12

$$\binom{12}{3}\binom{9}{4}\binom{5}{5} = \cancel{2770}\ 2772.$$

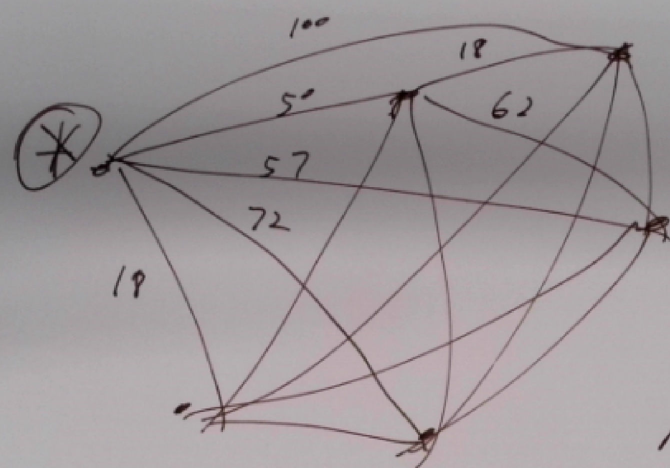
$$\binom{12}{5}\binom{7}{3}\binom{4}{4}$$

$$\binom{12}{5}\binom{7}{4}\binom{3}{3}$$

$$\binom{12}{4}\binom{8}{3}\binom{5}{5}$$

$$\vdots$$

Traveling Salesperson (TS)



$\underline{n}$

n	n
$n-1$	n
$n-2$	n
$\vdots$	n
	n
	$\vdots$

$\sim n!$

$\sim n^n$

Complexity

$n \quad \sim n^2$

$\Theta(n^2)$

$\Theta(n^3)$ polynomial time

$\Theta(n)$

$\Theta(n^n)$ TS: $\sim \Theta(n^n)$

Is there a poly. time alg. for TS?

Language & Grammars

Syntax vs. Semantics

```
If (1 > 2) {
    x = x;
    x = x;
    x = x + 0;
} else {
   x = x + 0;
}
```

The sleeping colorless

Green gas is laughing.

Sentence = noun phrase + verb phrase

noun phrase = article + adj + noun

or article + noun

verb phrase = verb + adverb

or verb

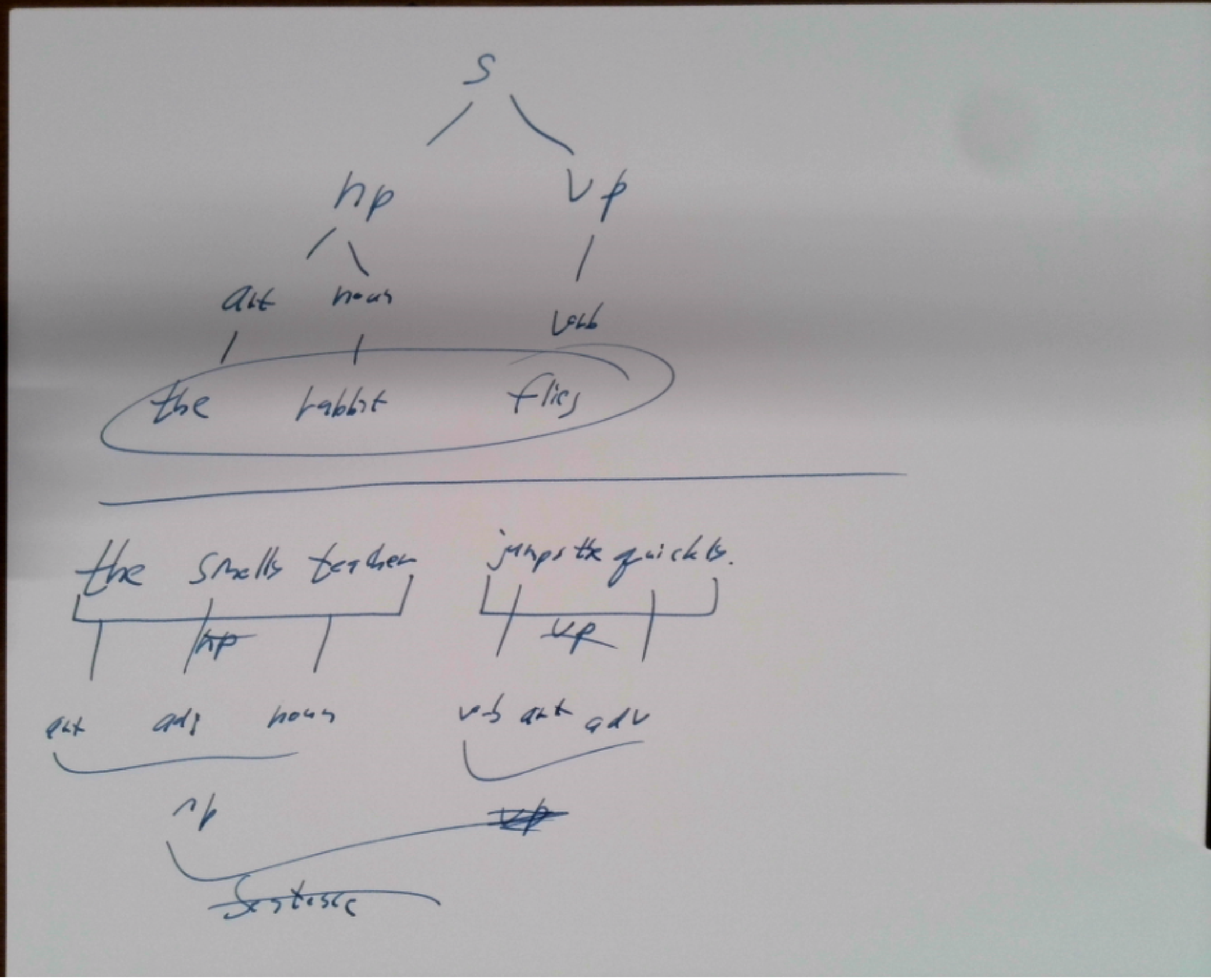
article = "a" or "the"

