COMP9418: Advanced Topics in Statistical Machine Learning

Assignment Proference Pelp

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Introduction

- In this lecture, we study algorithm to compute queries of the form
 - MAP: maximum a posteriori hypothesis
 - MPE: maximum a posteriori explanationect Exam Help
- In these queries, we are interested in finding the most probable instantiations of a subset of variables
- We discuss variations of the Christolet Management of the Chr

Introduction: Example

yes

male

 $\Theta_{S|C}$

.05

- Consider a Bayesian network on the right
 - male no 95 yes \overline{ve} 20

 It concerns a population of 55% female yes 01 no ve 20 males and 45% females Assignment Broject $Exam_nHelp$ 80
 - They can suffer of a medical condition C that is more likely ihttps males
 - There are two diagnosis tests for T_1 and T_2
 - T_2 is more effective on females
 - Both tests are equally effective on males

s://tutores	S.C	om					
SC	T_2	$\Theta_{T_2 C,S}$	T_1	T_2	\boldsymbol{A}	$\Theta_{A T_1,T_2}$,
Cinate osta	1 te 1	rc. \$ 0	ve		yes	1	
male yes	\overline{ve}	.20	ve	ve	no	0	1
male no	ve	.20	ve	\overline{ve}	yes	0	\
male no	\overline{ve}	.80	ve	\overline{ve}	no	1	
female yes	ve	.95	\overline{ve}	ve	yes	0	
female yes	\overline{ve}	.05	\overline{ve}	ve	no	1	
female no	ve	.05	\overline{ve}	\overline{ve}	yes	1	
female no	\overline{ve}	.95	\overline{ve}	\overline{ve}	no	0	

 $\Theta_{T_1|C}$

.80

yes ve

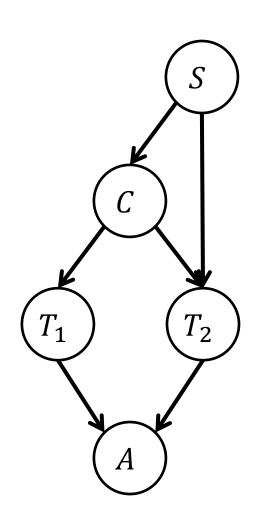
 $\Theta_{\mathcal{S}}$

.55

male

Introduction: Example

- We can partition this population in four groups
 - Males and females, with or without the condition
- Suppose a person takes both the third and the suppose a person takes both the suppose a person takes between the suppose a person tak
- - This is an example of MAP Whatie Stutores
 - The most likely instantiation of S and C given A = yes
 - In this query, S and C are MAP variables
- The answer for this example is
 - S = male and C = no with posterior probability of $\sim 49.3\%$



MAP and Inference

- Variable and factor elimination algorithms can compute MAP instantiations
 - They are efficient with small number of MAP variables in the small number of MAP variables.
 - We compute the posterior marginal over MAP variables and select the instantiation with maximal probability rcs.com
- However, this approach is expanential in the number of MAP variables
- Our objective in this lecture is to present algorithms for MAP instantiations
 - Not necessarily exponential in the number of MAP variables

MAP and MPE

- MPE is a special case of MAP when MAP variables contain all unobserved network variables
 - In the previous example, Assignment Project Example pan MAP groups
 - Males and females, with or without the /tutorcs_com
 Males and females, with or without the /tutorcs_com condition and the four possible outcomes for the two tests
- This is the MAP instantiation for S, C, T_1 and T_2
 - The answer is S = female, C = no, $T_1 = \overline{ve}, T_2 = \overline{ve}$
 - With posterior probability ~47%

- This case of MAP is known as MPE instantiation
 - MPE instantiations are much easier to

 - That is why they have their own name
- WeChat: cstutorcs MPE projection on variables S and C is

$$S = female, C = no$$

- But the MAP answer of previous slides is S = male and C = no
- Although this technique is sometimes used as an approximation for MAP

Computing MPE

- Given a network
 - lacktriangle The MPE probability for the variables $oldsymbol{Q}$ of a network given evidence $oldsymbol{e}$ is defined as

$$MPE_P(\boldsymbol{e}) \stackrel{\text{def}}{=} \max_{\boldsymbol{q}} P(\boldsymbol{q}, \boldsymbol{e})$$

- There may be several in Assignment Projects Fram Helmitv

$$MPE(e) \stackrel{\text{def}}{=} argmax P(q, e)$$

MPE instantiations can be characterized estimations q that maximize the posterior distribution

$$MPE(e) \stackrel{\text{def}}{=} \underset{q}{argmax} P(q|e)$$

- Since $P(q|e) = \frac{P(q,e)}{P(e)}$
- P(e) is independent of the instantiation q

Returning to our example

amplo	S	С	$\Theta_{S C}$	C	T_1	$\Theta_{T_1 C}$
ample	male	yes	.05	yes	ve	.80
	male	no	.95	yes	\overline{ve}	.20
	female	yes	.01	$n_{\mathcal{O}}$	vе	.20
Assignm	Female (oject	boxa	m_nH	clp	.80

male

female .45

https://tutorcs.com

~				~				ı	
_	S	С	T_2	$\Theta_{T_2 C,S}$	T_1	T_2	Α	$\Theta_{A T_1,T_2}$	2
WeC	mate			· -	ve		yes	1	_
	male	yes	\overline{ve}	.20	ve	ve	no	0	
	male	no	ve	.20	ve	\overline{ve}	yes	0	
	male	no	\overline{ve}	.80	ve	\overline{ve}	no	1	
f	emale	e yes	ve	.95	\overline{ve}	ve	yes	0	
f	emale	e yes	\overline{ve}	.05	\overline{ve}	ve	no	1	
f	emale	e no	ve	.05	\overline{ve}	\overline{ve}	yes	1	
f	emale	e no	\overline{ve}	.95	\overline{ve}	\overline{ve}	no	0	

		S	C	T_1	T_2	\boldsymbol{A}	P(.)			
Returning to our example	2 1	male	yes	ve	ve	yes	.017600	-		
We can compute the joint	3	male	yes	ve	\overline{ve}	no	.004400		(5	\mathcal{S}
probability for this Bayesian	5	male	yes	\overline{ve}	ve	no	.004400			-
network Assi	gnmer	itmPaleje	oeE	XEAT	१ म्ब	pes	.001100			
(Even rows omitted since they	9	male	no	ve	ve	yes	.020900		\mathcal{L}	
	https:/	turdec	s. eo 1	\mathbf{n}^{pe}	\overline{ve}	no	.083600	(('	
- TI NADE' I I'I'	13	male	no	\overline{ve}	ve	no	.083600			
(assuming no evidence) is given	We © h	amalsti	itorc	$s\overline{ve}$	\overline{ve}	yes	.334400		À	
in row 31	17	female	yes	ve	ve	yes	.003420	$\left(T_{1}\right)$	\int_{T}	$\binom{7}{2}$
 MPE probability (MPE_P) is 	19	female	yes	ve	\overline{ve}	no	.000180	$\binom{r_1}{r_1}$	1	
.338580	21	female	yes	\overline{ve}	ve	no	.000855			
.550500	23	female	yes	\overline{ve}	\overline{ve}	yes	.000045			
	25	female	no	ve	ve	yes	.004455	ζ_A	1	
	27	female	no	ve	\overline{ve}	no	.084645		'	
	29	female	no	\overline{ve}	ve	no	.017820			
	31	female	no	\overline{ve}	\overline{ve}	yes	.338580			9

