Exploiting Structure in Parsing to 1-Endpoint-Crossing Graphs

Starstruck

Robin Kurtz & Marco Kuhlmann

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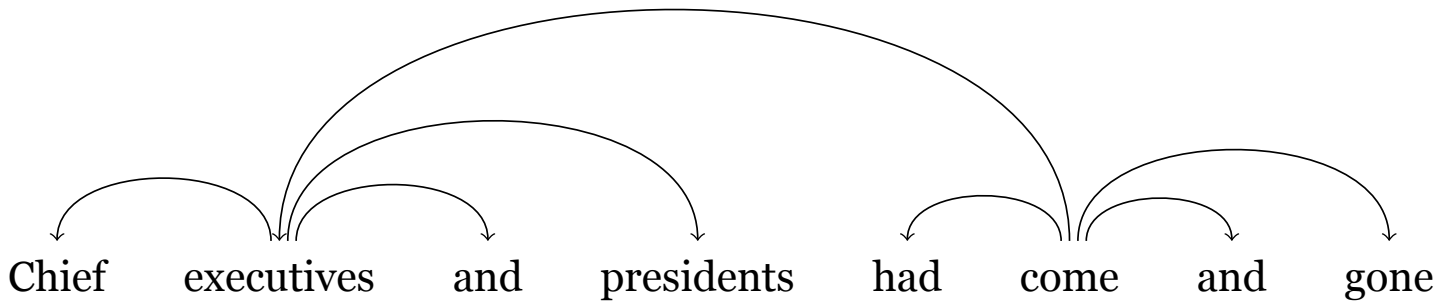
Syntactic Dependency Trees

Chief executives and presidents had come and gone

$$\hat{y} = \underset{y \in T(x)}{\arg\max}\, \mathrm{score}(y)$$

Syntactic Dependency Trees



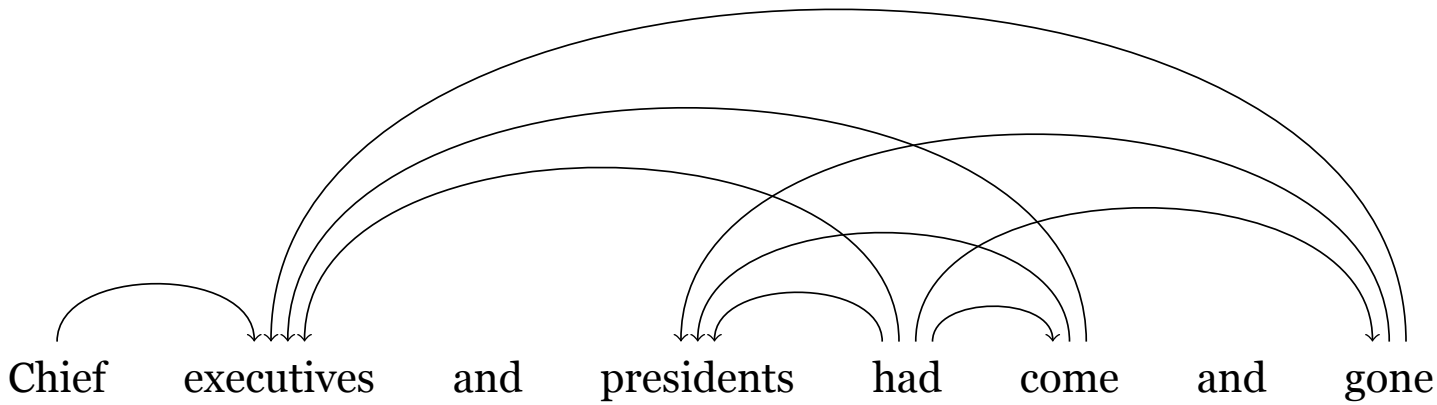
$$\hat{y} = \underset{y \in T(x)}{\arg\max}\, \mathrm{score}(y)$$

Semantic Dependency Graphs

Chief executives and presidents had come and gone

$$\hat{y} = \underset{y \in G(x)}{\arg\max}\, \mathrm{score}(y)$$

Semantic Dependency Graphs



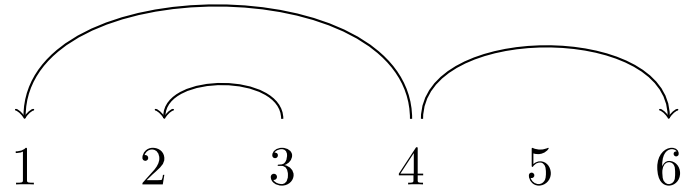
$$\hat{y} = \underset{y \in G(x)}{\arg\max}\, \mathrm{score}(y)$$

SDP 2016 Data

- 37,067 WSJ sentences
- DM: DELPH-IN MRS Bi-Lexical Dependencies
- PAS: Enju Predicate-Argument Structures
- PSD: Prague Semantic Dependencies
- CCD: Combinatory Categorial Grammar Dependencies

Stephan Oepen et al. 2016. Towards comparability of linguistic graph banks for semantic parsing.

Coverage



class		DM	PAS	PSD	CCD	
nc	G	69.29	59.85	65.04	49.53	$O(n^3)$
	A	97.63	97.24	96.01	95.83	

Marco Kuhlmann and Peter Jonsson. 2015. Parsing to noncrossing dependency graphs.

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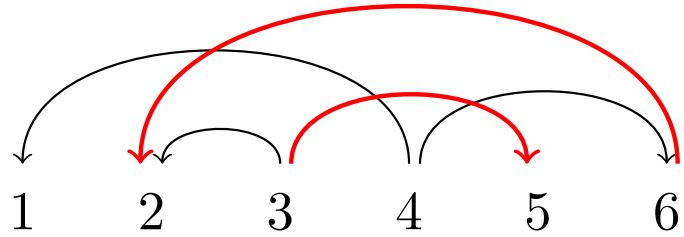

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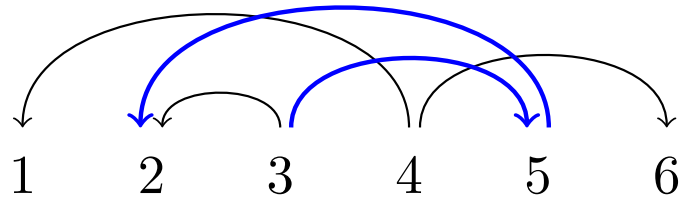
	A	97.63	97.24	96.01	95.83	
pn ≤ 2	G	99.46	99.48	97.64	98.33	NP
	A	99.97	99.97	99.76	99.89	

Marco Kuhlmann and Peter Jonsson. 2015. Parsing to noncrossing dependency graphs.

Coverage



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pn ≤ 2	G	99.46	99.48	97.64	98.33	NP
	A	99.97	99.97	99.76	99.89	
1ec	G	97.30	97.18	95.85	96.16	$O(n^4)$
	A	99.83	99.85	99.60	99.75	

Emily Pitler. 2013. Models for improved tractability and accuracy in dependency parsing.

Rules

(1) $Int[i,j] \leftarrow Int[i+1,j]$
(2) $Int[i,j] \leftarrow s[i,j] + Int[i,j]$
(3) $Int[i,j] \leftarrow s[i,k] + Int[i,k] + Int[k,j]$
(4) $Int[i,j] \leftarrow s[i,k] + R[i,k,l] + Int[k,l] + L[l,j,k]$
(5) $Int[i,j] \leftarrow s[i,k] + LR[i,k,l] + Int[k,l] + Int[l,j]$
(6) $Int[i,j] \leftarrow s[i,k] + LR[i,k,j] + Int[k,j]$
(7) $Int[i,j] \leftarrow s[i,k] + Int[i,l] + L[l,k,i] + N[k,j,l]$
(8) $Int[i,j] \leftarrow s[i,k] + R[i,l,k] + Int[l,k] + L[k,j,l]$
(9) $LR[i,j,x] \leftarrow R[i,j,x]$
(10) $LR[i,j,x] \leftarrow L[i,j,x]$
(11) $LR[i,j,x] \leftarrow L[i,k,x] + R[k,j,x]$
(12) $N[i,j,x] \leftarrow s[x,k] + N[i,k,x] + Int[k,j]$
(13) $N[i,j,x] \leftarrow Int[i,j]$
(14) $N[i,j,x] \leftarrow s[i,x] + N[i,j,x]$
(15) $N[i,j,x] \leftarrow s[j,x] + N[i,j,x]$

