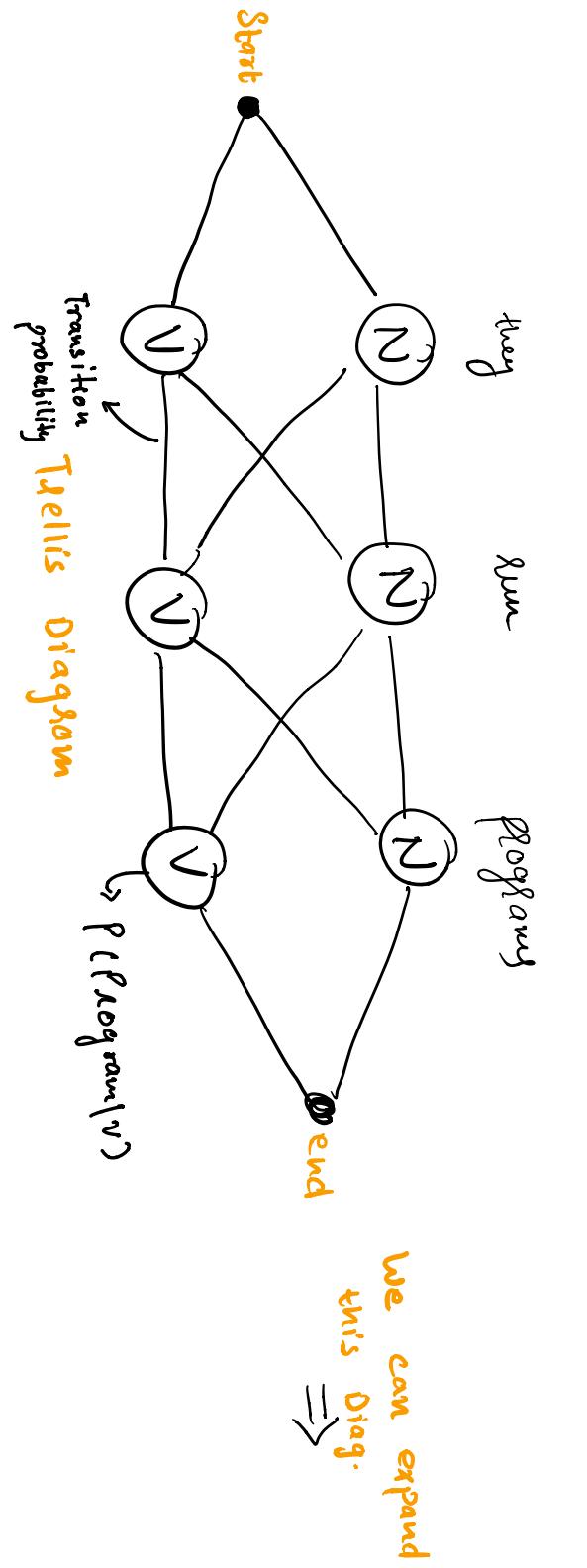