- We can compute MPE_p using Variable Elimination
 - However, when eliminating a variable, we maximize out instead of summing it out
- To maximize out a variable B from a factor $\phi(A,B,C)$, we produce another factor over remaining variables A and S ignment Project Exam Help
 - By merging all rows that agree pathe values of these remaining variables
 - As we merge rows, we drop reference to the maximized variable and assign to the resulting row the
 maximum probability associate the maximum probability associate the maximum probability associate the maximum probability associated the maximum probability associated the maximum probability associated the maximized variable and assign to the resulting row the

A	В	С	$\phi(A,B,C)$	_			
0	0	0	7				1 (4 0)
0	0	1	4.5		Α	С	$\max_{B} \phi(A, C)$
0	1	0	.2		0	0	7
0	1	1	2		0	1	4.5
1	0	0	3		1	0	3
1	0	1	.5		1	1	3
1	1	0	1.2				
1	1	1	3				

- The result of maximizing out variable B from factor ϕ is
 - Another factor, $\max \phi$ that does not mention B
- - The probability assigned to this factor is the MPE probability
 - This method can be extended to provide the MPE instantiation (more later) we chat: cstutorcs
- Maximization is commutative
 - Allow us to refer to maximizing out a set of variables without specifying the order
 - Also, $\max_X \phi_1 \phi_2 = \phi_1 \max_X \phi_2$ if variable X appears only in ϕ_2

MPE VE: Algorithm

```
m{Q} \leftarrow variables in the network m{\pi} \leftarrow elimination order of variables m{Q} m{S} \leftarrow \{ \phi^{e} : \phi \text{ is a factor of the network} \} for i=1 to |m{Q}| do \sigma_{i} \leftarrow \prod_{k} \phi_{k} where \phi_{k} belongs to m{S} and mentions variable \pi(i) \tau_{i} \leftarrow \max_{\pi(i)} \sigma_{i} https://tutorcs.com replace all factors \phi_{k} in m{S} by factor \tau_{i} return trivial factors \sigma_{k} in m{S} by factor \sigma_{i}
```

Notes:

- All factors are eliminated leading to a trivial factor
- $\phi^{m{e}}$ is a factor with the rows of factor ϕ that match the evidence $m{e}$
- Pruning should eliminate edges only since all variables are relevant to the answer
- This algorithm has the same complexity as VE, i.e., the time and space complexity are $O(n \exp(w))$ for n variables and an elimination width w

Returning to our example

Let us run MPE VE on this

 $C \underline{T_1} \Theta_{T_1|C}$ $\Theta_{S|C}$ male .05 .80 yes yes ve no.95 yes \overline{ve} .20 male example

Assignment altoject by am Help

With the elimination order .20

 $\pi = S, C, A, T_1, T_2$

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Tittpb.//tatorob.c	VIII				I	
S C T_2	$\Theta_{T_2 C,S}$	T_1	T_2	A	$\Theta_{A T_1,T}$, 2_
WeChate ostute	rcs0	ve	ve	yes	1	
male yes ve	.20	ve	ve	no	0	
male no ve	.20	ve	\overline{ve}	yes	0	
male no ve	.80	ve	\overline{ve}	no	1	
female yes ve	.95	\overline{ve}	ve	yes	0	
female yes ve	.05	\overline{ve}	ve	no	1	
female no ve	.05	\overline{ve}	\overline{ve}	yes	1	
female no \overline{ve}	.95	\overline{ve}	\overline{ve}	no	0	

 Θ_{S}

.55

male

female .45

yes

no

 $|\phi_1(S,C)|$

.05

.95

C $T_1 | \phi_2(T_1, C)$

yes ve

yes ve

.80

.20

.20

.80

Returning to our example

Let us run MPE VE on this female yes
Assignment Project example

With the elimination order

 $\pi = S, C, A, T_1, T_2$

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male

male

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$\phi_4(T_2,C,S)$	T_1 T_2 A	$\phi_5(T_1,T_2,A)$
tutoles	ve ve yes	1
.20	ve ve no	$0 \int_{T}$
.20	ve ve yes	$0 \begin{array}{c} I \\ I \end{array}$
.80	ve ve no	1
.95	ve yes	0
.05	ve ve no	1
.05	ve ve yes	1
.95	\overline{ve} \overline{ve} no	0
	φ ₄ (T ₂ , C, S) tutoθes .20 .20 .80 .95 .05	$\phi_4(T_2, C, S)$ T_1 T_2 A ve ve ve yes ve

 $\phi_3(S)$

.55

.45

male

female



mple $\frac{S}{male}$ $\frac{C}{yes}$ $\frac{\phi_1(S,C)}{yes}$ $\frac{C}{ve}$ $\frac{T_1}{yes}$ $\frac{\phi_2(T_1,C)}{yes}$ $\frac{\delta}{ve}$ $\frac{$



With the elimination order

$$\pi = S, C, A, T_1, T_2$$

https://tutorcs.com

<i>S</i>	$\phi_3(S)$	_
male	.55	×
female	.45	

	<i>S</i>	С	T_2	$\phi_4(T_2, \mathbf{G})$	S)	has c	strit	T_{2}	$\sigma_1(T_2, S, C)$
	male	yes	ve	.80		male	yes	ve	.440
	male	yes	\overline{ve}	.20		male	yes	\overline{ve}	.110
Ī	male	no	ve	.20		male	no	ve	.110
×	male	no	\overline{ve}	.80	≈	male	no	\overline{ve}	.440
	female	yes	ve	.95		female	yes	ve	.428
	female	yes	\overline{ve}	.05		female	yes	\overline{ve}	.023
	female	no	ve	.05		female	no	ve	.023
	female	no	\overline{ve}	.95		female	no	\overline{ve}	.428

T_1	T_2	A	$\phi_5(T_1,T_2,A)$
ve	ve	yes	1
ve	ve	no	0
ve	\overline{ve}	yes	0
ve	\overline{ve}	no	1
\overline{ve}	ve	yes	0
\overline{ve}	ve	no	1
\overline{ve}	\overline{ve}	yes	1
\overline{ve}	\overline{ve}	no	0
			ĺ

- Returning to our example
 - Let us run MPE VE on this

 $T_1 | \phi_2(T_1, C)$.80 yes ve .20 yes ve .20 .80

Assignment Project Exam Help And use the elimination order $\pi = S, C, A, T_1, T_2$ https://tutorcs.com