adj = "large" or "human" or "smelly"

noun = "rabbit" or "teacher"

~~a~~ verb = "eats" or "jumps" or "flies"

adverb = "quickly" or "happily"


S
np
vp
art
noun
verb
the
rabbit
flies
the smelly teacher
jumps the quickly.
np
vp
art
adj
noun
verb
art
adv
np
vp
Sentence

A Vocabulary V is a finite, non-empty set of symbols.

A word or sentence over V is a finite-length string of elements of V.

λ = empty string.

$V^* = \{\text{all words over } V\}$

A language over V is a subset of V^*.

Q: How to specify a language?

1) use rules

2) make a full list of all words

*3) Describe a grammar

A phrase structure grammar $G = (V, T, S, P)$

V = Vocabulary

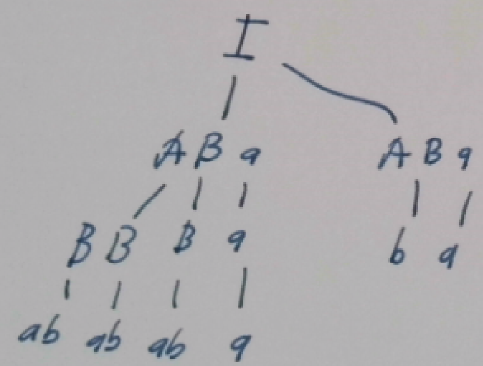
T = set of terminal symbols $\subseteq V$

S = start symbol $(S \in V)$

P = set of production rules

Example: $V = \{a, b, A, B, I\}$ $T = \{a, b\}$ $S = I$

$P = \{ I \to ABa,\ A \to BB,\ B \to ab,\ AB \to b \}$



ababab a

b a

DEFS: Let $w_0 = L\, z_0\, R$ | $G = (V, T, S, P)$

$w_1 = L\, z_1\, R$

Suppose $z_0 \to z_1 \in P$

Then we say "w_1 is directly derivable from w_0"

$$w_0 \Rightarrow w_1$$

If $w_0 \Rightarrow w_1 \Rightarrow w_2 \Rightarrow \dots \Rightarrow w_n$

then we say "w_n is derivable from w_0"