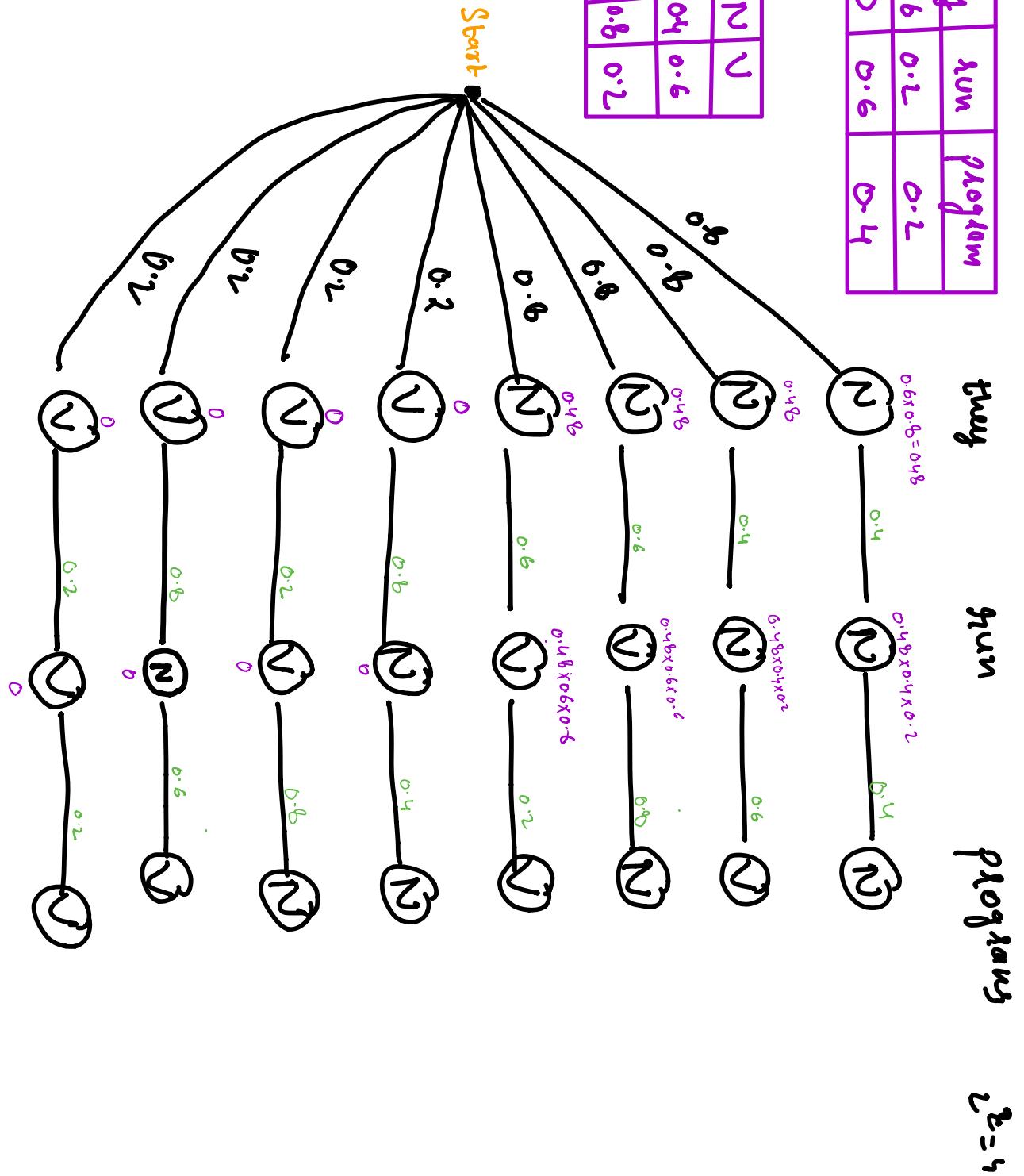
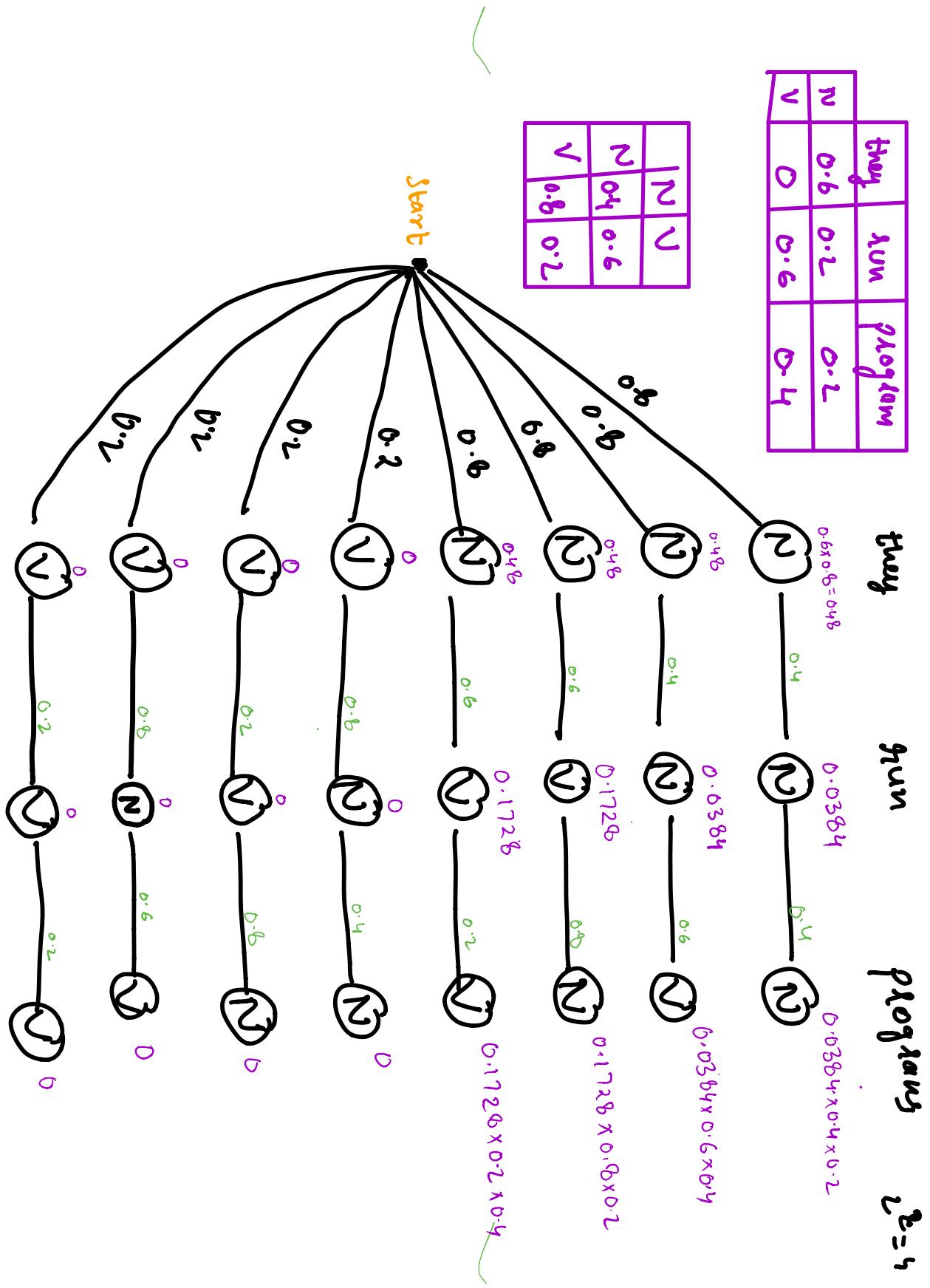