		<u>S</u>	С	T_2	$\sigma_1(T_2,S_1)$	S = S	C T	Γ_2	$\sigma_2(T_2, S, C)$	T_1	T_2 A	$\phi_5(T_1,T_2,T_3)$	<u>A)</u>
S C	$ \phi_1(S,C) $	male	yes	ve	W 440 ¹¹	ial: CSull male	yes v	ге	.0220	ve	ve yes	1	
male yes		male	yes	\overline{ve}	.110	male	yes \overline{v}	\overline{e}	.0055	ve	ve no	0	
male no	.95	male	no	ve	.110	male	no v	e e	.1045	ve	ve yes	0	
female yes	X	male	no	\overline{ve}	.440	≈ male	$no \overline{v}$	\overline{e}	.4180	ve	ve no	1	
female no	.99	female	yes	ve	.428	female	yes v	e e	.0043	\overline{ve}	ve yes	0	
jemaie no	• 7 7	female	yes yes	\overline{ve}	.023	female	yes \overline{v}	\overline{e}	.0002	\overline{ve}	ve no	1	
		female	e no	ve	.023	female	no v	e e	.0228	\overline{ve}	ve yes	1	
		female	e no	\overline{ve}	.428	female	$no \overline{v}$	\overline{e}	.4237	\overline{ve}	ve no	0	16

Returning to our example

Let us run MPE VE on this example

And use the elimination

order $\pi = S, C, A, T_1, T_2$ https://tutorcs.com

pie	yes ve	.80
nis	yes ve	.20
·	no ve	.20
ssignment Project Exam	hette	.80

S	С	T_2	$\sigma_2(T_2, S, C)$	WeCh	at: cstutorcs
male	yes	ve	.0220	WCCII	at. estutores
male	yes	\overline{ve}	.0055	$C T_2$	$\tau_2(T_2, C)$
male	no	ve	.1045	yes ve	.0220
male	no	\overline{ve}	.4180	\longrightarrow yes \overline{ve}	.0055
female	yes	ve	.0043	no ve	.1045
female	yes	\overline{ve}	.0002	\sim no \overline{ve}	.4237
female	no	ve	.0228		
female	no	\overline{ve}	.4237		

T_1	T_2 A	$\phi_5(T_1, T_2, A)$	
ve	ve yes	1	\mathcal{L}
ve	ve no	0 (,	T.
ve	ve yes	0	
ve	ve no	1	
\overline{ve}	ve yes	0	_
\overline{ve}	ve no	1	
\overline{ve}	ve yes	1	A
\overline{ve}	\overline{ve} no	0	

 $C T_1 \phi_2(T_1, C)$

Returning to our example

C T_1 $\phi_2(T_1,C)$ $\tau_2(T_2,C)$.0220 .80 yes ve yes ve .0055 yes ve yes ve .20 E_{423}^{1045} He_{10}^{no} $\frac{ve}{ve}$.20

Let us run MPE VE on this Assignment Project example

And use the elimination

order $\pi = S, C, A, T_1, T_2$ https://tutorcs.com

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T_1	T_2	A	$\phi_5(T_1,T_2,A)$	
ve	ve	yes	1	
ve	ve	no	0 (T_1 T_2
ve	\overline{ve}	yes	0 \	$\begin{pmatrix} 1_1 \\ 1_2 \end{pmatrix}$
ve	\overline{ve}	no	1	
\overline{ve}	ve	yes	0	
\overline{ve}	ve	no	1	
\overline{ve}	\overline{ve}	yes	1	A
\overline{ve}	\overline{ve}	no	0	_

.80

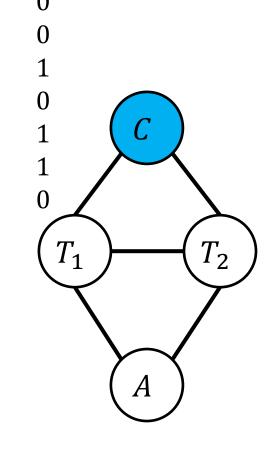
Returning to our example

- Let us run MPE VE on this example
- Assignment Project Example And use the elimination order $\pi = S, C, A, T_1, T_2$ https://tutorcs.com

nment Project Exam I	Help	\overline{ve}	no	
3	\overline{ve}	ve	yes	
tps://tutorcs.com		ve		
1	\overline{ve}	\overline{ve}	yes	
CeChaterestatoros Ta	\overline{ve}	\overline{ve}	no	

<u></u>	T_2	$\tau_2(T_2,C)$	<u></u>	T_1	$\phi_2(T_1, C)$	
yes	ve	.0220	yes	ve	.80	
yes	\overline{ve}	.0055 ×	yes	\overline{ve}	.20 ~	,
no	ve	.1045		ve	.20 ~	
no	\overline{ve}	.4237	no	\overline{ve}	.80	
700		11207	100		100	

	1 1-0		CI-QDC	<u> </u>
	yes	ve	ve	.0176
•	yes	ve	\overline{ve}	.0044
	yes	\overline{ve}	ve	.0044
;	yes	\overline{ve}	\overline{ve}	.0011
	no	ve	ve	.0209
	no	ve	\overline{ve}	.0836
	no	\overline{ve}	ve	.0847
	no	\overline{ve}	\overline{ve}	.3390



 $T_1 \ T_2 \ A \ \phi_5(T_1, T_2, A)$

ve ve yes

ve ve no

ve ve yes

Returning to our example

Let us run MPE VE on this

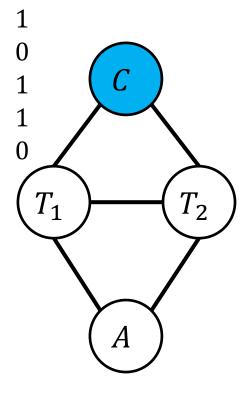
Assignment Project Exam H

And use the elimination

order $\pi = S, C, A, T_1, T_2$ https://tutorcs.com

<u></u>	T_2	T_1	$\sigma_3(C, T_1, T_2)$	We	Ch_2	it: cstutorcs
yes	ve	ve	.0176	***		ii. Cstatores
yes	ve	\overline{ve}	.0044	<u>T</u> 2	T_1	$\tau_3(T_2,T_1)$
yes	\overline{ve}	ve	.0044	ve	ve	.0209
yes	\overline{ve}	\overline{ve}	.0011	ve	\overline{ve}	.0836
no	ve	ve	.0209	\overline{ve}	ve	.0847
no	ve	\overline{ve}	.0836	\overline{ve}	\overline{ve}	.3390
no	\overline{ve}	ve	.0847			
no	\overline{ve}	\overline{ve}	.3390			

	T_1	T_2	A	$\phi_5(T_1, T_2, A)$
	ve	ve	yes	1
	ve	ve	no	0
	ve	\overline{ve}	yes	0
I	elb	\overline{ve}	no	1
	\overline{ve}	ve	yes	0
	\overline{ve}	ve	no	1 (
	\overline{ve}	\overline{ve}	yes	1 /
	\overline{ve}	\overline{ve}	no	0



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- Returning to our example
 - Let us run MPE VE on this

order $\pi = S, C, A, T_1, T_2$ https://tutorcs.com

.0209 ve ve .0836 ve \overline{ve} Assignment Project Exam Helpe

And use the elimination .0847 .3390

 T_2 T_1

T_1	T_2	A	$\phi_5(T_1,T_2,A$	<u>4)</u>
ve	ve	yes	1	
ve	ve	no	0	(T_1) (T_2)
ve	\overline{ve}	yes	0	
ve	\overline{ve}	no	1	
\overline{ve}	ve	yes	0	
\overline{ve}	ve	no	1	(A)
\overline{ve}	\overline{ve}	yes	1	
\overline{ve}	\overline{ve}	no	0	