$$w_0 \overset{*}{\Rightarrow} w_n$$

DEF: The language generated by G $L(G) =$

{ Strings of terminals which are derivable from S }

$$L(G) = \{ w \in T^* : S \overset{*}{\Rightarrow} w \}$$

DEFS: Let $w_0 = L\,z_0\,R$ $\qquad G = (V, T, S, P)$

$w_1 = L\,z_1\,R$

Suppose $z_0 \to z_1 \in P$

Then we say "w_1 is <u>directly derivable</u> from w_0"

$$w_0 \Rightarrow w_1$$

If $w_0 \Rightarrow w_1 \Rightarrow w_2 \Rightarrow \ldots \Rightarrow w_n$

then we say "w_n is derivable from w_0"

$$w_0 \stackrel{*}{\Rightarrow} w_n$$

DEF: The language generated by G $L(G) =$

{ Strings of terminals which are derivable from S }

$$L(G) = \{ w \in T^* : S \stackrel{*}{\Rightarrow} w \}$$

$V=\{I,0,1\}$, $T=\{0,1\}$, $S=I$, $P=\{I\to 11I,\ I\to 0\}$ $\quad G=(V,T,S,P)$

$L(G)=\{0, 110, 11110, 111110, \dots\} = 1^n0$, n even $n\geq 0$

$=(11)^n0$, $n\geq 0$

$$\begin{array}{c}I\\ |\\ 11I\\ |\\ 0\end{array}\qquad\qquad \begin{array}{c}I\\ |\\ 11I\\ |\\ 11I\\ |\\ 0\end{array}$$

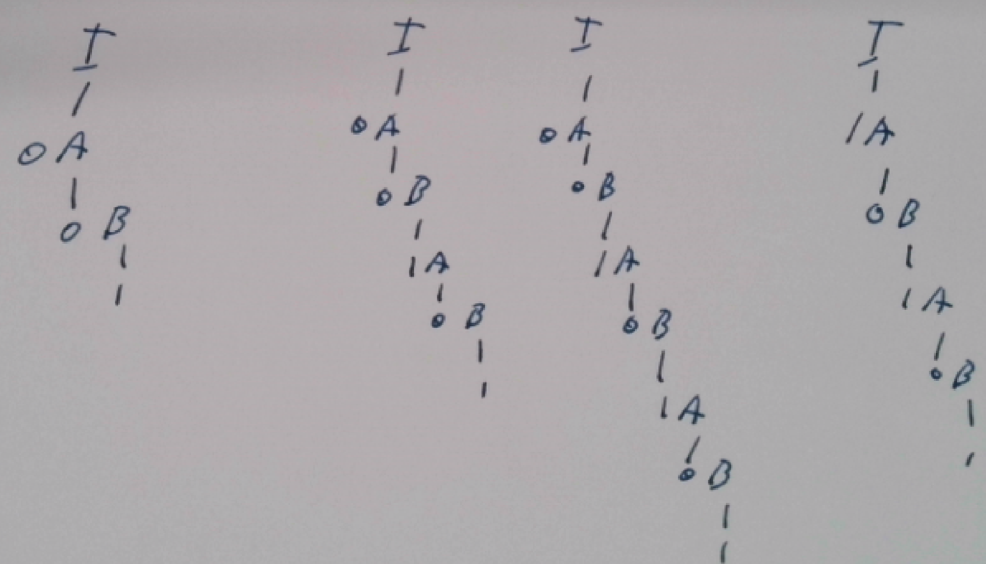
$G=(V,T,S,P)$

$V=\{0,1,A,B,I\}$, $T=\{0,1\}$, $S=I$,

$P=\{I\to 0A,\ I\to 1A,\ A\to 0B,\ B\to 1A,\ B\to 1\}$

$L(G)=\{001,\ 00101,\ 0010101,\ 10101,\ 101,\ 1010101,\ \dots\}$

$0(01)^n$ or $1(01)^n$ $n\geq 1$



Constructing a Grammar

$L(G) = \{\lambda, 01, 0011, 000111, 00001111, \ldots\} = \cancel{(01)^n, n \geq 0}$

$(0)^n (1)^n, n \geq 0$

$V = \{0, 1, I\}$ $T = \{0, 1\}$ $S = I$

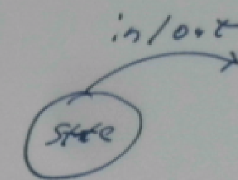
$P = \{I \to \lambda, \cancel{I \to 01,} I \to 0I1\}$