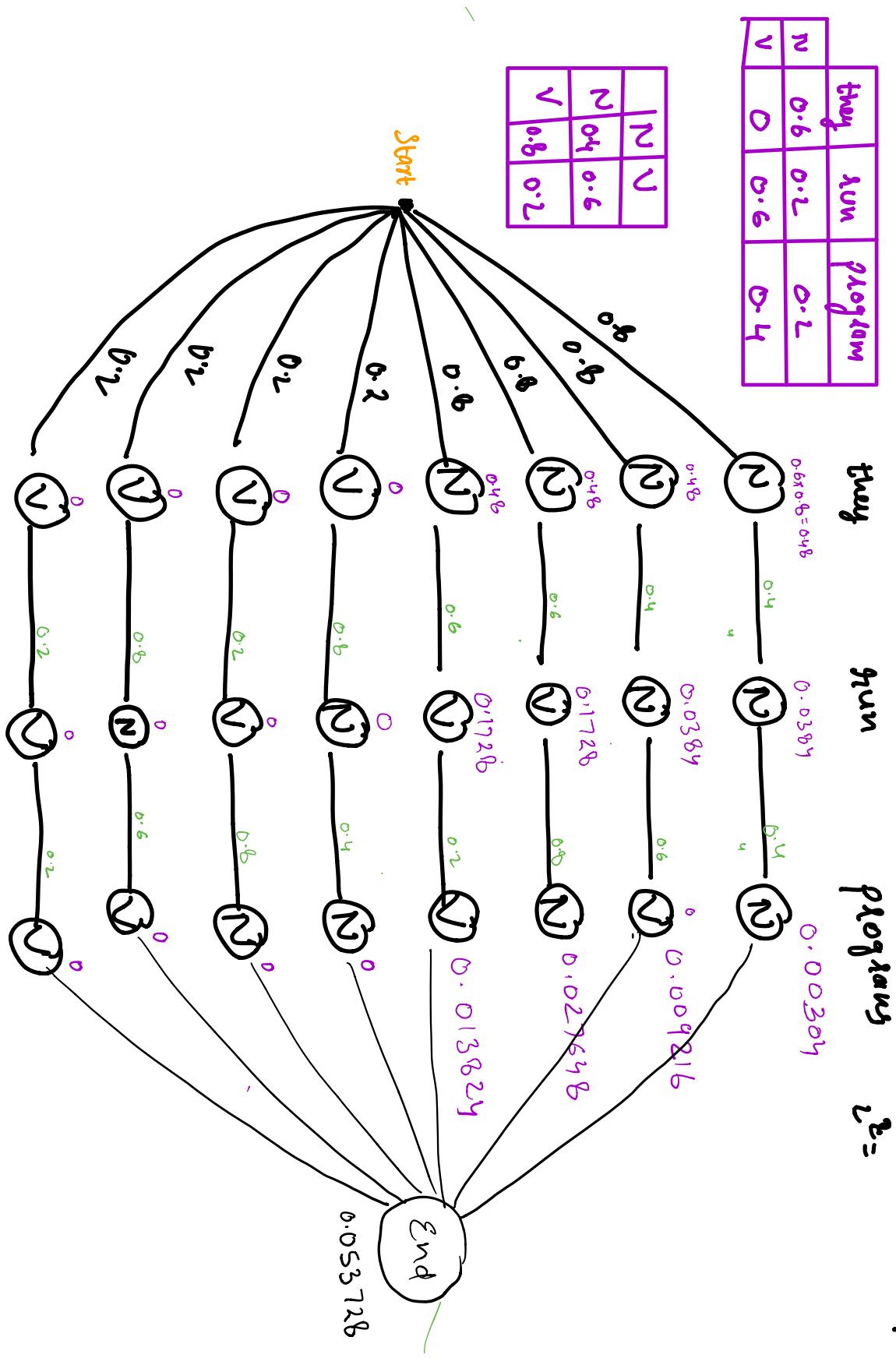