 $\tau_3(T_2,T_1)$

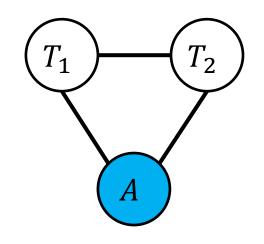
Returning to our example

Let us run MPE VE on this example

Assignment Project Exam order $\pi = S, C, A, T_1, T_2$ https://tutorcs.com

	T_2	T_1	$\tau_3(T_2,T_1)$
	ve	ve	.0209
	ve	\overline{ve}	.0836
n	He?	pe	.0847
	\overline{ve}	\overline{ve}	.3390

T_1 T_2 A	$\phi_5(T_1,T_2,A)$	WeChat: cstutorcs
ve ve yes	1	
ve ve no	0	T_1 T_2 $\tau_4(T_1,T_2)$
ve ve yes	0	ve ve 1
ve ve no	1	\overline{ve} \overline{ve} 1
ve ve yes	0	\overline{ve} ve 1
ve ve no	1	\overline{ve} \overline{ve} 1
ve ve yes	1	
ve ve no	0	



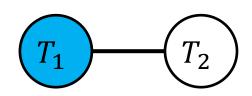
Returning to our example

 \overline{ve} \overline{ve}

.3390

Let us run MPE VE on this example

• And use the elimination \overline{ve} \overline{ve} \overline{ve} 1 order $\pi = S, C, A, T_1, T_2$ https://tutorcs.com



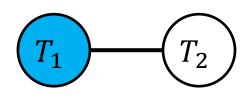
Returning to our example

Let us run MPE VE on this

Assignment Project Exam Help

And use the elimination order $\pi = S, C, A, T_1, T_2$ https://tutorcs.com

T_1	T_2	$ \tau_4(T_1,T_2) $	2)	T_2	T_1	$ au_3(T_2,T_1) $	_	T_1	T_2	$\sigma_5(T_1,T_2)$
ve	ve	1		ve	ve	.0209	-	ve	ve	.0209
ve	\overline{ve}	1	×	ve	\overline{ve}	.0836	=	ve	\overline{ve}	.0847
\overline{ve}	ve	1		\overline{ve}	ve	.0847		\overline{ve}	ve	.0836
\overline{ve}	\overline{ve}	1		\overline{ve}	\overline{ve}	.3390		\overline{ve}	\overline{ve}	.3390

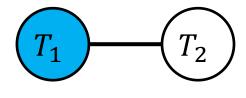


- Returning to our example
 - Let us run MPE VE on this example

Assignment Project Exam Help

And use the elimination order $\pi = S, C, A, T_1, T_2$ https://tutorcs.com

T_1	T_2	$\sigma_5(T_1,T_2)$		
ve	ve	.0209	T_2	$\tau_5(T_2)$
ve	\overline{ve}	.0847	> ve	.0836
\overline{ve}	ve	.0836	\overline{ve}	.3390
\overline{ve}	\overline{ve}	.3390		



- Returning to our example
 - Let us run MPE VE on this example
 - Assignment Project Exam Help

 And use the elimination

order $\pi = S, C, A, T_1, T_2$ https://tutorcs.com

$$T_2$$
 $\tau_5(T_2)$ ve .0836 ve .3390



We can also be interested

in the MPE instantiation

- Returning to our example
 - Let us run MPE VE on this example
 - example
 Assignment Project Exam Help of information of information of information order $\pi = S, C, A, T_1, T_2$ https://tutoedimination
 - $MPE_P \approx 0.3390$

Recovering MPE Instantiation

We can modify the previous algorithm to compute the MPE instantiation

In addition to the MPE probability

- The idea is to use extended signment Project Exame Hero
 - It assigns to each instantiation a pumber to and an instantiation
- We use $\phi[x]$ to denote the WeChat: instantiation
 - While continuing to use $\phi(x)$ for denoting the number
 - The instantiation $\phi[x]$ is used to record the MPE instantiation as it is being constructed

Project	EX3	lm t	118110 \	_			1
Project male	yes	\overline{ve}	.0055	<u></u>	T_2	$\phi(.)$	ϕ [.]
utonese.c	•			yes	ve	.0220	male
male	no	\overline{ve}	.4180	yes	\overline{ve}	.0055	male
: Esmals	rxes	ve	.0043	no	ve	.1045	male
female	yes	\overline{ve}	.0002	no	\overline{ve}	.4237	female
female	no	ve	.0228				
female	no	\overline{ve}	.4237				

Returning to our example

Let us run MPE VE on this
 example, but now
 computing the MPE
 Assignm
 instantiation with evidence

$$A = yes$$

S C 0	$\Theta_{C S}$ (T_{2}	$\Theta_{T_1 C}$	S	$\Theta_{\mathcal{S}}$		
		es v		male	.55		
male no	.95 y	es $\overline{v\epsilon}$	ē . 20	female	.45	\sum_{j}	ノ
ignment Project	01 n 5x am	Hel	e .20 .80				
https://tutorcs.c	1			I	$\left(C\right)$	·	
S C T_2	$\Theta_{T_2 C,S}$	T_1	T_2 A	$\Theta_{A T_1,T_2}$		⁻ \	
WeChate ostuto	rc&0	ve	ve yes	1	K	Y	_
male yes ve	.20	ve	ve no	0 (T_1	$\int_{T_{-}}$	
male no ve	.20	ve	ve yes	0	$\frac{1}{2}$	T_2	<u> </u>
male no ve	.80	ve	ve no	1	T		
female yes ve	.95	\overline{ve}	ve yes	0	<u> </u>		
female yes \overline{ve}	.05	\overline{ve}	ve no	1			
female no ve	.05	\overline{ve}	ve yes	1	(A		
female no ve	.95	\overline{ve}	ve no	0			

Returning to our example

Let us run MPE VE on this
 example, but now
 computing the MPE
 Assignt
 instantiation with evidence

A = yes

	_	S	С	$\phi_1(S,C)$	<u></u>	T_1	$\phi_2(T_2)$	$T_1, C)$	<i>S</i>	$\phi_3(S)$		
		male	yes	.05	yes	ve	3.	30	male	.55	C	
		male	no	.95	yes	\overline{ve}	.2	20	female	.45	72	
	•	female	e yeş	ect 5xar	no	ve	.2	20			/ \	
S .	ignn	Perhale	Praj	ect Bxai	n_{no}	eer	3.	30		\angle		
	1 44	114	4							$\left(\right)$	\	
	nttp			es.com	7 77			, , , , , , , , , , , , , , , , , , ,				
	<u>S</u>	<u> </u>	$T_2 \phi$	$o_4(T_2, C, S)$	T_1	T_2	<u>A</u>	$\phi_5(T_1)$	$T_2,A)$		\	
	Wal	Chras	rest	utoles	ve	ve	yes		1		K	
	mal	e yes	\overline{ve}	.20	ve	ve	no		T_1		\int_{T}	
	mal	e no	ve	.20	ve	\overline{ve}	yes		$0 \begin{array}{c} I_1 \end{array}$		T_2	
	mal	e no	\overline{ve}	.80	ve	\overline{ve}	no		$1 \qquad \mathbf{T}$			
	femo	ile yes	ve	.95	\overline{ve}	ve	yes		0			
	femo	ale yes	\overline{ve}	.05	\overline{ve}	ve	no		1			
	femo	ale no	ve	.05	\overline{ve}	\overline{ve}	yes		1	A	/	
	femo	ıle no	\overline{ve}	.95	\overline{ve}	\overline{ve}	no		0			