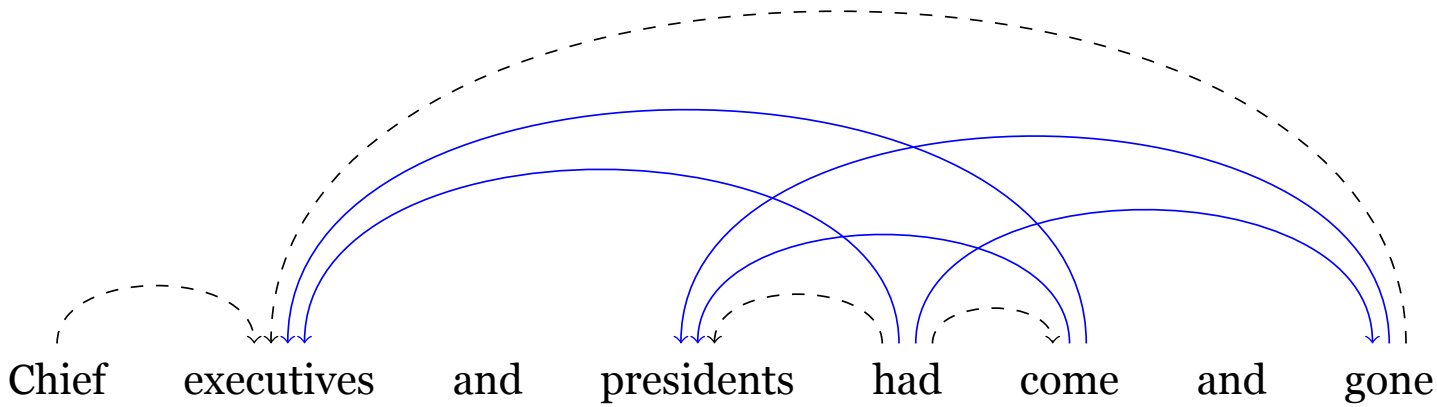
Emily Pitler. 2013. Models for improved tractability and accuracy in dependency parsing.

Rules contd.

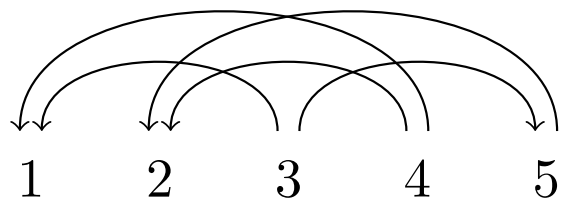
$$
\begin{aligned}
&(16)\quad L[i,j,x] \leftarrow Int[i,j] \\
&(17)\quad L[i,j,x] \leftarrow s[x,k] + L[i,k,x] + Int[k,j] \\
&(18)\quad L[i,j,x] \leftarrow s[i,k] + L[i,k,x] + Int[k,j] \\
&(19)\quad L[i,j,x] \leftarrow s[x,k] + Int[i,k] + L[k,j,i] \\
&(20)\quad L[i,j,x] \leftarrow s[i,x] + L[i,j,x] \\
&(21)\quad L[i,j,x] \leftarrow s[j,x] + L[i,j,x] \\
&(22)\quad L[i,j,x] \leftarrow s[i,j] + L[i,j,x] \\
&(23)\quad R[i,j,x] \leftarrow Int[i,j] \\
&(24)\quad R[i,j,x] \leftarrow s[x,k] + Int[i,k] + R[k,j,x] \\
&(25)\quad R[i,j,x] \leftarrow s[j,k] + Int[i,k] + R[k,j,x] \\
&(26)\quad R[i,j,x] \leftarrow s[x,k] + R[i,k,j] + Int[k,j] \\
&(27)\quad R[i,j,x] \leftarrow s[i,x] + R[i,j,x] \\
&(28)\quad R[i,j,x] \leftarrow s[j,x] + R[i,j,x] \\
&(29)\quad R[i,j,x] \leftarrow s[i,j] + R[i,j,x]
\end{aligned}
$$

Emily Pitler. 2013. Models for improved tractability and accuracy in dependency parsing.

Semantic Dependency Graphs



Truly 1ec?



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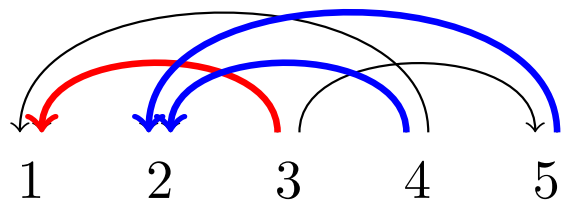

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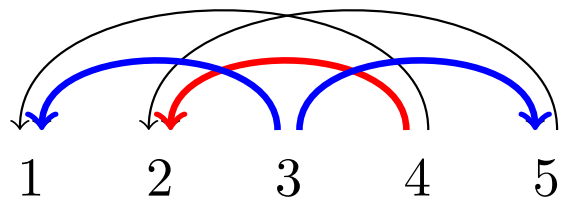

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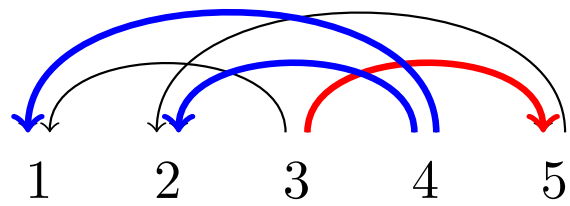

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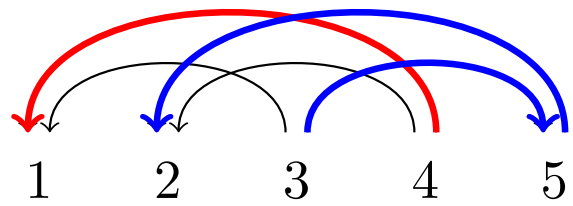
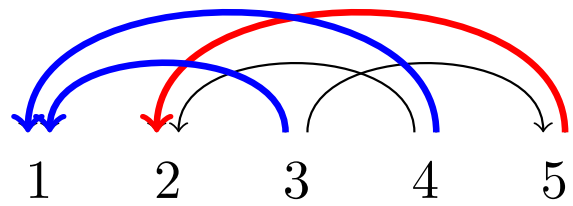
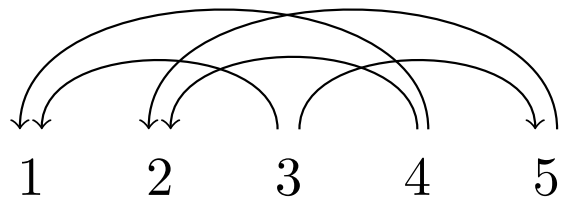


Truly 1ec?

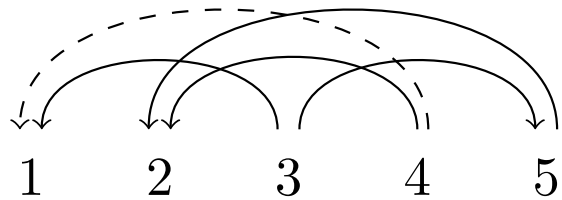


Follow the Rules



$$(5) \qquad Int[1,5] \leftarrow s[1,4] + LR[1,4,5] + Int[4,5]$$

Follow the Rules



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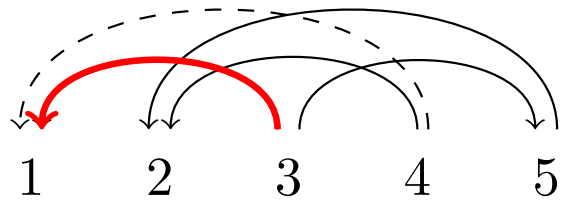
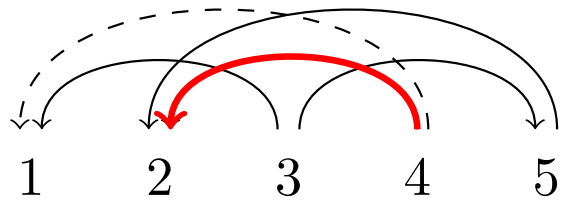


$$(5) \qquad Int[1,5] \leftarrow s[1,4] + LR[1,4,5] + Int[4,5]$$

$$(11) \qquad LR[1,4,5] \leftarrow L[1,k=2,5] + R[k=2,4,5]$$

Follow the Rules



$$(5) \qquad Int[1,5] \leftarrow s[1,4] + LR[1,4,5] + Int[4,5]$$

$$(11) \qquad LR[1,4,5] \leftarrow L[1,k=3,5] + R[k=3,4,5]$$

"Unheard-of combinations of circumstances demand unheard-of rules."