① @ :

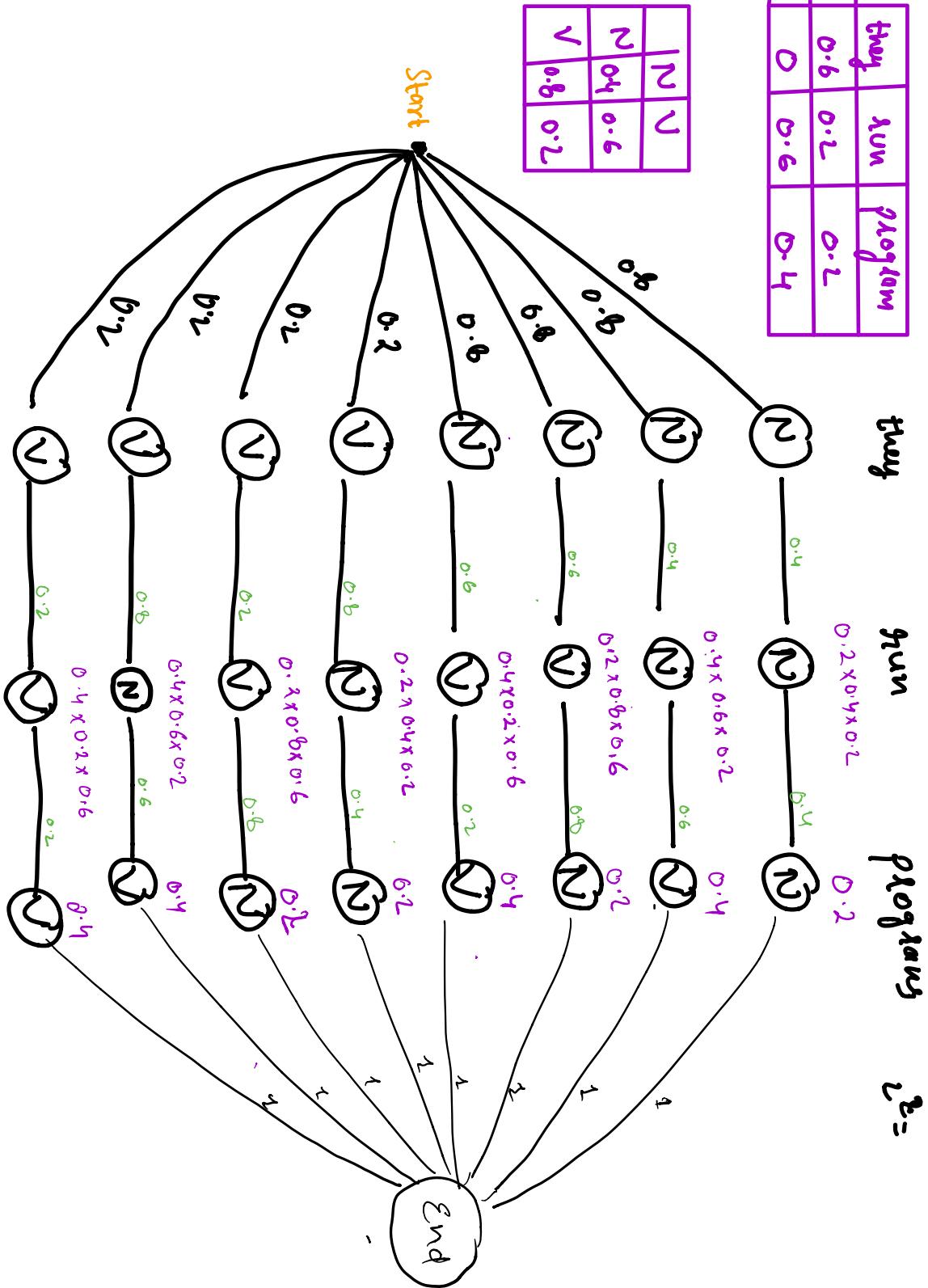


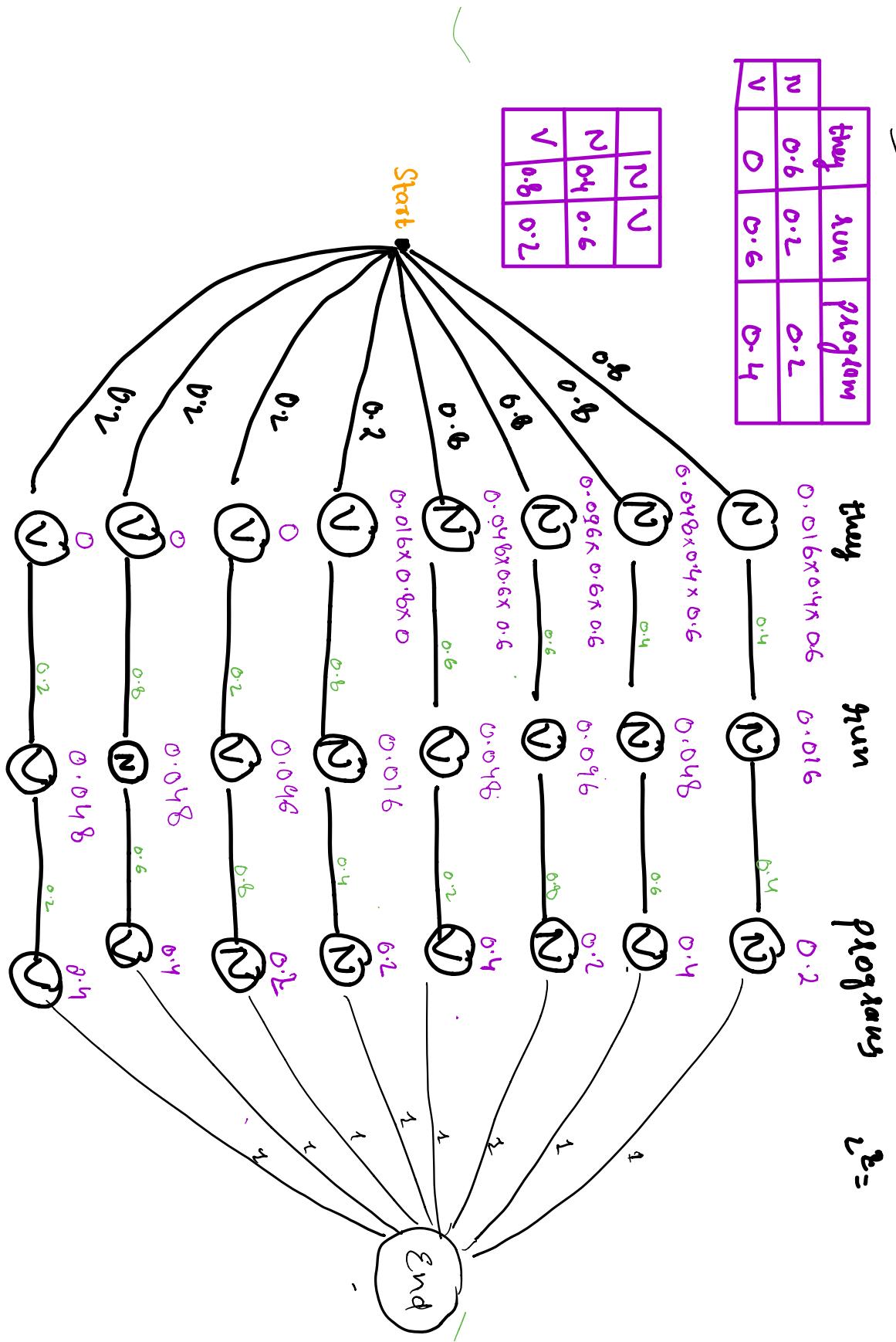






Backward



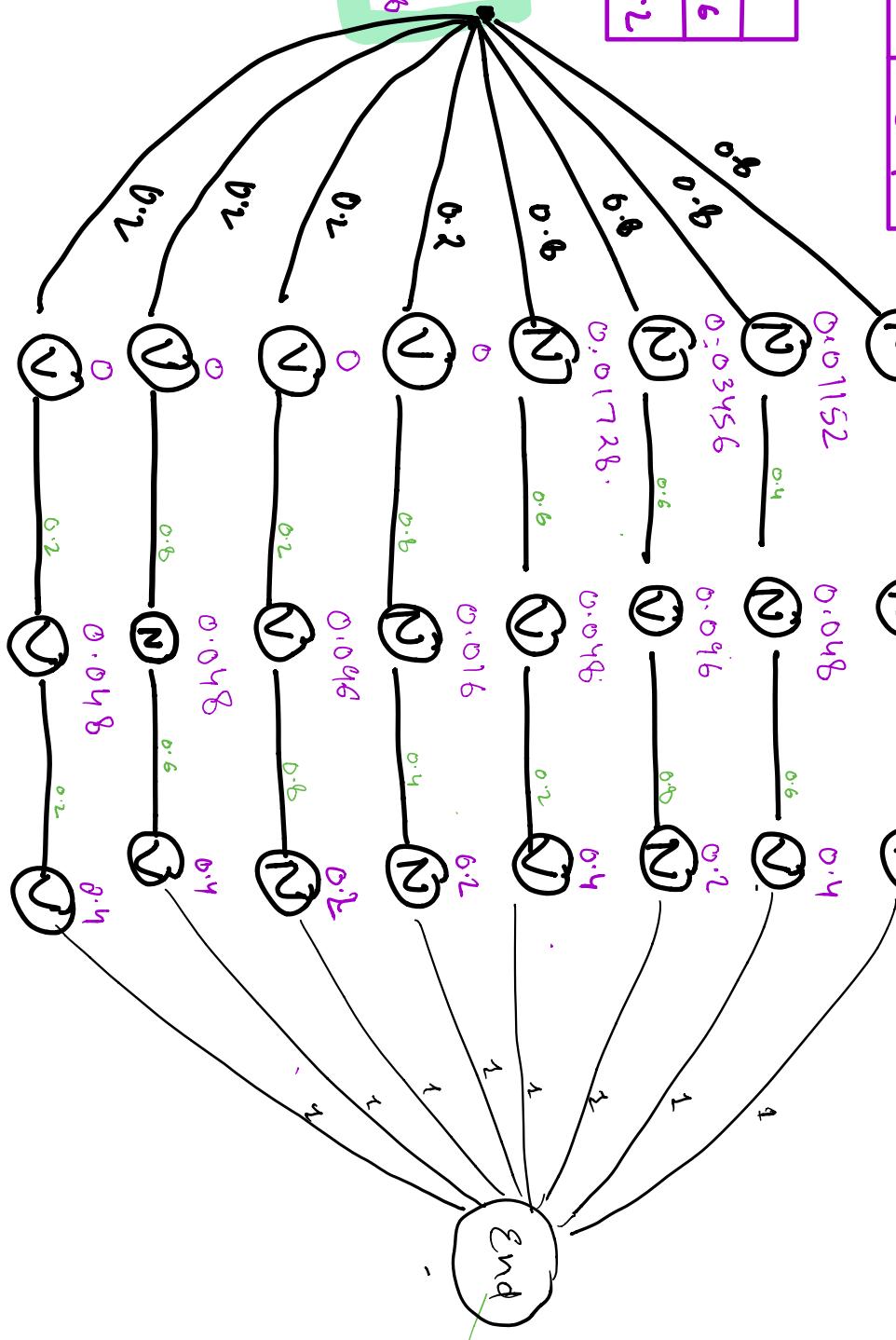


4

	they	run	program
n	0.6	0.2	0.2
v	0	0.6	0.4

they run program
 $0.6 \times 0.2 = 0.12$ $0.6 \times 0.2 = 0.12$ $0.6 \times 0.4 = 0.24$

$\Sigma =$



⑥

Tag the sequence "They run programs" \Rightarrow "N V N"

Using forward algo, we will pick the path with highest prob.