Returning to our example

Let us run MPE VE on this
 example, but now
 computing the MPE
 Assign
 instantiation with evidence

$$A = yes$$

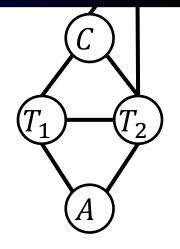
		S	$\boldsymbol{\mathcal{C}}$	$\phi_1(S,C)$	C	T_1	$\phi_2(T_2)$	$T_1, C)$	<i>S</i>	$\phi_3(S)$		
		male	yes	.05	yes	ve	3.	30	\overline{male}	.55	\int_{C}	
		male	no	.95	yes	\overline{ve}	.2	20	female	.45	$\int S$	
	<i>. f</i>	emale	yes	ect 5xar	no	ve	.2	20			/ \	
5.	ignm	emale	TAJ	ect syxar	n_{nb}	l e f	3.	30				
	1 44	/ / 4	4							(c))	
	http			cs.com				l			/ I	
_	S	<u> </u>	$T_2 q$	$b_4(T_2,C,S)$	T_1	T_2	а	$\phi_{5}(T_{1})$	T_2, a			
	Wale	Char	rest	utoles	ve	ve	yes		1		V	
	male	e yes	\overline{ve}	.20	ve	\overline{ve}	yes		$0 {\color{red} C_T}$		\int_{T}	
	male	e no	ve	.20	\overline{ve}	ve	yes		$\int_{0}^{0} T_{1}$		$\neg T_2$	$^{2}\mathcal{J}$
	male	e no	\overline{ve}	.80	\overline{ve}	\overline{ve}	yes		1		7	
	fema	le yes	ve	.95								
	fema	le yes	\overline{ve}	.05							1	
	fema	le no	ve	.05						A		
	fema	le no	\overline{ve}	.95								



Returning to our example

 Let us run MPE VE on this example, but now computing the MPE Assignation with evidence

	S	С	$ \phi_1(S,C) $	<u></u>	T_1	$\phi_2(T_1,C)$
	male	yes	.05	yes	ve	.80
	male	no	.95	yes	\overline{ve}	.20
J	female	yeş	.01	n_{Q}	ve	.20
	female	roje	ct E xar	$n_{no}H$	eep	.80



$$A = yes$$

https://tutorcs.com

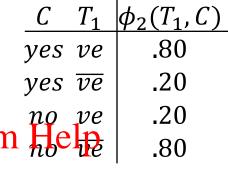
		S	С	T_2	$\phi_4(T_2,C)$	S) S	$\boldsymbol{\mathcal{C}}$	T_2	$\sigma_1(T_2, S, C)$
		$\overline{}$ male	yes	ve	.800	Chatle		ores	.440
		male	yes	\overline{ve}	.20	male	yes	\overline{ve}	.110
S	$\phi_3(S)$	male	no	ve	.20	male	no	ve	.110
male	.55	× male	no	\overline{ve}	.80	≈ male	no	\overline{ve}	.440
female	.45	female	yes	ve	.95	female	yes	ve	.428
		female	yes	\overline{ve}	.05	female	yes	\overline{ve}	.023
		female	no	ve	.05	female	no no	ve	.023
		female	no	\overline{ve}	.95	female	no no	\overline{ve}	.428

T_1	T_2	а	$\phi_5(T_1,T_2,a)$
ve	ve	yes	1
ve	\overline{ve}	yes	0
\overline{ve}	ve	yes	0
\overline{ve}	\overline{ve}	yes	1



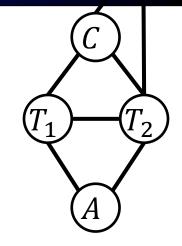
Assignment Project Exam Help

$$A = yes$$



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			S	\mathcal{C}	T_2	$\sigma_1(T_2,S_n)$	S = S	C	T_2	$\sigma_2(T_2, S,$
C	С	$ \phi_1(S,C) $	male	yes	ve	W.440 ⁿ	at: estuto male	yes	ve	.0220
	yes	$\frac{\varphi_1(3,c)}{.05}$	male	yes	\overline{ve}	.110	male	yes	\overline{ve}	.0055
male	no	.95	male	no	ve	.110	male	no	ve	.1045
female		.01 ×	male	no	\overline{ve}	.440	≈ male	no	\overline{ve}	.4180
female	•	.01	female	yes	ve	.428	female	yes	ve	.0043
jeniaie	no	•))	female	yes	\overline{ve}	.023	female	yes	\overline{ve}	.0002
			female	no	ve	.023	female	no	ve	.0228
			female	no	\overline{ve}	.428	female	no	\overline{ve}	.4237



 T_2 a $\phi_5(T_1, T_2, a)$

ve ve yes

ve ve yes

ve yes

 \overline{ve} \overline{ve} yes

Returning to our example

Let us run MPE VE on this example, but now computing the MPE Assignation with evidence

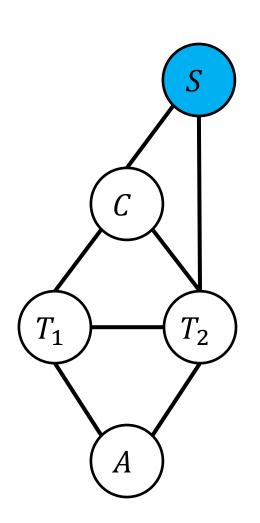
$$A = yes$$

T_1 T_2 a	$\phi_5(T_1,T_2,a)$	$C T_1$	$\phi_2(T_1, C)$
ve ve yes	1	yes ve	.80
ve ve yes		yes ve	.20
ve ve yes	oject Exam	no ve	.20
innent ver	oject ₁ Exam	i Hette	.80

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<u>S</u>	<u>C</u>	T_2	$\sigma_2(T_2, S, C)$
male	yes		.0220
male	yes	\overline{ve}	.0055
male	no	ve	.1045
male	no	\overline{ve}	.4180
female	yes	ve	.0043
female	yes	\overline{ve}	.0002
female	no	ve	.0228
female	no	\overline{ve}	.4237

<u></u>	T_2	$\tau_2(T_2,C)$	
>yes	ve	.0220	male
> yes	\overline{ve}	.0055	male
> no	ve	.1045	male
> no	\overline{ve}	.4237	female



Returning to our example

Let us run MPE VE on this example, but now computing the MPE Assignment instantiation with evidence

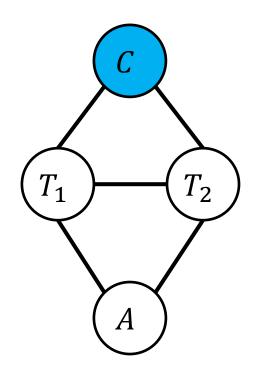
$$A = yes$$

T_1 T_2 a	$\phi_5(T_1, T_2, a)$
ve ve yes	1
ve ve yes	0
ve ve yes	oject Exam Help