– Charlotte Brontë, Jane Eyre

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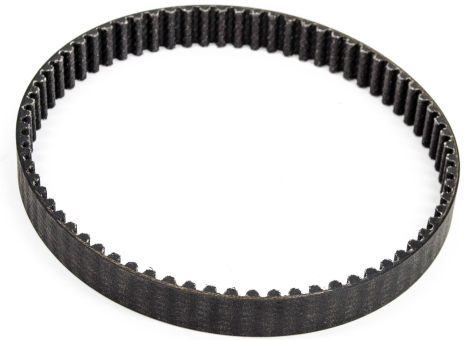
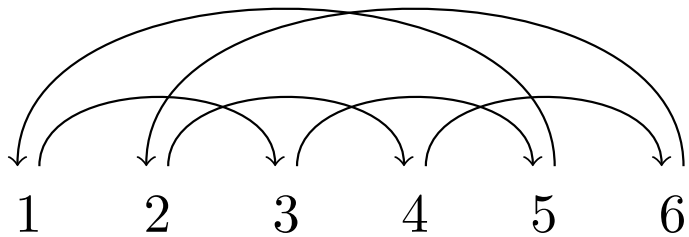
Cog belts





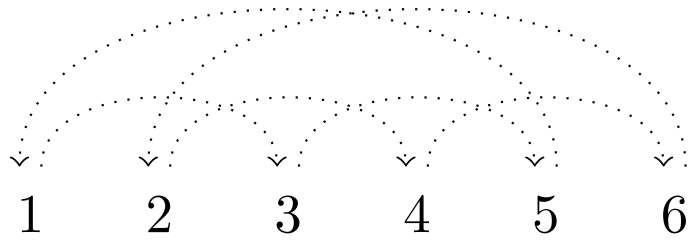
More Rules

$$C[i,j,x,y] \leftarrow s[x,y] + s[i,j] + Int[i,y] + Int[y,j] \tag{30}$$

$$C[i,j,x,y] \leftarrow s[x,k] + Int[i,k] + C[k,j,i,y] \tag{31}$$

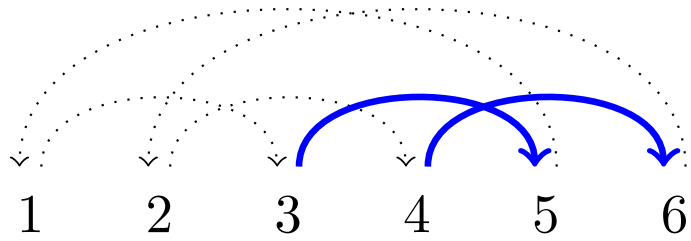
$$Int[i,j] \leftarrow s[i,k] + s[i,y] + s[l,j] + Int[i,l] + Int[l,k] + C[k,j,l,y] \tag{32}$$

More Rules



$$C[4,6,3,5] \leftarrow s[3,5] + s[4,6] + Int[4,5] + Int[5,6]$$
$$C[3,6,2,5] \leftarrow s[2,4] + Int[3,4] + C[4,6,3,5]$$
$$Int[1,6] \leftarrow s[1,3] + s[1,5] + s[2,6] + Int[1,2] + Int[2,3] + C[3,6,2,5]$$

More Rules



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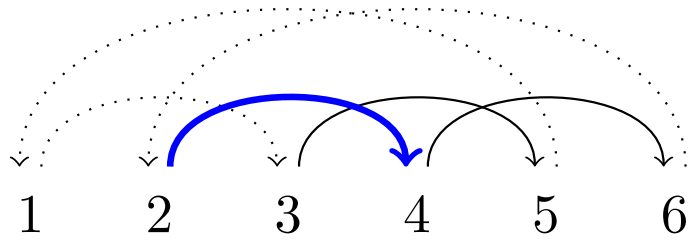
More Rules



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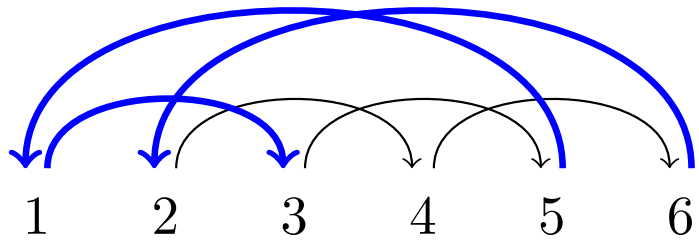
More Rules



$$C[4,6,3,5] \leftarrow s[3,5] + s[4,6] + Int[4,5] + Int[5,6]$$
$$C[3,6,2,5] \leftarrow s[2,4] + Int[3,4] + C[4,6,3,5]$$
$$Int[1,6] \leftarrow s[1,3] + s[1,5] + s[2,6] + Int[1,2] + Int[2,3] + C[3,6,2,5]$$

Reach for the stars

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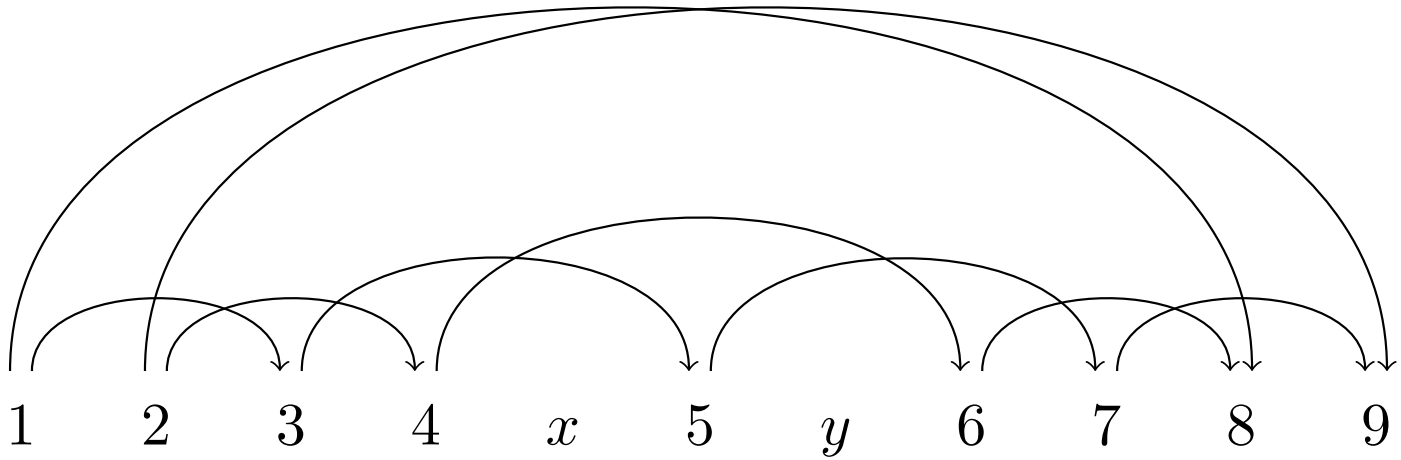
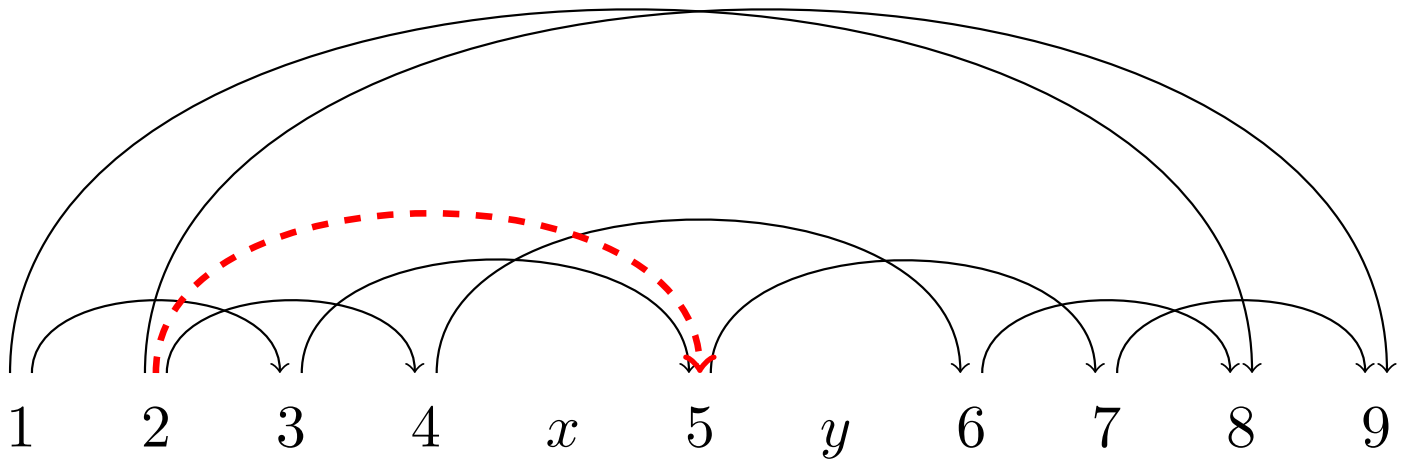
Was that all?



Was that all?



