_t, S_{t-1}, \ldots S_1) = P(S_{t+1} \mid S_t)$$

$P(S_t \mid S_{t-1})$

$$P(S_{t+1} = R \mid S_t = S) =$$

$$P(S_{t+1} = S \mid S_t = S)$$

Transition Probability

Bayes Networks

Markov Model

(Rainy) —0.4→ (Sunny)   0.8

(Rainy) 0.6   (Sunny)

(Sunny) —0.2→ (Rainy)

	t R	t S
t-1 R	0.6	0.4
t-1 S	0.2	0.8
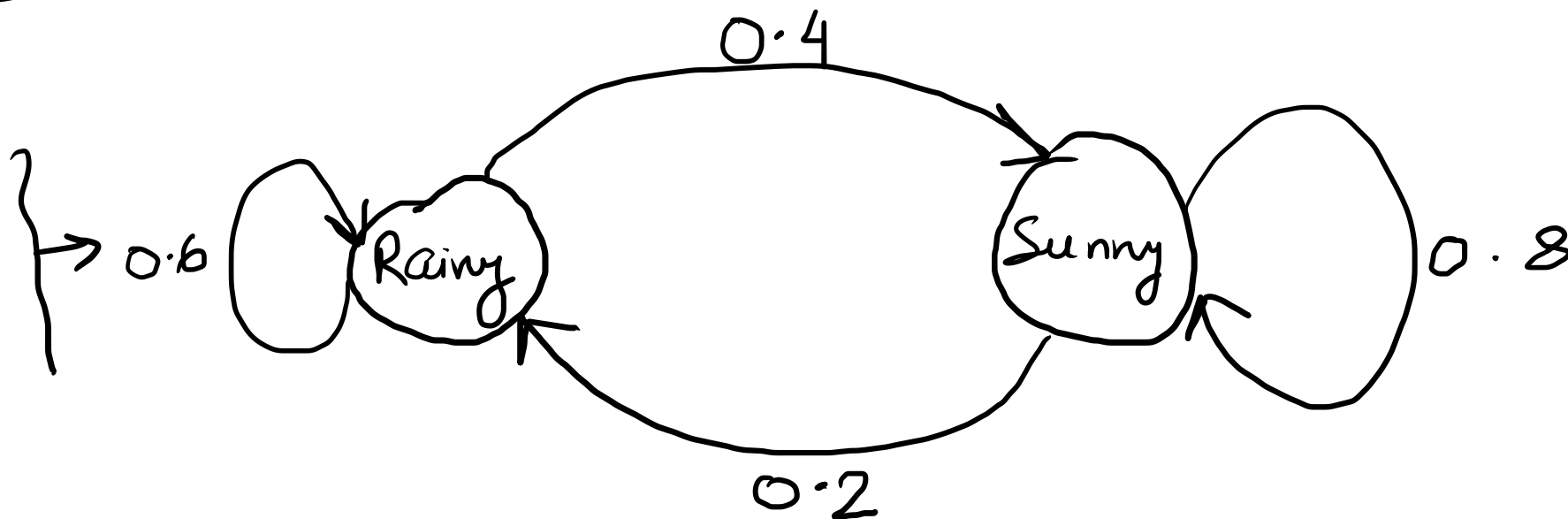
Transition probability table of HMM

1) $P(SSSRRSR)$

$= P(\overset{1}{S}, \overset{2}{S}, \overset{3}{S}, \overset{4}{R}, \overset{5}{R}, \overset{6}{S}, \overset{7}{R})$