$L(G) = 0^m 1^n, m, n \geq 0$

$V = \{0, 1, I, A, B\}$, $T = \{0, 1\}$ $S = I$

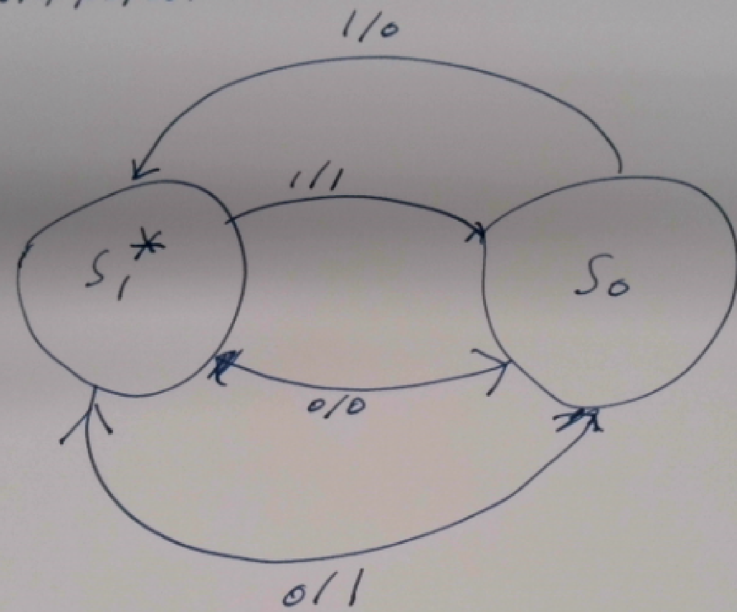
$P = \{A \to \lambda, A \to 0A, B \to \lambda, B \to 1B, I \to AB\}$

Finite State Machines (FSM)



PS/IN/NS/out

Example:

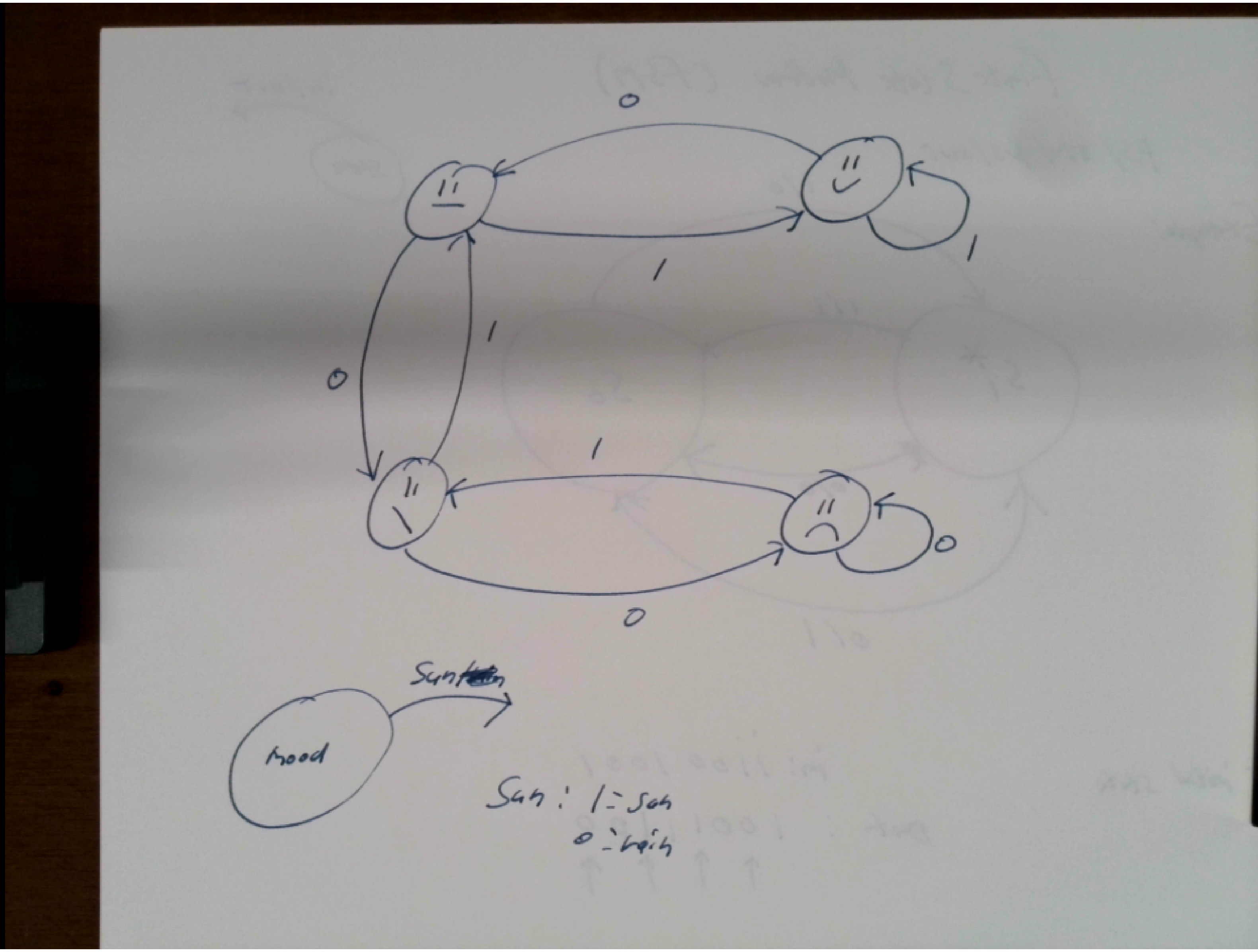


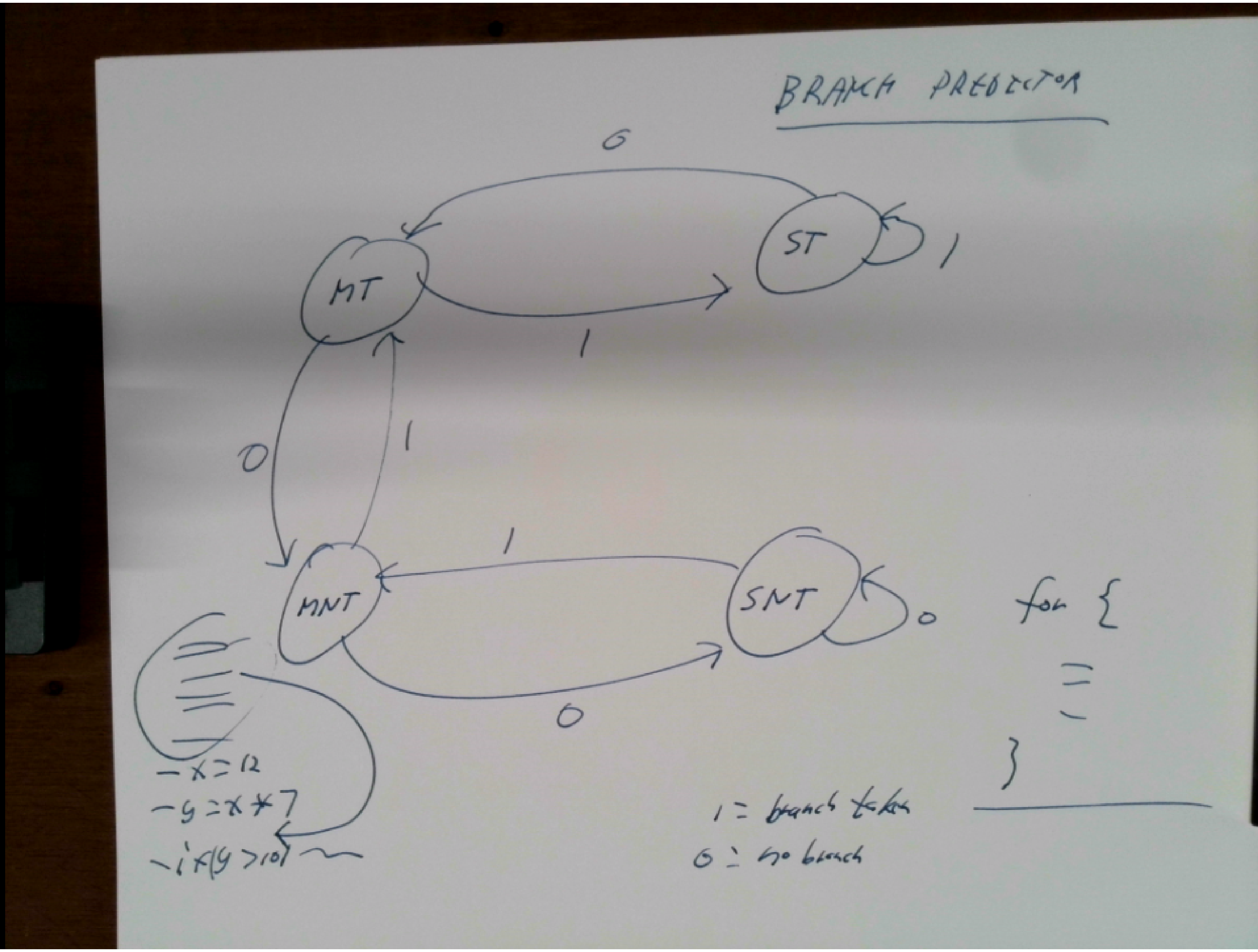
* initial state

in: 1100 1001

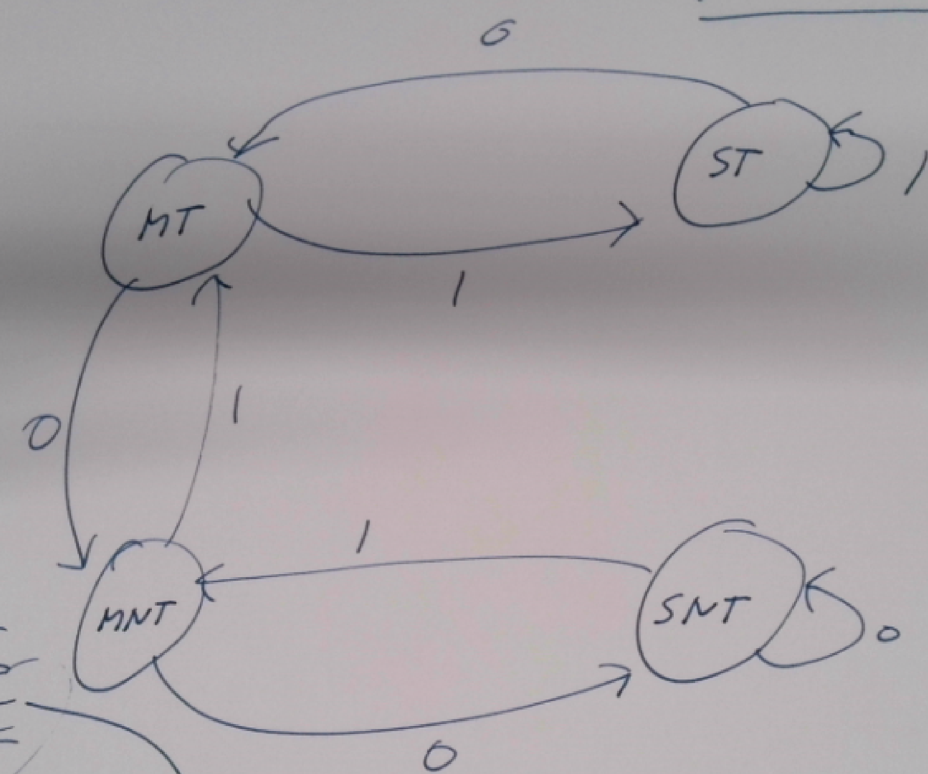
out: 1001 1100

↑ ↑ ↑ ↑


0
1
1
1
0
1
0
0
Sun
mood
Sun : 1 = sun
0 = rain


BRANCH PREDICTOR
ST
MT
MNT
SNT
0
1
for {
}
1 = branch taken
0 = no branch
- x = 12
- y = x * 7
- if(y > 10)

BRANCH PREDICTOR



- x = 12
- y = x * 7
- if (y > 10) ~

for {
}

1 = branch taken
0 = no branch