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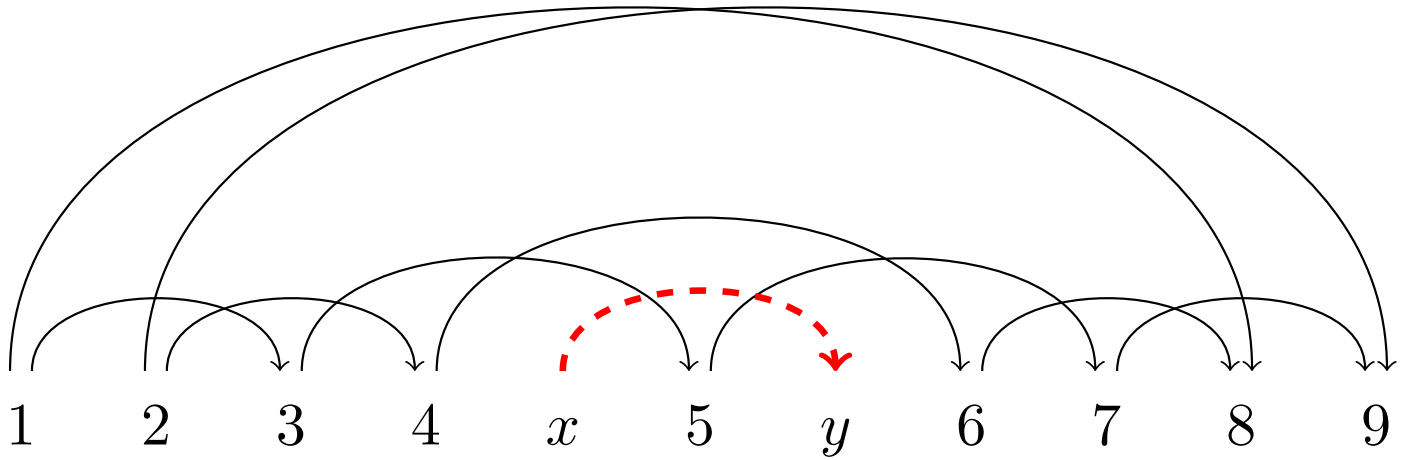

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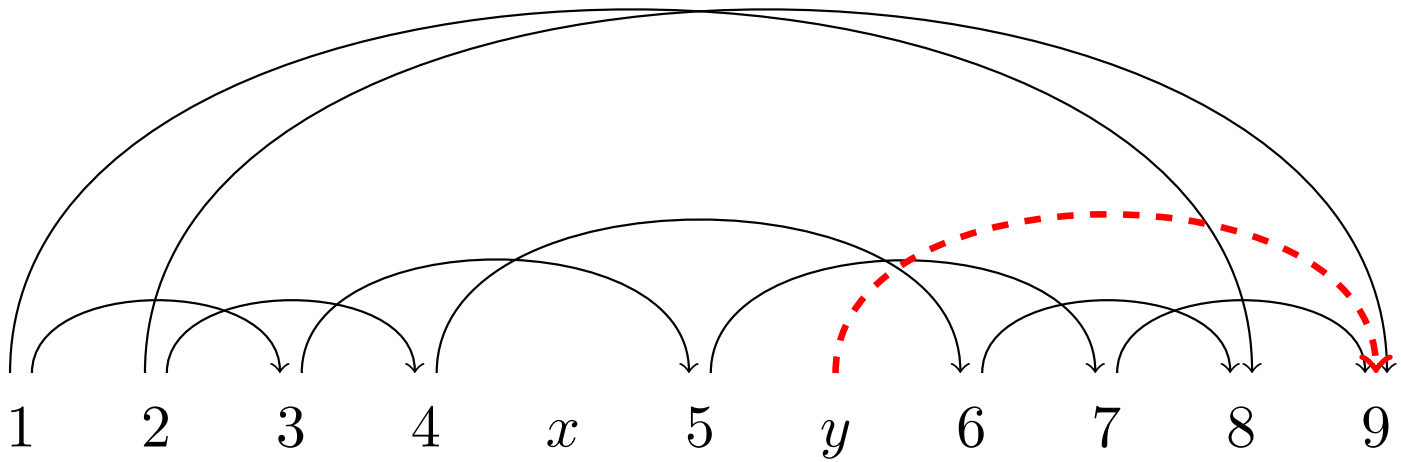
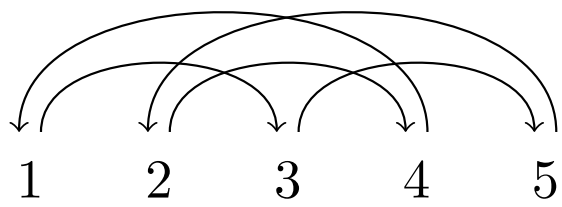
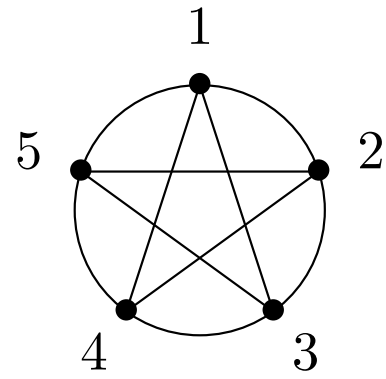
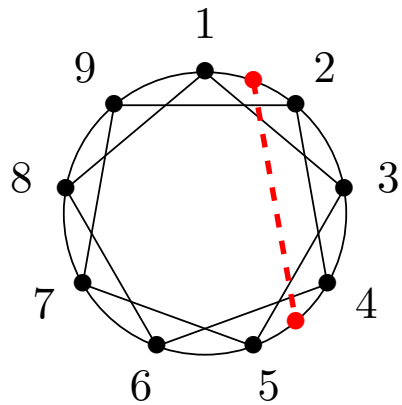