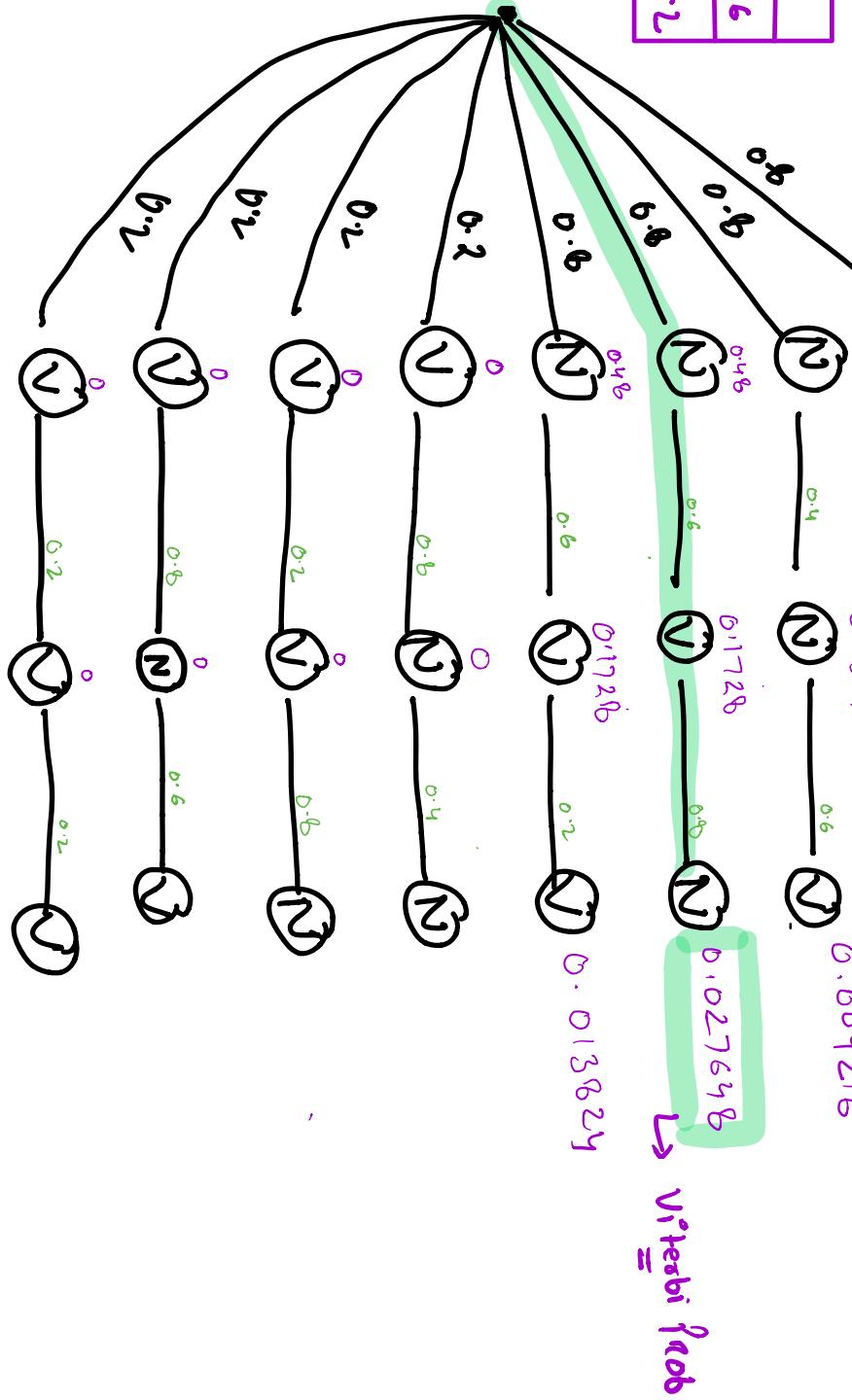
they

run

programs

they	N	V	program
0.6	0.2	0.2	
V	O	O	0.4

they	N	V	program
0.4	0.6	0.2	
V	O	O	0.4



Q2 A We have given :

"Submit the homework through canvas"

Taking 1 word at a time

"submit": Possible production rules

$S \rightarrow \text{submit}$

$$P = 0.01$$

$\text{VP} \rightarrow \text{submit}$

$$P = 0.1$$

$\text{Verb} \rightarrow \text{Submit}$

$$P = 0.5$$

Rule	Probability
$S \rightarrow \text{NP VP}$	0.8
$S \rightarrow \text{submit}$	0.01
$S \rightarrow \text{Verb NP}$	0.05
$S \rightarrow \text{VP PP}$	0.03
$\text{NP} \rightarrow \text{Canvas}$	0.16
$\text{NP} \rightarrow \text{Gradescope}$	0.04
$\text{NP} \rightarrow \text{Det Nominal}$	0.6
$\text{Nominal} \rightarrow \text{Nominal Noun}$	0.2
$\text{Nominal} \rightarrow \text{Nominal PP}$	0.5
$\text{Nominal} \rightarrow \text{homework}$	0.15
$\text{VP} \rightarrow \text{submit}$	0.1
$\text{VP} \rightarrow \text{contain}$	0.04
$\text{VP} \rightarrow \text{Verb NP}$	0.5
$\text{VP} \rightarrow \text{VP PP}$	0.3
$\text{PP} \rightarrow \text{Prep NP}$	1.0
$\text{Det} \rightarrow \text{the}$	0.6
$\text{Prep} \rightarrow \text{through}$	0.2
$\text{Verb} \rightarrow \text{submit}$	0.5

Table 4: Initial probabilities

"the": Possible production rules

$\text{Det} \rightarrow \text{the}$

$$P = 0.6$$

"homework": Possible production rules

$\text{Nominal} \rightarrow \text{homework}$

$$P = 0.15$$

"through": Possible production rules

$\text{Prep} \rightarrow \text{through}$

$$P = 0.2$$

"canvas": Possible production rules

$\text{NP} \rightarrow \text{canvas}$

$$P = 0.16$$

Submit the homework through canvas

Taking 2 word at a time

"Submit the" : Possible combinations

S Det , VP Det , V Det

No production rule for this

$$P = 0$$

"the homework" : Possible combinations

→ Det Nominal

Production rule: $NP \rightarrow \text{Det Nominal}$

$$\text{Prob} = P(\text{Det}) * P(\text{Nominal}) * P(NP)$$

$$= 0.6 \times 0.15 \times 0.6$$

$$P = 0.054$$

"homework through"

Possible combinations: Nominal prep

No production rule

$$P = 0$$

"through Canvas"

Possible combinations: Prep NP

Production rule: $PP \rightarrow \text{Prep NP}$

$$\text{Prob} = P(\text{Prep}) * P(NP) * P(PP)$$

$$= 0.2 \times 0.16 \times 1$$

$$P = 0.032$$

Taking 3 word at a time

"Submit the homework"

Possible combinations: $\text{Submit} \Rightarrow S, VP, \text{Verb}$
 $\text{the homework} \Rightarrow NP$
 $\hookrightarrow S\ NP, VP\ NP, \text{Verb}\ NP$

Possible Production rule:

$$S \rightarrow \text{Verb}\ NP$$

$$P = P(\text{Verb}) * P(NP) * P(S)$$

$$P = 0.5 * 0.054 * 0.05$$

$$P = 0.00135$$

$$VP \rightarrow \text{Verb}\ NP$$

$$P = P(\text{Verb}) * P(NP) * P(VP)$$

$$P = 0.5 * 0.054 * 0.5$$

$$P = 0.0135$$

"the homework through"