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WeChatccstutorcs $\sigma_3(C, T_1, T_2)$
--

С	T_2	$\tau_2(T_2,C)$		C	T_1	$\phi_2(T_1,C)$	yes	ve	ve	.0176	male
yes	_	.0220	male	yes	ve	.80	yes	ve	\overline{ve}	.0044	male
yes	\overline{ve}	.0055	male 🗸	yes	\overline{ve}	.20	yes	\overline{ve}	ve	.0044	male
	ve	.1045				.20	yes	\overline{ve}	\overline{ve}	.0011	male
no	\overline{ve}	.4237	female	no	\overline{ve}	.80	no	ve	ve	.0209	male
		I	l)			1	no	ve	\overline{ve}	.0836	male
							no	\overline{ve}	ve	.0847	female
							no	\overline{ve}	\overline{ve}	.3390	female



Returning to our example

 Let us run MPE VE on this example, but now computing the MPE Assig instantiation with evidence

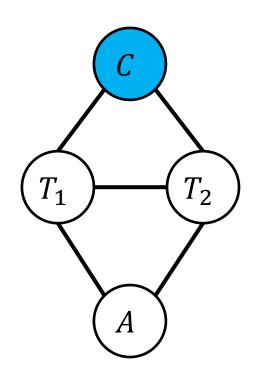
$$A = yes$$

	T_1	T_2	а	$\phi_5(T_1, T_2, a)$
			yes	1
	ve	\overline{ve}	yes	0
) 1	ve nm	ve en	yes Pro	oject Exam Help
>	ve	ve	yes	Jeet Exam Help

https://tutorcs.com

	T_2	T_1	$\sigma_3(C,T_1,T_2)$	
yes	ve	ve	.0176	male
yes	ve	\overline{ve}	.0044	male _
yes	\overline{ve}	ve	.0044	male
yes	\overline{ve}	\overline{ve}	.0011	male _
no	ve	ve	.0209	male 🚽
no	ve	\overline{ve}	.0836	male 🖊
no	\overline{ve}	ve	.0847	f emale 🖊
no	\overline{ve}	\overline{ve}	.3390	female

T_2 T_1	$ au_3(T_2,T_1) $	
ve ve	.0209	male, no
>ve ⊽e	.0836	male, no
> ve ve	.0847	female, no
> ve ve	.3390	female, no



 $| au_3(T_2,T_1)|$

.0209

.0836

Het7

.3390

ve ve

male, no

male, no

female, no

female, no

Returning to our example

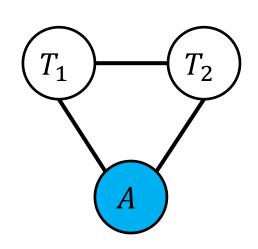
A = yes

Let us run MPE VE on this example, but now computing the MPE instantiation with evidence

 $ve \overline{ve}$ Assignment Project Exam \overline{ve} \overline{ve}

WeChat:	cstutores

T_1 T_1	Γ_2 a	$\phi_5(T_1,T_2,a)$	<u>u)</u>	T_1	T_2	$\tau_4(T_1,T_2)$
ve i	e yes	1 .		ve	ve	1
ve ī	ves	0 -		ve	\overline{ve}	0
ve v	e yes	0 -		\overline{ve}	ve	0
\overline{ve} \overline{v}	ves	1 .		\overline{ve}	\overline{ve}	1



Returning to our example

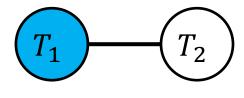
T_2 T_1	$\tau_3(T_2,T_1)$		T_1 T_2	$\tau_4(T_1, T_2)$		T_1	T_2	$\sigma_5(T_1,T_2)$		(T_1)	T_2
ve ve	.0209	male, no	ve ve	1		ve	ve	.0209	male, no		
ve ve	.0836	male, no	$\downarrow ve \overline{ve}$	0	≈	ve	\overline{ve}	0	female, no		
ve ve	.0847	female, no	$\hat{v}e$ ve	0	~	\overline{ve}	ve	0	male, no		
\overline{ve} \overline{ve}	.3390	female, no	$\overline{ve} \ \overline{ve}$	1		\overline{ve}	\overline{ve}	.3390	female, no		

Returning to our example

A = yes

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T_1	T_2	$\sigma_5(T_1,T_2)$				
ve	ve	.0209	male,no 🗕	 T_2	$\tau_5(T_2)$	
ve	\overline{ve}	0	female, no 🚤	ve	.0290	male, no, ve
\overline{ve}	ve	0	male, no 🗕	\overline{ve}	.3390	female, no, \overline{ve}
\overline{ve}	\overline{ve}	.3390	female, no 🗂		- '	



Returning to our example

A = yes

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T_2	$\tau_5(T_2)$		_		
ve	.0290	male, no, ve		τ_6	
\overline{ve}	.3390	$female, no, \overline{ve}$.3390	female, no, ve , ve



- Returning to our example

A = yes

- Since P(e) = P(A = yes) = .7205
 - $MPE_p(\mathbf{Q}|\mathbf{e}) = 47\%$

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https://tutorcs.com

T_2	$\tau_5(T_2)$		_		
ve	.0290	male, no, ve		$ au_6$	
\overline{ve}	.3390	female, no, \overline{ve}		.3390	$female, no, \overline{ve}, \overline{ve}$



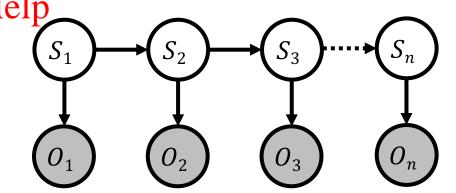
MPE and HMM

 We have seen MPE queries in the context of HMM

If we apply the VE algorithm with same order, we obtain the Forward algorithm



 Therefore both algorithms have linear time and space complexity



Computing MAP

- Given a network
 - The MAP probability for the variables M given evidence e is defined as

$$MAP_P(\boldsymbol{M}, \boldsymbol{e}) \stackrel{\text{def}}{=} \max_{\boldsymbol{m}} P(\boldsymbol{m}, \boldsymbol{e})$$

- There may be several instantiations m with maximal probability
 Each of them is a MAP instantiation

 - The set of such instantiations is defined as https://tutorcs.com
- MPE instantiations can be characterized as instantiations mthat maximize the posterior distribution as that maximize the posterior distribution as the contract of the co

• Since
$$P(\boldsymbol{m}|\boldsymbol{e}) = \frac{P(\boldsymbol{m},\boldsymbol{e})}{P(\boldsymbol{e})}$$

• P(e) is independent of the instantiation m

$$MAP(\mathbf{M}, \mathbf{e}) \stackrel{\text{def}}{=} \underset{m}{argmax} P(\mathbf{m}, \mathbf{e})$$

$$MAP(\mathbf{M}, \mathbf{e}) \stackrel{\text{def}}{=} argmax P(\mathbf{q}|\mathbf{e})$$

Computing MAP by Variable Elimination

- We can compute the MAP probability $MAP_P(\pmb{M}, \pmb{e})$ using the VE algorithm
 - First, summing out all non-MAP variables: computes the marginal P(M, e) in factored form Assignment Project Exam Help
 - Second, maximizing out MAP variables M: solve MPE problem over the resulting marginal https://tutorcs.com
- The resulting algorithm can be thought of a combination of MPE and VE algorithms
- We can use extended factors just as when computing an MPE instantiation

