

Rytter for CFPQ

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May 22, 2018

1 Linear input

Let the input grammar is

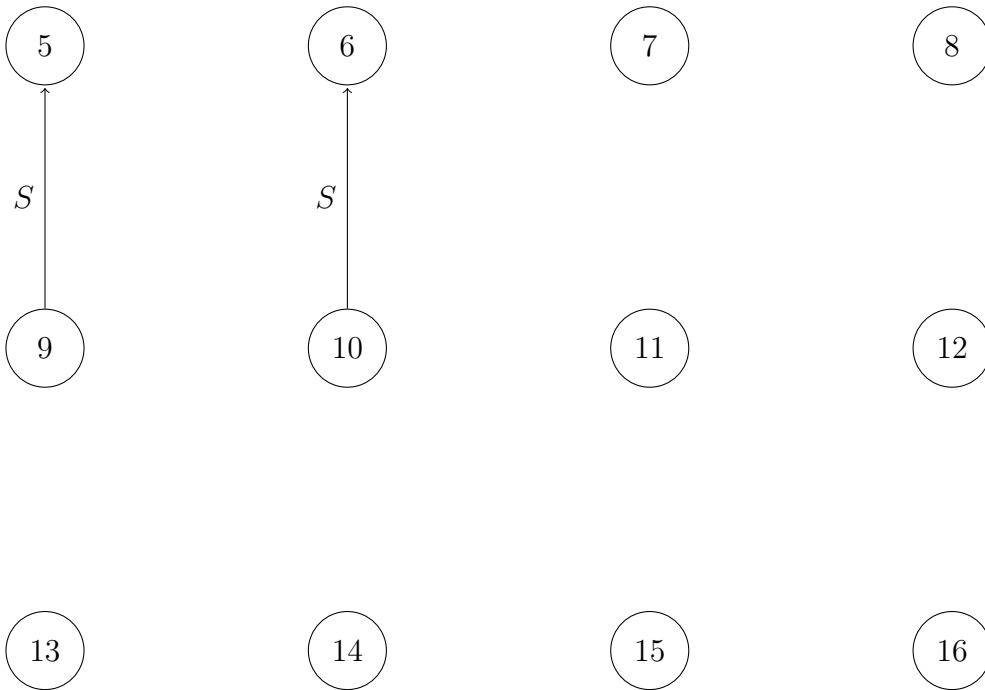
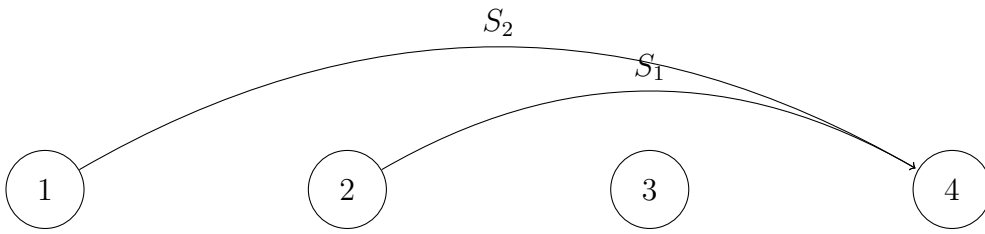
$$\begin{aligned}S &\rightarrow a S b \\S &\rightarrow S S \\S &\rightarrow a b\end{aligned}$$

The input grammar in CNF is

$$\begin{aligned}S &\rightarrow A S_1 \\S_1 &\rightarrow S B \\S &\rightarrow S S \\S &\rightarrow A B \\A &\rightarrow a \\B &\rightarrow b\end{aligned}$$

Input: *abab*

Grid:



2 Graph input

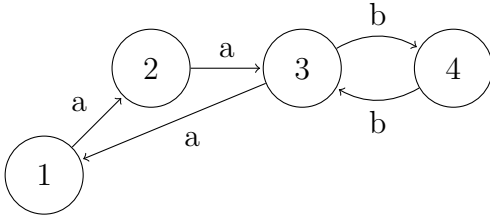
Let the input grammar is

$$\begin{aligned} S &\rightarrow a S b \\ S &\rightarrow a b \end{aligned}$$

The input grammar in CNF is

$$\begin{aligned} S &\rightarrow A S_1 \\ S_1 &\rightarrow S B \\ S &\rightarrow A B \\ A &\rightarrow a \\ B &\rightarrow b \end{aligned}$$