Chord Diagrams

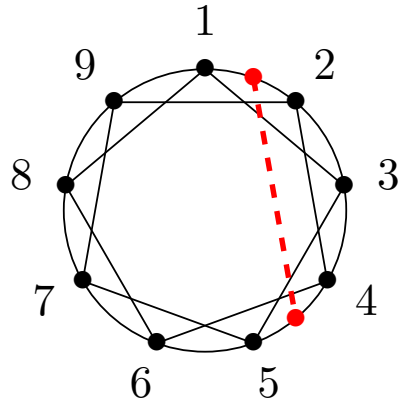


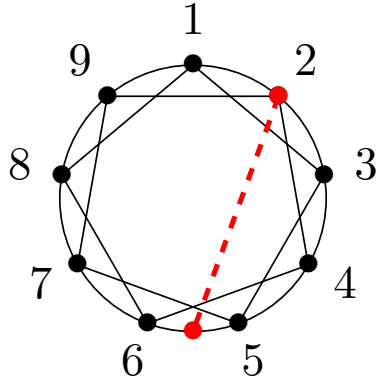


Isolation

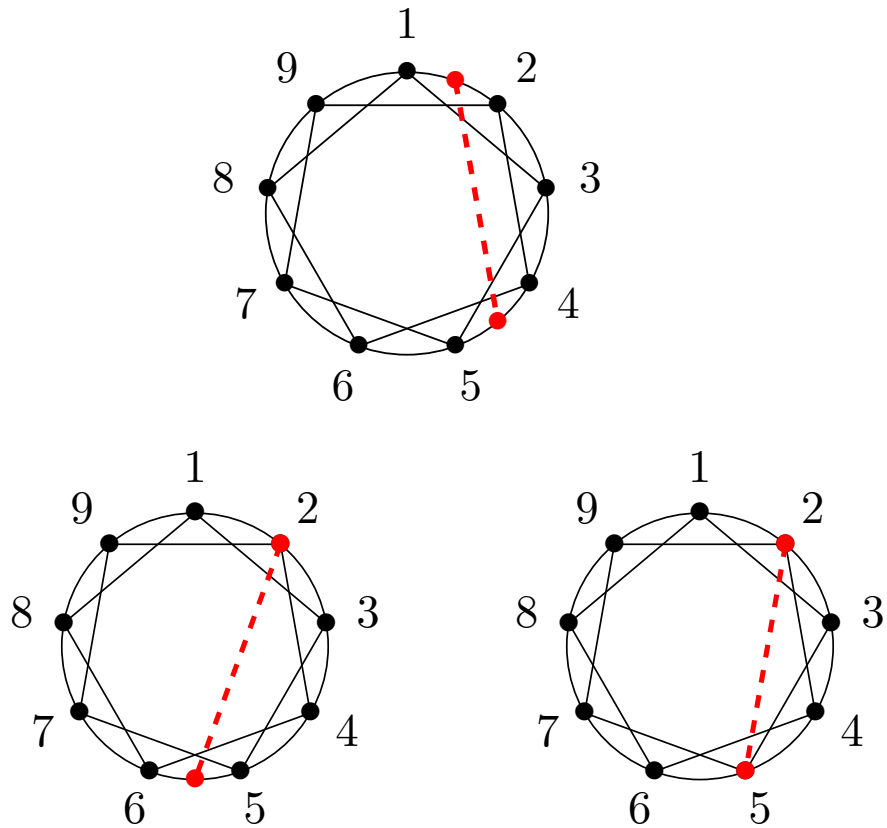


Isolation

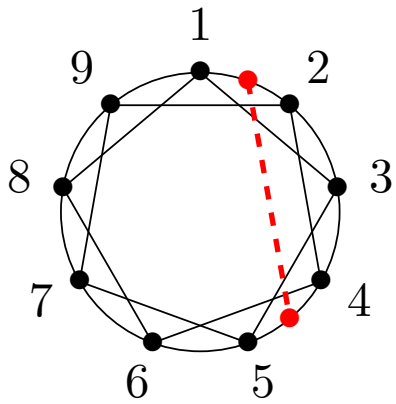


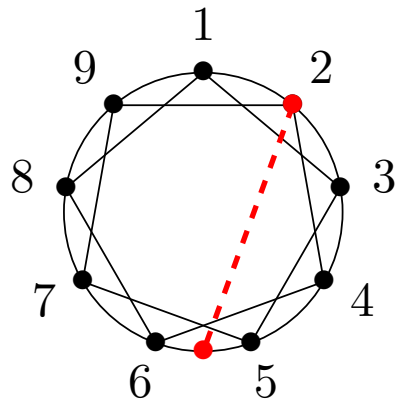


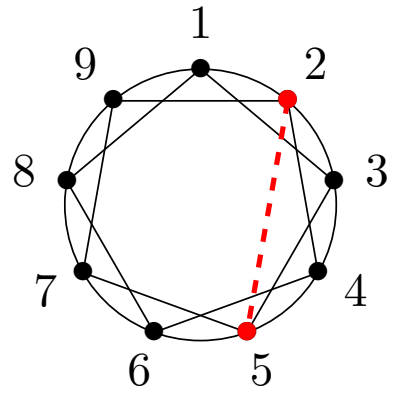
Isolation

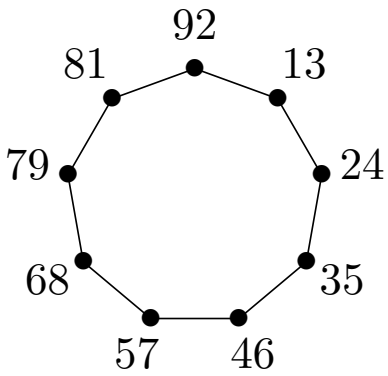


Crossing Graphs









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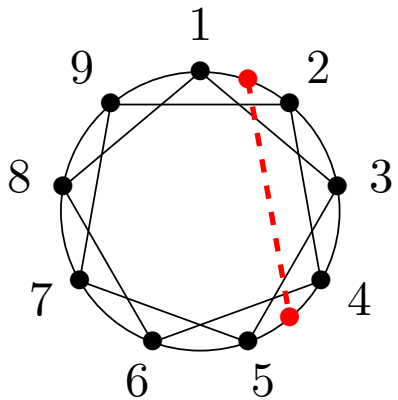
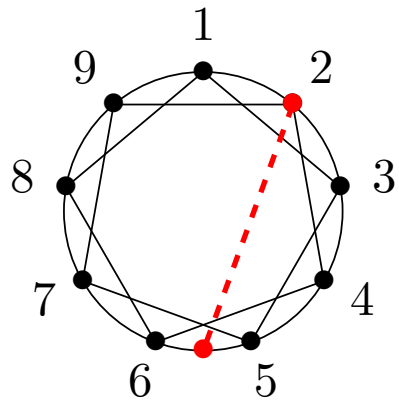
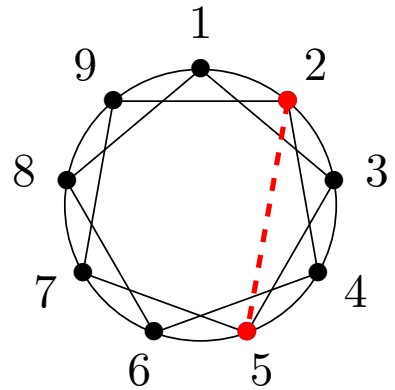
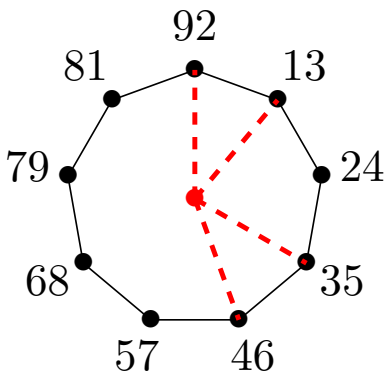
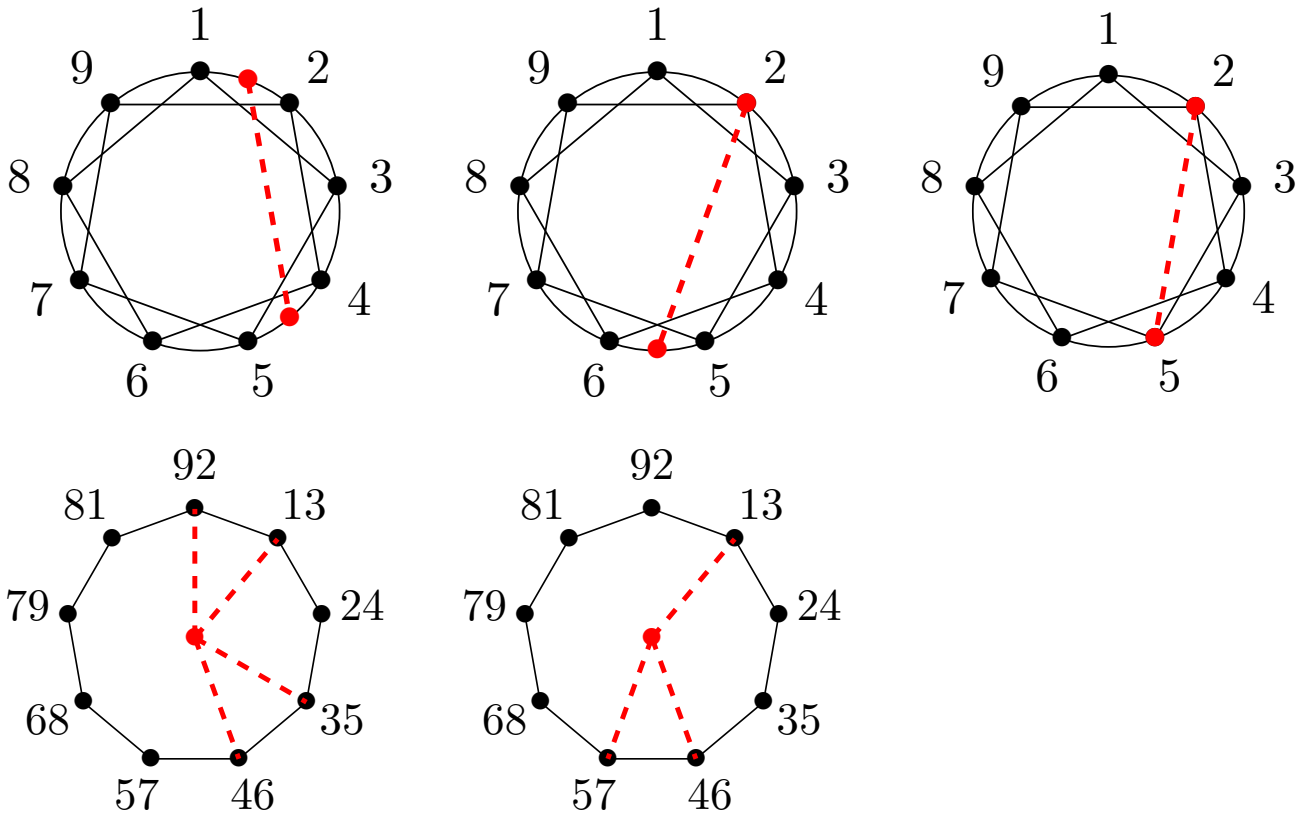