MAP VE: Algorithm

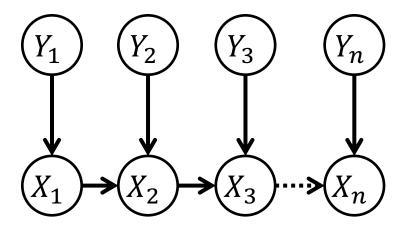
```
Q \leftarrow \text{variables in the network}
\pi \leftarrow elimination order of variables Q in which variables M appear last
S \leftarrow \{\phi^e : \phi \text{ is a factor of the network}\}\
for i = 1 to length of order \pi do \sigma_i \leftarrow \prod_k \varphi_k where \varphi_k belongs to S and mentions variable \pi(i)
      if \pi(i) \in M then https://tutorcs.com
\tau_i \leftarrow \max_{\pi(i)} \sigma_i
                WeChat: cstutorcs
        else
              \tau_i \leftarrow \sum_{\pi(i)} \sigma_i
        replace all factors \phi_k in S by factor \tau_i
 return trivial factor \prod_{\tau \in S} \tau
```

Notes:

- If the network is a Bayesian network, you can prune nodes and edges
- The elimination is special in the sense the MAP variables appear last
- The algorithm perform both types of elimination: maximizing-out MAP variables and summing-out non-MAP variables

MAP VE Complexity

- Given n variables and an elimination order of width w
 - The time and space complexity of MAP is $O(n \exp(w))$
 - Like MPE VE algorithm
- However, MAP variable orderes constrained Exam Help
 - It requires MAP variables to be last in the order https://tutorcs.com
 - This means that we may not be able to use a good ordering because low-width orders do not satisfy this constraint stutores
- For example, the polytree structure on the right
 - It has treewidth of 2 since it has at most two parents per node
 - If we want to compute MAP for variables $M = \{Y_1, ..., Y_n\}$, any order that M comes last has $width \ge n$
 - Therefore, MPE VE is linear, but MAP VE is exponential in this case



MAP VE Complexity

- In general, we cannot use arbitrary elimination orders
 - We cannot interleave variables that are summing out with those maximizing out
 - Maximization does not commute with summation

Assignment Project Exam Help
$$\sum_{\substack{max f \\ Y}} |(\mathbf{z})| \ge \max_{\substack{x \\ Y}} \sum_{\substack{x \\ Y}} |(\mathbf{z})|$$
*https://tutorcs.com

for all instantiations z

- The complexity of MAP VE is at best exponential in the constrained treewidth
 - A variable order π is **M**-constrained iff variables **M** appear last in the order π .
 - The *M-constrained treewidth* of a graph is the width of its best *M*-constrained variable order
- Computing MAP is therefore more difficult than computing MPE in the context of VE

10 + 4 + 0 = 0 / / 4 + 1 + 0 + 0 = 0 = 0 = 0

Let us run MAP VE with evidence A = yes and MAP variables S and C, and elimination order $\pi = A, T_1, T_2, S, C$ Assignm

_	S	С	$\Theta_{C S}$	<u>C</u>	T_1	$\Theta_{T_1 C}$
	male	yes	.05	yes	ve	.80
	male	no	.95	yes	\overline{ve}	.20
j	female female	yes	.01	nq	ve elp	.20
	female	no	15gx a	no	e p	.80

male

female .45

nttps://tu	torc	S.C	om				Ī	
S	С	T_2	$\Theta_{T_2 C,S}$	T_1	T_2	A	$\Theta_{A T_1,T_2}$	2
WeChate	COSTS	1 te 1	c §0	ve	ve	yes	1	
male	yes	\overline{ve}	.20	ve	ve	no	0	
male	no	ve	.20	ve	\overline{ve}	yes	0	/
male	no	\overline{ve}	.80	ve	\overline{ve}	no	1	
femal	e yes	ve	.95	\overline{ve}	ve	yes	0	
femal	e yes	\overline{ve}	.05	\overline{ve}	ve	no	1	
femal	e no	ve	.05	\overline{ve}	\overline{ve}	yes	1	
femal	e no	\overline{ve}	.95	\overline{ve}	\overline{ve}	no	0	

 $|\phi_1(S,C)|$ C $T_1 | \phi_2(T_1, C)$ $\phi_3(S)$ S Let us run MAP VE with evidence— .55 .05 .80 male male yes ve yes A = yes and MAP variables S .95 .20 yes ve female male .45 noand C, and elimination order Assignment Project Exam Help .20 $\pi = A, T_1, T_2, S, C$.80 https://tutorcs.com $C T_2 | \phi_4(T_2, C, S) | T_1 T_2 A | \phi_5(T_1, T_2, A)$ Weethers restutores ve ve yes male yes ve .20 ve ve no T_1 T_2 .20 male 0 no ve ve ves male .80 $no \ \overline{ve}$ ve ve no .95 female yes ve ve yes female yes \overline{ve} .05 ve no female no ve .05 ve ves female no \overline{ve} .95 \overline{ve} \overline{ve} no

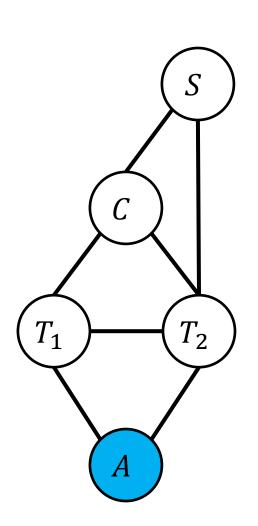
 $|\phi_1(S,C)|$ C $T_1 | \phi_2(T_1, C)$ $\phi_3(S)$ S Let us run MAP VE with evidence— .55 .05 .80 male male yes ve yes A = yes and MAP variables S .95 .20 yes ve female male .45 noand C, and elimination order Assignment Project Exam Help .20 $\pi = A, T_1, T_2, S, C$.80 https://tutorcs.com $T_1 \ T_2 \ a \ | \phi_5(T_1, T_2, a)$ C $T_2 \phi_4(T_2, C, S)$ Weethers restutores ve ve yes male yes ve .20 ve ve yes T_2 .20 0 male no ve ve ves male .80 ve ves $no \overline{ve}$.95 female yes ve female yes \overline{ve} .05 female no ve .05 female no \overline{ve} .95

Let us run MAP VE with evidence

$$A = yes$$
 and MAP variables S and C , and elimination order $\pi = A, T_1, T_2, S, C$ Assignment Project Exam Help

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T_1 T_2 a	$\phi_5(T_1,T_2,a)$	T_1	T_2	$\tau_1(T_1,T_2)$
ve ve yes	1	– ve	ve	1
ve ve yes	0	- ve	\overline{ve}	0
ve ve yes	0 —	<i>− ve</i>	ve	0
ve ve yes	1	<i>− ve</i>	\overline{ve}	1



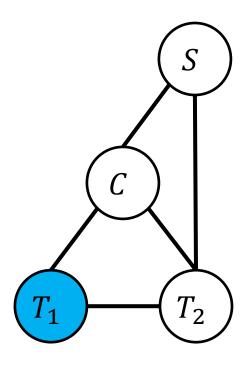
Let us run MAP VE with evidence

$$A = yes$$
 and MAP variables S and C , and elimination order $\pi = A, T_1, T_2, S, C$ Assign