$= P(S) \cdot P(S|S) \, P(S|S) \, P(R|S) \cdot P(R|R) \cdot$

$P(S|R) \cdot P(R|S)$

$= P(S_1 = S) \cdot P(S_2 = S | S_1 = S)$

$\cdot P(S_3 = S | S_2 = S)$

$\qquad\qquad\qquad\qquad P(S_7 = R | S_6 = S)$

$= (1) \cdot (0.8)(0.8)(0.2)(0.6)(0.4)(0.2)$

$= 0.0049152$

$S_t = \text{state}$
$S = \text{Sunny}$
$R = \text{Rainy}$

$P(S) = 1$
$P(R) = 0$

t

	R	S
t_{-1} R	0.6	0.4
S	0.2	0.8

↑ Transition probability table of HMM

$P(S/R)$ ↑

$P(R/SR)$ ↑

$P(R/RSR)$ ↑

$P(S/RRSR)$ ↑
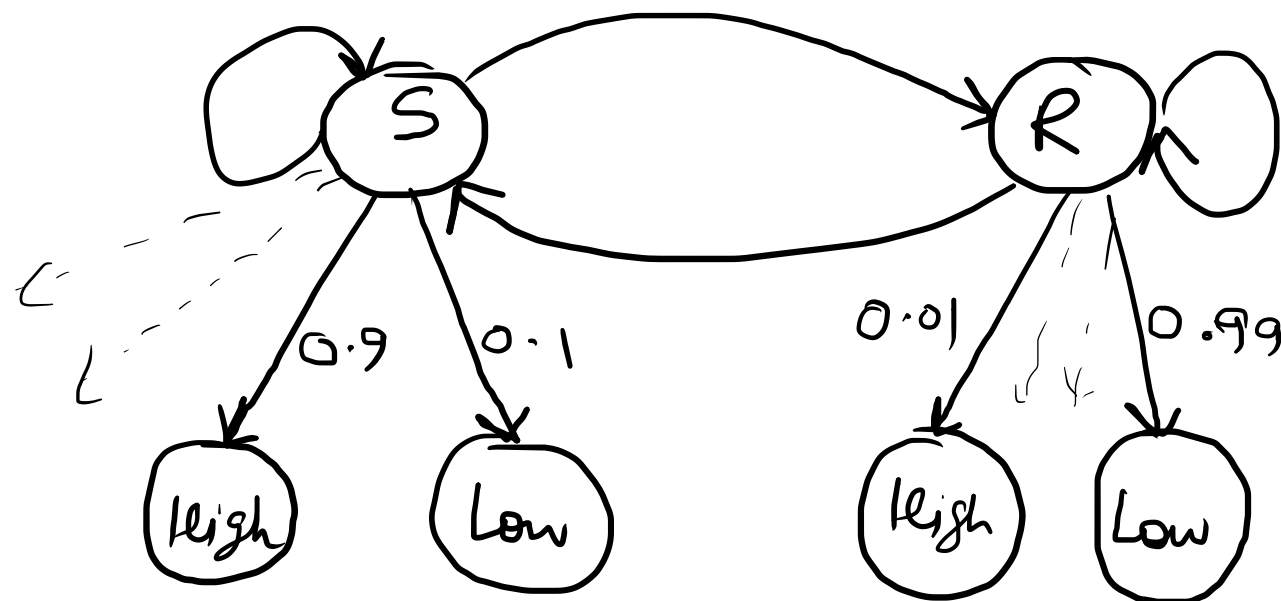
$P(S/SRRSR)$ ↑

$P(S/SSRRSR)$

Problem :- Given SSSRRSR this sequence what is the probability of next state $P(S_8 = R | SSSRRSR)$
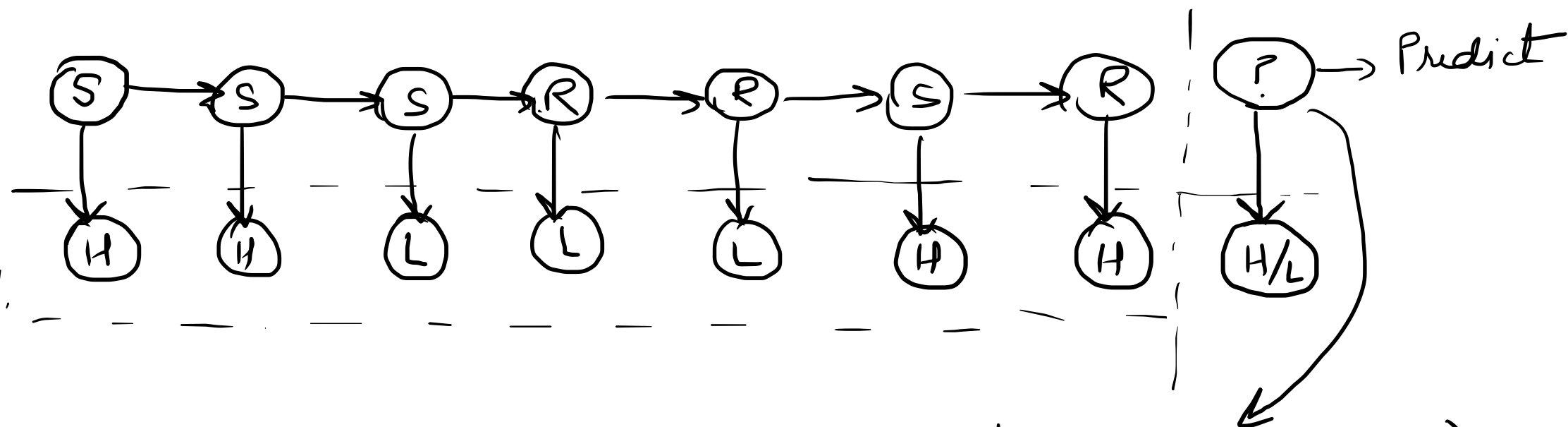
$P(S_8 = S | SSSRRSR)$

Hidden Markov Model

- Priors
- Transition probability table
- Observation Table

Observation Table (Obs):

Status S_t	H	L
S	0.9	0.1
R	0.01	0.99

Transition: S → S 0.9, S → Low 0.1, R → High 0.01, R → Low 0.99

States: S → S → S → R → R → S → R   ? → Predict

Observations: H   H   L   L   L   H   H   H/L

$$P(S \mid \underset{1\ 2\ 3\ 4\ 5\ 6\ 7}{SSSRRSR} \ \underset{1\ 2\ 3\ 4\ 5\ 6}{HHLLHH})$$