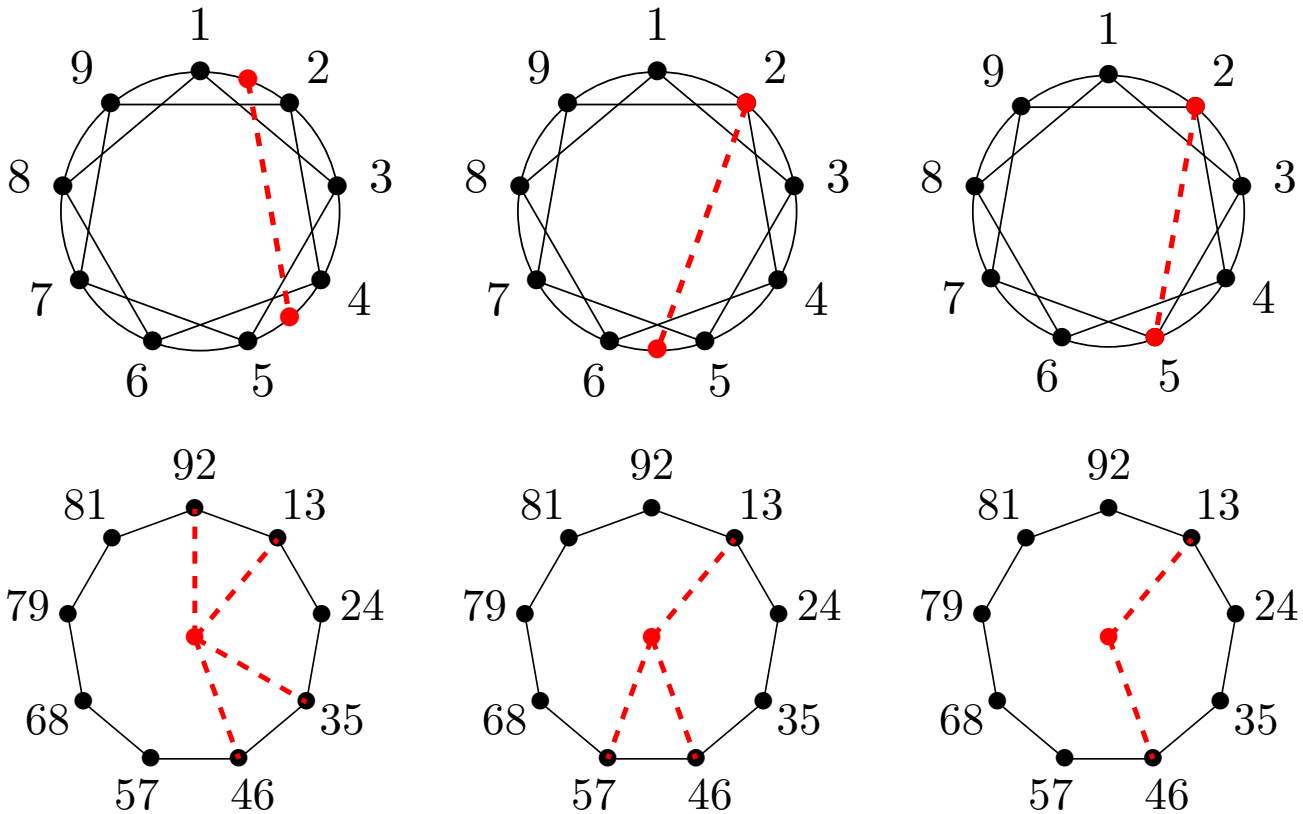




Crossing Graphs



Crossing Graphs

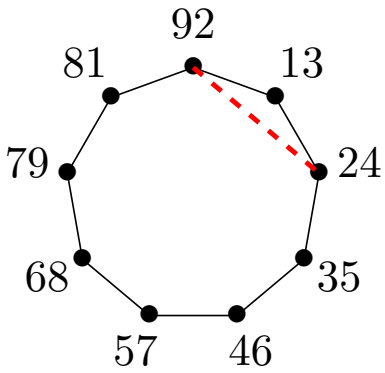


Isolation

Lemma 6

Any cycle of length $m \geq 5$ in a crossing graph of a 1ec graph forms a connected component of that graph. □

Shortcuts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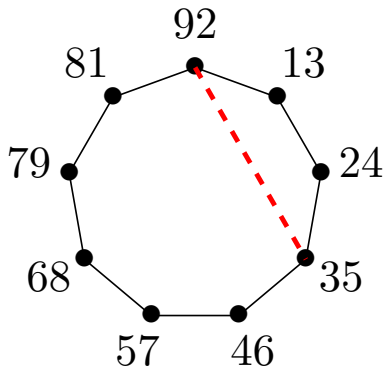
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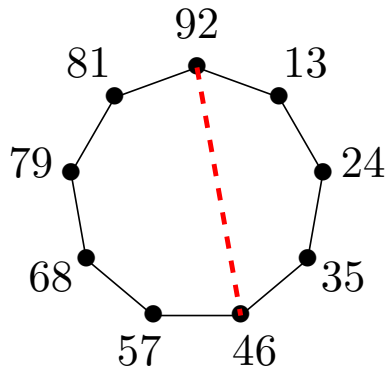
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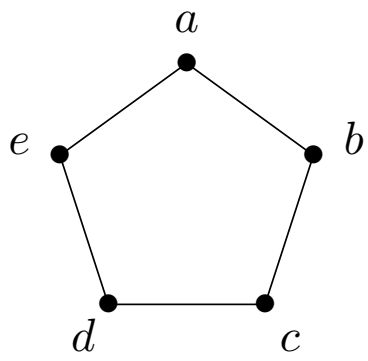
Polygons



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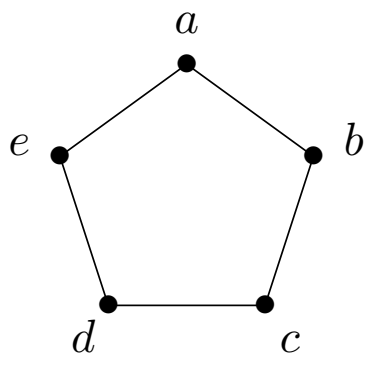
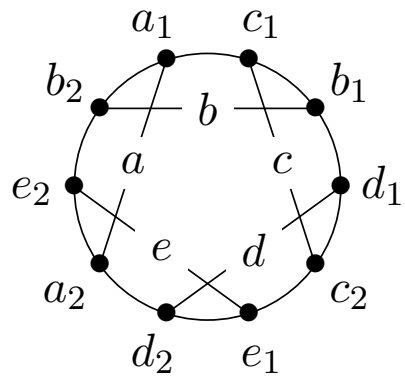
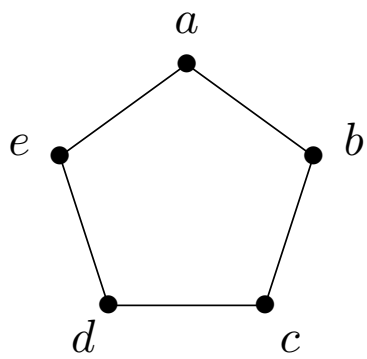
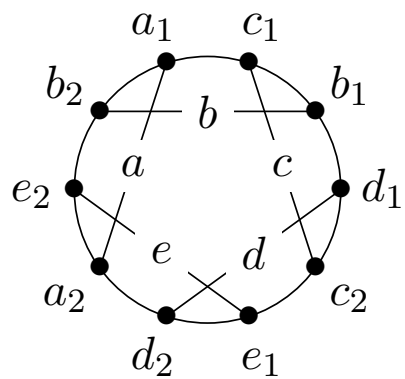
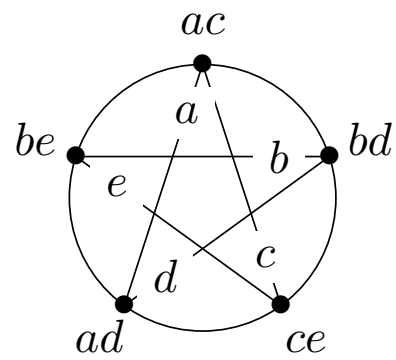




Polygons

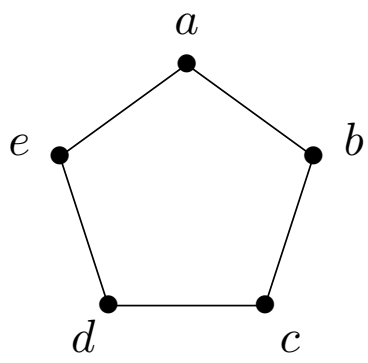






Csaba P. Gabor, Kenneth J. Supowit, and Wen-Lian Hsu. 1989. Recognizing circle graphs in polynomial time.