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https://Tutobecsocom_ T_2 , C)

						yes	ve	ve	.80
					We	eleh	ate.	c st i	ıtorc§
T_1	T_2	$\tau_1(T_1,T_2)$	<u></u>	T_1	$\phi_2(T_1, C)$	yes	\overline{ve}	ve	0
ve	ve	1	yes	ve	.80	yes	\overline{ve}	\overline{ve}	.20
ve	\overline{ve}	0 ×	yes	\overline{ve}	.20 _	no	ve	ve	.20
ve	ve	0	no	ve	.20	no	ve	\overline{ve}	0
\overline{ve}	\overline{ve}	1	no	\overline{ve}	.80	no	\overline{ve}	ve	0
		•			•	n_0	<u>12P</u>	<u>12P</u>	80

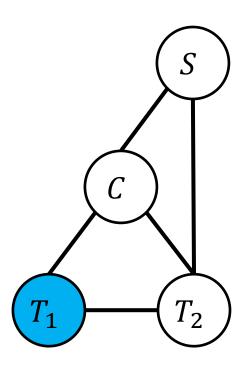


Let us run MAP VE with evidence

$$A = yes$$
 and MAP variables S and C , and elimination order $\pi = A, T_1, T_2, S, C$ Assign

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	T_1	T_2	$\sigma_2(T_1,T_2,C)$		1	-
yes	ve	ve	.80		We	Chat: cstutores
yes	ve	\overline{ve}	0	<u></u>	T_2	$\tau_2(T_2,C)$
yes	\overline{ve}	ve	0	yes	ve	.80
yes	\overline{ve}	\overline{ve}	.20 —	yes	\overline{ve}	.20
no	ve	ve	.20 —	no	ve	.20
no	ve	\overline{ve}	0	no	\overline{ve}	.80
no	\overline{ve}	ve	0			
no	\overline{ve}	\overline{ve}	.80			

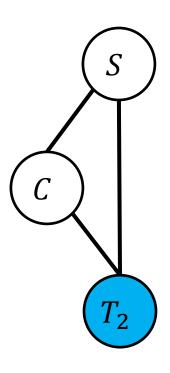


Let us run MAP VE with evidence

A = yes and MAP variables S and C, and elimination order $\pi = A, T_1, T_2, S, C$ Assign

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			S	С	T_2	$\phi_4(T_2, C, S)$	<u> </u>	$\boldsymbol{\mathcal{C}}$	T_2	$\sigma_3(T_2, S, C)$
			male	yes	ve	We@hat:			ve	.64
<u></u>	T_2	$\tau_2(T_2,C)$	_ male	yes	\overline{ve}	.20	male	yes	\overline{ve}	.04
yes	ve	.80	male	no	ve	.20	male	no	ve	.04
yes	\overline{ve}	.20	× male	no	\overline{ve}	.80 =	₌ male	no	\overline{ve}	.64
no	ve	.20	female	yes	ve	.95	female	yes yes	ve	.76
no	\overline{ve}	.80	female	yes	\overline{ve}	.05	female	yes yes	\overline{ve}	.01
			female	no	ve	.05	female	e no	ve	.01
			female	no	\overline{ve}	.95	female	e no	\overline{ve}	.76

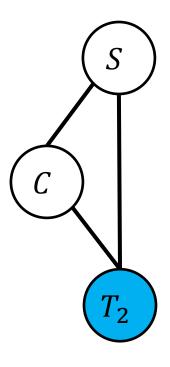


Let us run MAP VE with evidence

$$A = yes$$
 and MAP variables S and C , and elimination order $\pi = A, T_1, T_2, S, C$ Assignment Project Exam Help

1, 1₁, 1₂, 5, 6

S (\mathcal{L}	T_2	$\sigma_3(T_2, S, C)$	
male ye	es	ve	.64	WeChat: cstutorcs
male ye	es	\overline{ve}	.04	$S C \tau_3(C,S)$
male n	. 0	ve	.04	male yes .68
male n	. o	\overline{ve}	.64 ——	male no .68
female ye	es	ve	.76	female yes .77
female ye	es	\overline{ve}	.01	female no .77
female n	. 0	ve	.01	
female n	20	\overline{ve}	.76	



Let us run MAP VE with evidence

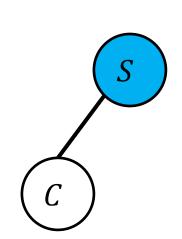
$$A = yes$$
 and MAP variables S and C , and elimination order $\pi = A T_1 T_2 S C$ Assignment

$$\pi = A, T_1, T_2, S, C$$

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		1				▼ ▼	Cilut.		
S	\mathcal{C}	$\tau_3(C,S)$	_				<i>S</i>	\mathcal{C}	$\sigma_4(C,S)$
male	yes	.68		S	$\phi_3(S)$		male	yes	.37
male	no	.68	×	male	.55	- ≈	male	no	.37
female	yes	.77		female	.45	. •	female	yes	.35
female	no	.77		•	'		female	no	.35

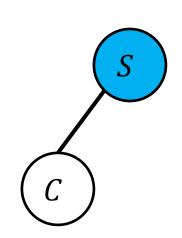


Let us run MAP VE with evidence

$$A = yes$$
 and MAP variables S and C , and elimination order $\pi = A, T_1, T_2, S, C$ Assign

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		ı		WeChat: cstutorcs						
S	C	$\sigma_4(C,S)$		S	\mathcal{C}	$ \phi_1(S,C) $		S	\mathcal{C}	$\sigma_5(C,S)$
male	yes	.37	-	male	yes	.05		male	yes	.018
male	no	.37	~	male	no	.95	≈	male	no	.351
female	yes	.35	^	female	yes	.01	~	female	yes	.004
female	no	.35		female	no	.99		female	no	.347



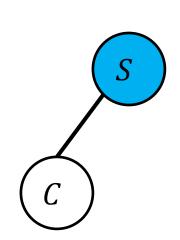
Let us run MAP VE with evidence

$$A = yes$$
 and MAP variables S and C , and elimination order $\pi = A, T_1, T_2, S, C$ Assign

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S	С	$\sigma_5(C,S)$		*****	mut. C
male	yes	.018	C	$ \tau_5(\mathcal{C}) $	
male	no	.351	yes —	.018	male
female	yes	.004	no	.351	male
female	no	.347			



- Let us run MAP VE with evidence A = yes and MAP variables S and C, and elimination order
- Since P(e) = P(A = yes) = .7205
 - $MAP_p(S, C|e) \approx 49\%$

$$\pi = A, T_1, T_2, S, C$$

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C

Conclusion

- MPE and MAP queries can be answered with simple adaptations of the VE algorithm
 - We introduced an elimination operation with max
- In MPE, we operate only with multiplication and maximization operations

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 We can easily replace probabilities with log-probabilities

 - This creates numerically stable algorithms, since multiplying several small numbers can lead to underflows
- Task WeChat: cstutorcs
 - Read chapter 10 (except Sections 2.2, 2.3, 3.2 and 3.3) of the textbook