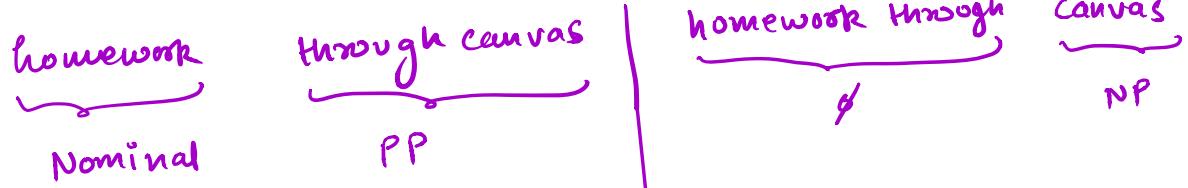
Possible combinations = $\frac{\text{the homework}}{NP} \frac{\text{through}}{\text{Prep}}$
 $\frac{\text{the}}{\text{Det}} \frac{\text{homework through}}{\varnothing}$

Possible production rule = 0

$$P = 0$$

"homework through canvas"

Possible combinations:



Production rule:

$$\text{Nominal} \rightarrow \text{Nominal PP}$$

$$P = P(\text{Nominal}) P(\text{PP}) P(\text{Nominal})$$

$$= 0.15 * 0.032 * 0.5$$

$$P = 0.0024$$

Taking 4 word at a time

"Submit the homework through"

Possible combinations are:

Submit the homework through

$\underbrace{\text{S}}$ $\underbrace{\text{the}}$ $\underbrace{\text{homework}}$ $\underbrace{\text{through}}$

{ S, VP, Verb } \emptyset

No prod. rule $P = 0$

Submit the homework through

$\underbrace{\text{S}}$ $\underbrace{\text{the}}$ $\underbrace{\text{homework}}$ $\underbrace{\text{through}}$

\emptyset \emptyset

$P = 0$

Submit the homework through,

$\underbrace{\text{S}}$ $\underbrace{\text{VP}}$, $\underbrace{\text{S}}$ \exists Prep

$P = 0$

"the homework through canvas"

Possible combinations

$\underbrace{\text{the}}$ $\underbrace{\text{homework through canvas}}$

Det Nominal

Production rule:

$$NP \rightarrow Det \ Nominal$$

$$P = P(C_{\text{Det}}) \ P(C_{\text{Nominal}}) \ P(NP)$$

$$P = 0.6 \times 0.0024 + 0.6$$

$$P = 0.000864$$

the homework
NP

through canvas
PP

NP PP \notin {Production Rule}

$$P=0$$

the homework through canvas
 ϕ NP

$$P=0$$

Taking 5 word at a time

Submit the homework through canvas
{S, VP, Verb} NP

SNP \notin {Production Rule}

VPNP \notin {Production Rule}

VerbNP \in {Production Rule}

Possible Prod. rules:

$$S \rightarrow \text{Verb } NP \quad | \quad P = P(\text{Verb}) P(NP) P(S)$$

$$= 0.5 \times 0.000864 \times 0.05$$

$$P(S_1) = 0.0000216$$

$$VP \rightarrow \text{Verb } NP \quad | \quad P = P(\text{Verb}) P(NP) P(VP)$$

$$= 0.5 \times 0.000864 \times 0.5$$

$$P(VP_1) = 0.000216$$

Submit the homework through canvas

$\underbrace{\text{Submit}}_{\phi}$ $\underbrace{\text{the homework}}_{\text{Nominal}}$

$$P = 0$$

Submit the homework through canvas

$\underbrace{\text{Submit the homework}}_{\{ \text{Vi, Sy} \}}$ $\underbrace{\text{through canvas}}_{\{ \text{PPY} \}}$

$S \text{ PP } \notin \{ \text{Prod. rules} \}$

$VP \text{ PP } \in \{ \text{Prod. rules} \}$

Possible Prod. rules.

$$S \rightarrow VP \text{ PP} \quad | \quad P = P(VP) P(PP) P(S)$$

$$= 0.0135 \times 0.032 \times 0.03$$

$$P(S_2) = 0.00001296$$

$$VP \rightarrow VP\ PP \quad | \quad P = P(VP) P(PP) P(VP)$$

$$= 0.0135 \times 0.032 \times 0.3$$

$P(VP_2) = 0.0001296$

Submit the homework through canvas

$\underbrace{\quad}_{\phi}$ $\underbrace{\quad}_{NP}$

No Prod. rule $P^0 = 0$

Final Probabilities

$$P(S_1) = 0.0000216$$

$$P(S_2) = 0.0001296$$

$$P(VP_1) = 0.000216$$

$$P(VP_2) = 0.0001296$$

We can built the table as:

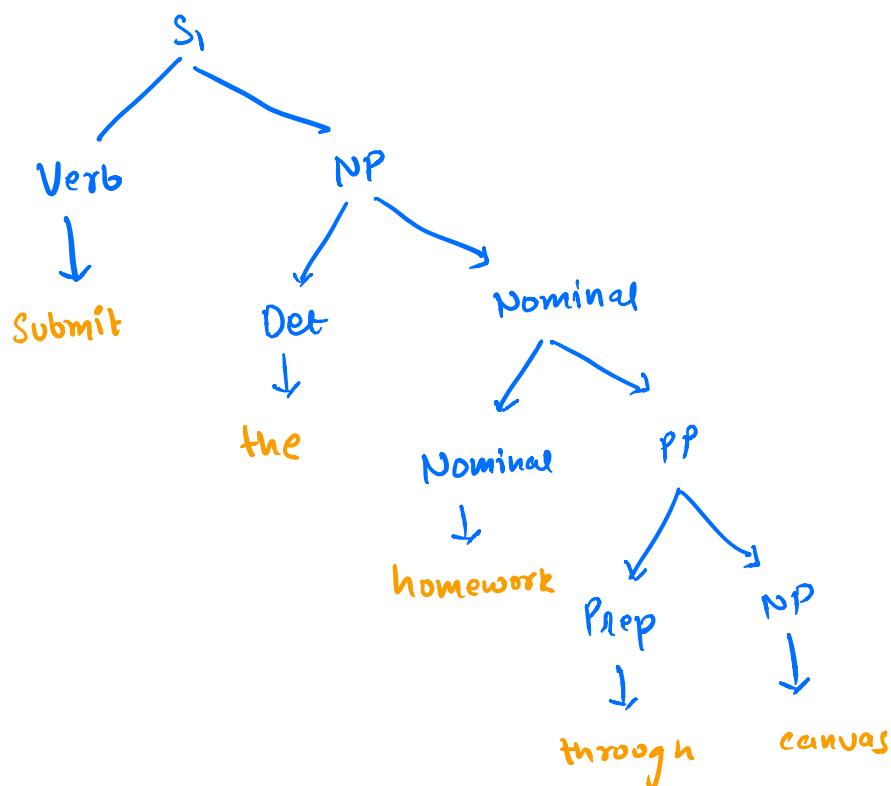
Submit	the	homework	through	Canvas																																						
$S = 0.01$ $VP = 0.1$ $Verb = 0.5$ $(0, 1)$		$VP = 0.0135$ $S = 0.00135$ $(0, 3)$		$S_1 = 0.0000216$ $S_2 = 0.000216$ $VP_1 = 0.000216$ $VP_2 = 0.0001296$ $(0, 5)$																																						
	$Det = 0.6$ $(0, 2)$	$NP = 0.054$ $(1, 3)$		$NP = 0.000864$ $(1, 5)$																																						
		$Nominal = 0.15$ $(2, 3)$		$Nominal = 0.0024$ $(2, 5)$																																						
			$P_{Prep} = 0.2$ $(3, 4)$	$PP = 0.032$ $(3, 5)$																																						
				$NP = 0.16$ $(4, 5)$																																						
<table border="1"> <thead> <tr> <th>Rule</th><th>Probability</th></tr> </thead> <tbody> <tr><td>$S \rightarrow NP VP$</td><td>0.8</td></tr> <tr><td>$S \rightarrow \text{submit}$</td><td>0.01</td></tr> <tr><td>$S \rightarrow \text{Verb NP}$</td><td>0.05</td></tr> <tr><td>$S \rightarrow VP PP$</td><td>0.03</td></tr> <tr><td>$NP \rightarrow \text{Canvas}$</td><td>0.16</td></tr> <tr><td>$NP \rightarrow \text{Gradescope}$</td><td>0.04</td></tr> <tr><td>$NP \rightarrow \text{Det Nominal}$</td><td>0.6</td></tr> <tr><td>$\text{Nominal} \rightarrow \text{Nominal Noun}$</td><td>0.2</td></tr> <tr><td>$\text{Nominal} \rightarrow \text{Nominal PP}$</td><td>0.5</td></tr> <tr><td>$\text{Nominal} \rightarrow \text{homework}$</td><td>0.15</td></tr> <tr><td>$VP \rightarrow \text{submit}$</td><td>0.1</td></tr> <tr><td>$VP \rightarrow \text{contain}$</td><td>0.04</td></tr> <tr><td>$VP \rightarrow \text{Verb NP}$</td><td>0.5</td></tr> <tr><td>$VP \rightarrow \text{VP PP}$</td><td>0.3</td></tr> <tr><td>$PP \rightarrow \text{Prep NP}$</td><td>1.0</td></tr> <tr><td>$\text{Det} \rightarrow \text{the}$</td><td>0.6</td></tr> <tr><td>$\text{Prep} \rightarrow \text{through}$</td><td>0.2</td></tr> <tr><td>$\text{Verb} \rightarrow \text{submit}$</td><td>0.5</td></tr> </tbody> </table>					Rule	Probability	$S \rightarrow NP VP$	0.8	$S \rightarrow \text{submit}$	0.01	$S \rightarrow \text{Verb NP}$	0.05	$S \rightarrow VP PP$	0.03	$NP \rightarrow \text{Canvas}$	0.16	$NP \rightarrow \text{Gradescope}$	0.04	$NP \rightarrow \text{Det Nominal}$	0.6	$\text{Nominal} \rightarrow \text{Nominal Noun}$	0.2	$\text{Nominal} \rightarrow \text{Nominal PP}$	0.5	$\text{Nominal} \rightarrow \text{homework}$	0.15	$VP \rightarrow \text{submit}$	0.1	$VP \rightarrow \text{contain}$	0.04	$VP \rightarrow \text{Verb NP}$	0.5	$VP \rightarrow \text{VP PP}$	0.3	$PP \rightarrow \text{Prep NP}$	1.0	$\text{Det} \rightarrow \text{the}$	0.6	$\text{Prep} \rightarrow \text{through}$	0.2	$\text{Verb} \rightarrow \text{submit}$	0.5
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Table 4: Initial probabilities

We look at the start symbol with high probability.

$$S_1 = 0.0000216$$

The tree that can be built using this as:



⑥: Prob. of the sentence:

$S = \text{"Submit the homework through canvas"}$

$$\text{Prob}(S) = S_1 + S_2$$

$$= 0.0000216 + 0.00001296$$

$$= 0.00003456 \quad \underline{\text{Ans}}$$