Polygons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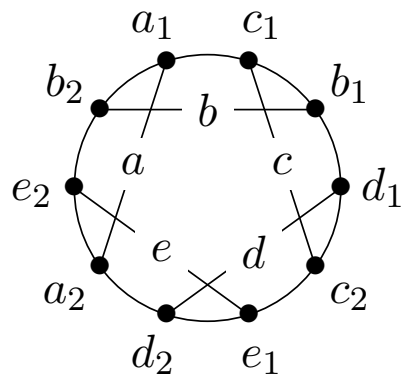
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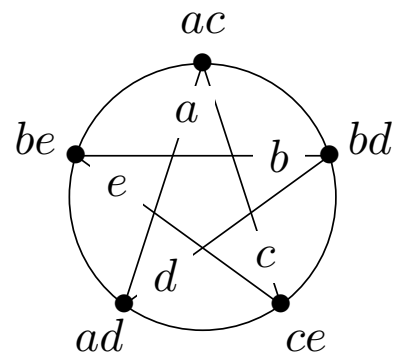
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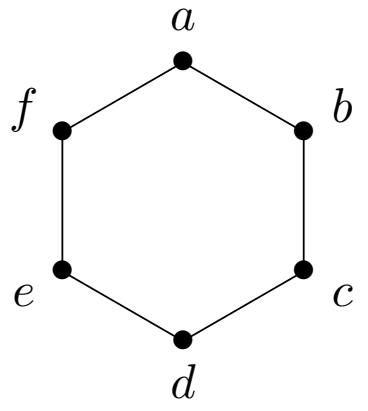
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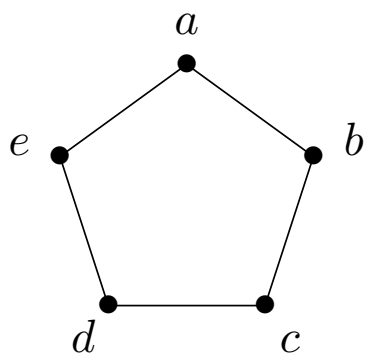
Polygons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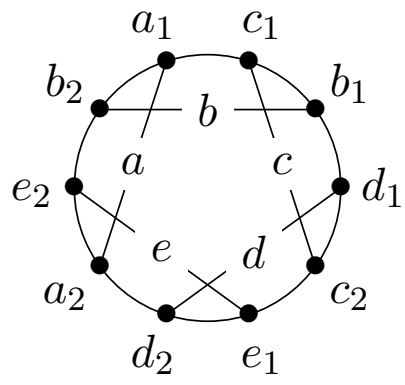
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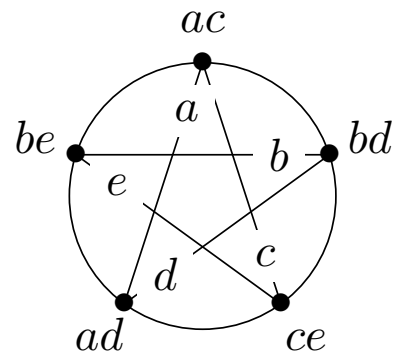
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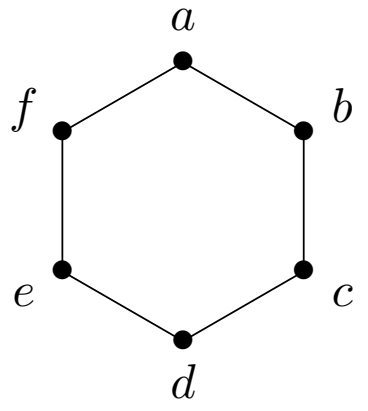
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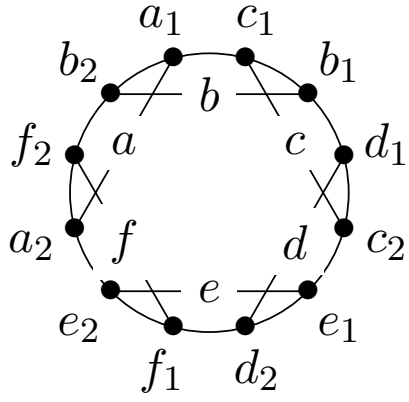
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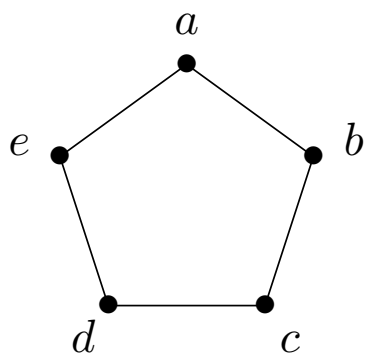
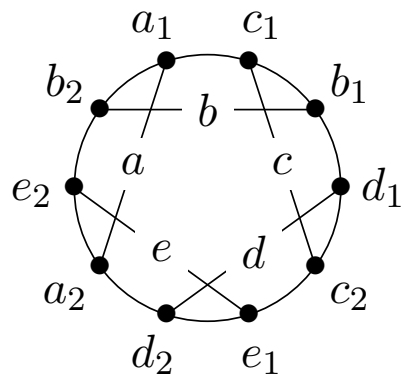
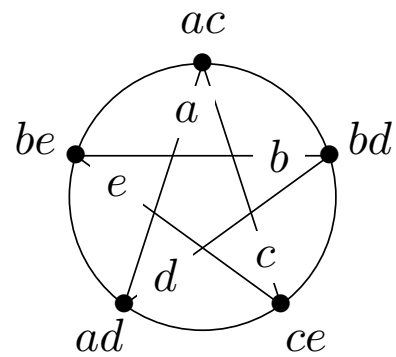
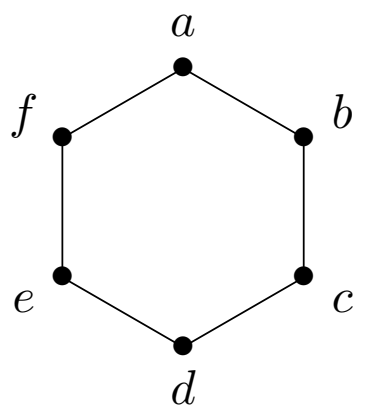
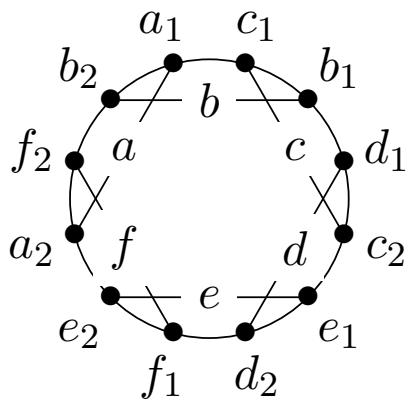
Polygons

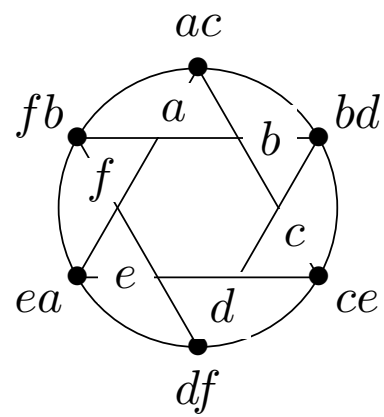






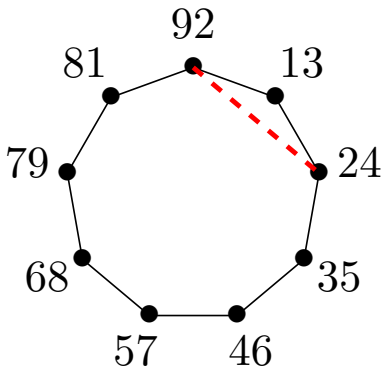






Csaba P. Gabor, Kenneth J. Supowit, and Wen-Lian Hsu. 1989. Recognizing circle graphs in polynomial time.

Shortcuts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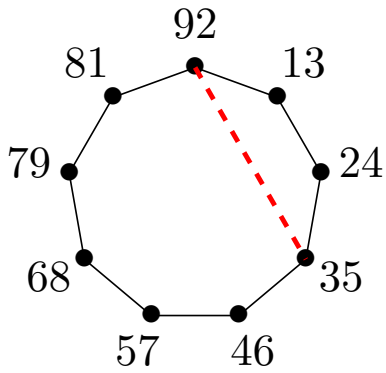
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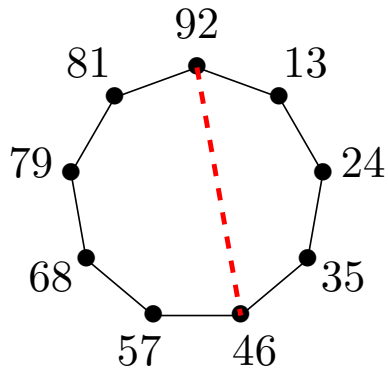
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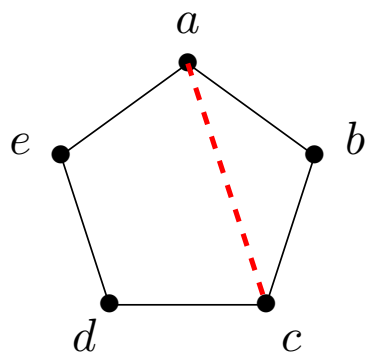
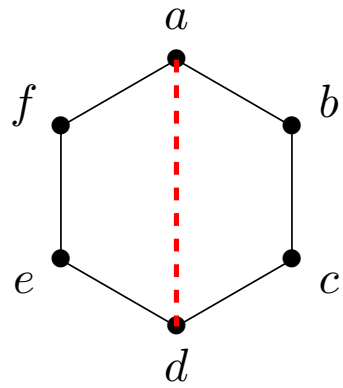
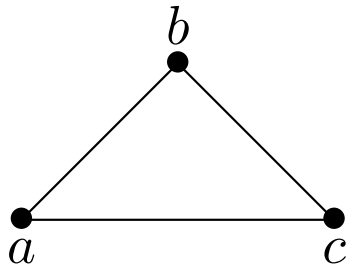
Shortcuts

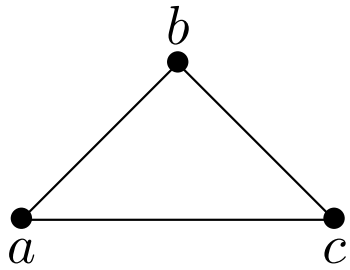


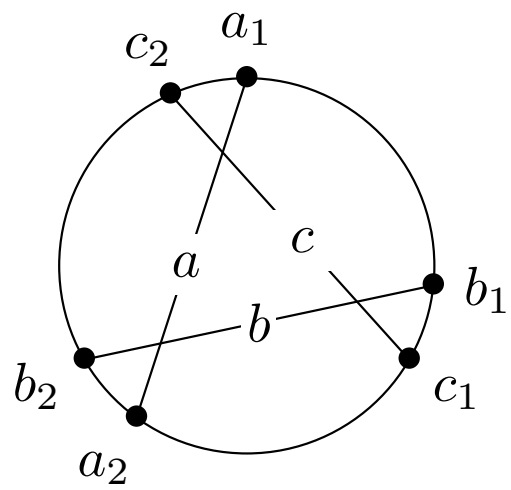


Triangles



Triangles





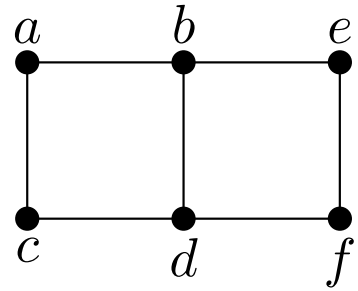
Triangles

Lemma 2

The crossing graphs of 1ec graphs do not contain triangles (cycles of length 3). □

Emily Pitler, Sampath Kannan, and Mitchell Marcus. 2013. Finding optimal 1-endpoint-crossing trees.

Dominoes



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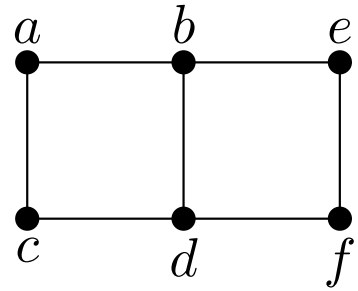
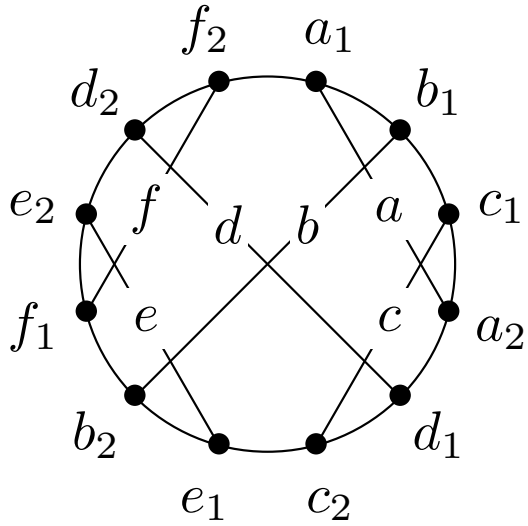
Dominoes





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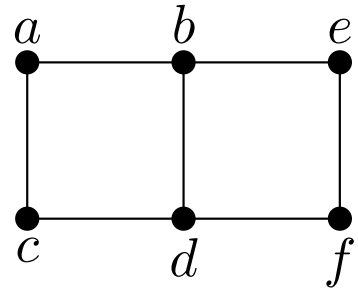
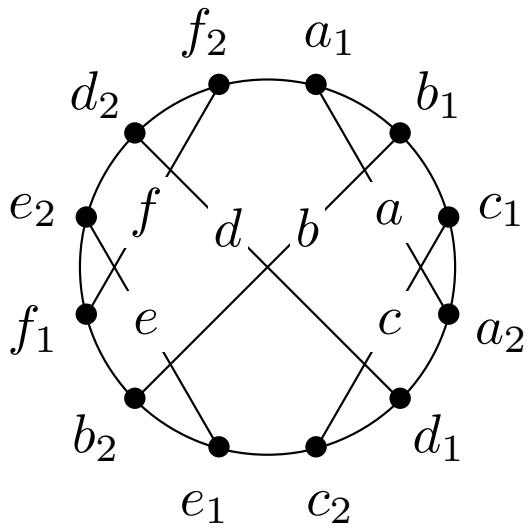
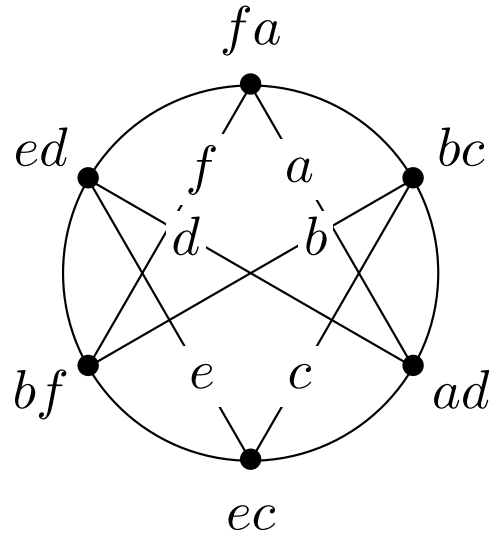
Dominoes







Csaba P. Gabor, Kenneth J. Supowit, and Wen-Lian Hsu. 1989. Recognizing circle graphs in polynomial time.

Dominoes

Lemma 4

The crossing graphs of 1ec graphs do not contain dominoes. □

Isolation

Lemma 6

Any cycle of length $m \geq 5$ in a crossing graph of a 1ec graph forms a connected component of that graph. □

Pagenumber

Theorem 4.1

1-Endpoint-Crossing trees $\subseteq$ 2-planar. □

Lemma 3

The pagenumber of 1ec graphs is at most 3. □

Per aspera ad astra.

Through hardships to the stars.

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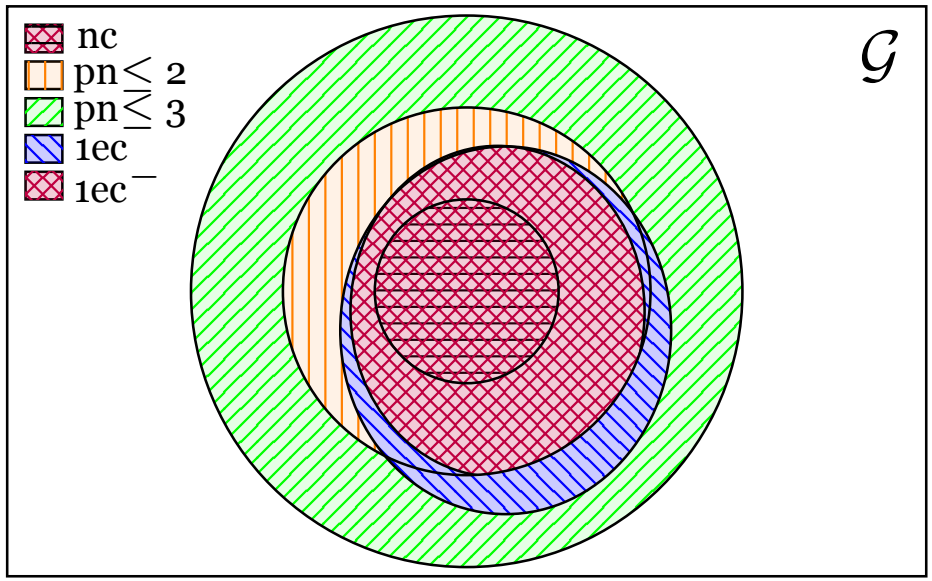
Which is what?



...and what is which?

Coverage

class		DM	PAS	PSD	CCD	
nc	G	69.29	59.85	65.04	49.53	$O(n^3)$
	A	97.63	97.24	96.01	95.83	
pn ≤ 2	G	99.46	99.48	97.64	98.33	NP
	A	99.97	99.97	99.76	99.89	
1ec	G	97.30	97.18	95.85	96.16	$O(n^5)$
	A	99.83	99.85	99.60	99.75	
1ec$^-$	G	97.30	97.18	95.81	96.11	$O(n^4)$
	A	99.83	99.85	99.60	99.75	

The Milkyway

The Milkyway

- *Parsing to 1-endpoint-crossing, pagenumber-2 graphs.*
  Junjie Cao, Sheng Huang, Weiwei Sun, and Xiaojun Wan. ACL 2017.

The Milkyway

- *Parsing to 1-endpoint-crossing, pagenumber-2 graphs.*
  Junjie Cao, Sheng Huang, Weiwei Sun, and Xiaojun Wan. ACL 2017.
- *Parsing with traces: An $O(n^4)$ algorithm and a structural representation.*
  Jonathan K. Kummerfeld and Dan Klein. TACL 2017.

“Every man and every woman is a st  r”

– Aleister Crowley

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Robin Kurtz
robin.kurtz@liu.se

www.liu.se

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