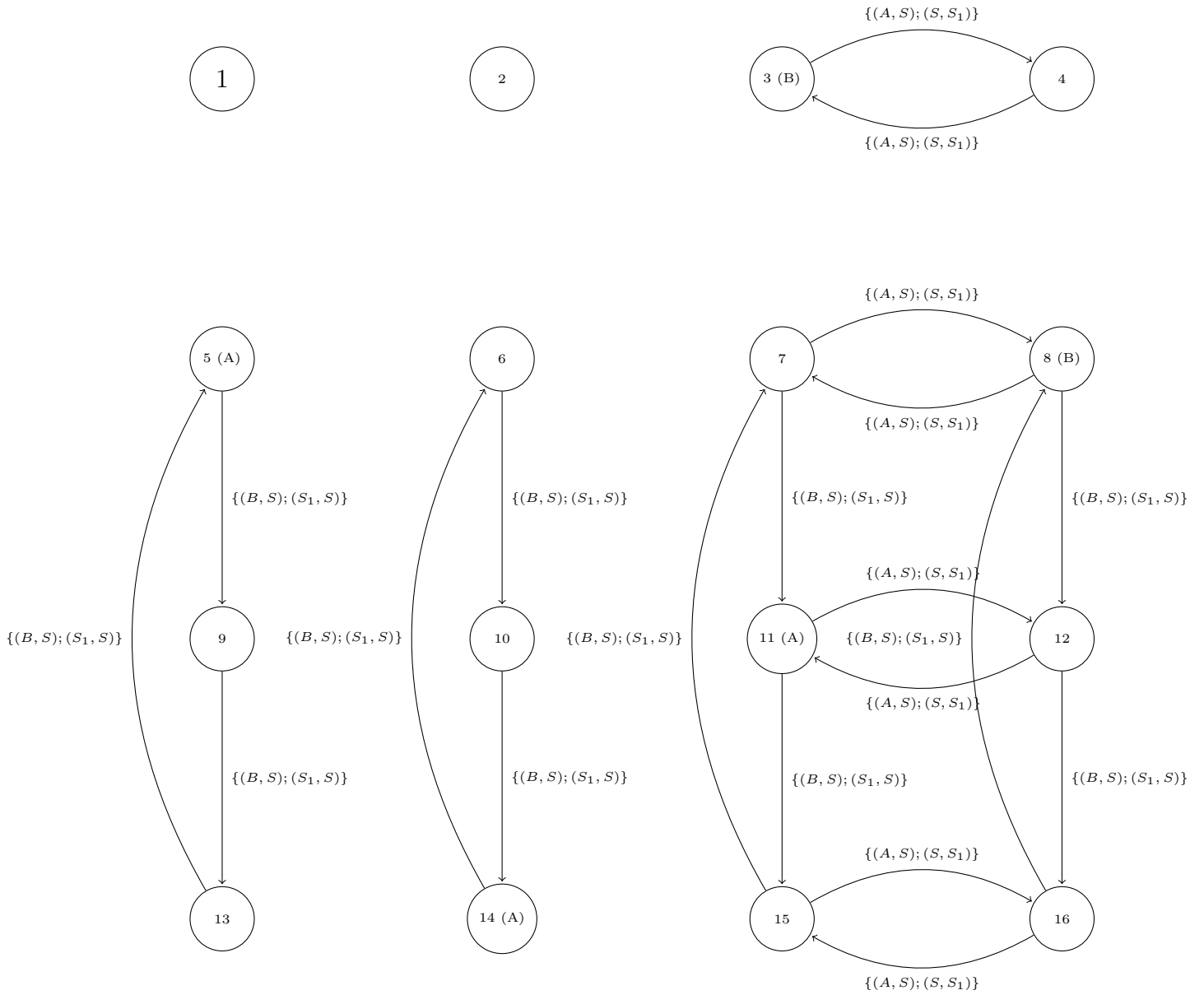
Let the input graph is



The *IMPLIED* relation:

$(B, 2, 3) \Rightarrow (S, 1, 3)$	$(B, 2, 4) \Rightarrow (S, 1, 4)$	$(B, 2, 2) \Rightarrow (S, 1, 2)$	$(B, 2, 1) \Rightarrow (S, 1, 1)$
$(B, 3, 4) \Rightarrow (S, 2, 4)$	$(B, 3, 3) \Rightarrow (S, 2, 3)$	$(B, 3, 2) \Rightarrow (S, 2, 2)$	$(B, 3, 1) \Rightarrow (S, 2, 1)$
$(B, 1, 2) \Rightarrow (S, 3, 2)$	$(B, 1, 3) \Rightarrow (S, 3, 3)$	$(B, 1, 4) \Rightarrow (S, 3, 4)$	$(B, 1, 1) \Rightarrow (S, 3, 1)$
$(S_1, 2, 3) \Rightarrow (S, 1, 3)$	$(S_1, 2, 4) \Rightarrow (S, 1, 4)$	$(S_1, 2, 2) \Rightarrow (S, 1, 2)$	$(S_1, 2, 1) \Rightarrow (S, 1, 1)$
$(S_1, 3, 4) \Rightarrow (S, 2, 4)$	$(S_1, 3, 3) \Rightarrow (S, 2, 3)$	$(S_1, 3, 2) \Rightarrow (S, 2, 2)$	$(S_1, 3, 1) \Rightarrow (S, 2, 1)$
$(S_1, 1, 2) \Rightarrow (S, 3, 2)$	$(S_1, 1, 3) \Rightarrow (S, 3, 3)$	$(S_1, 1, 4) \Rightarrow (S, 3, 4)$	$(S_1, 1, 1) \Rightarrow (S, 3, 1)$
$(A, 2, 3) \Rightarrow (S, 2, 4)$	$(A, 1, 3) \Rightarrow (S, 1, 4)$	$(A, 3, 3) \Rightarrow (S, 3, 4)$	$(A, 4, 3) \Rightarrow (S, 4, 4)$
$(A, 3, 4) \Rightarrow (S, 3, 3)$	$(A, 4, 4) \Rightarrow (S, 4, 3)$	$(A, 2, 4) \Rightarrow (S, 2, 3)$	$(A, 1, 4) \Rightarrow (S, 1, 3)$
$(S, 2, 3) \Rightarrow (S_1, 2, 4)$	$(S, 1, 3) \Rightarrow (S_1, 1, 4)$	$(S, 3, 3) \Rightarrow (S_1, 3, 4)$	$(S, 4, 3) \Rightarrow (S_1, 4, 4)$
$(S, 3, 4) \Rightarrow (S_1, 3, 3)$	$(S, 4, 4) \Rightarrow (S_1, 4, 3)$	$(S, 2, 4) \Rightarrow (S_1, 2, 3)$	$(S, 1, 4) \Rightarrow (S_1, 1, 3)$

Grid:



$H =$

$$\begin{pmatrix} \emptyset & \emptyset & \emptyset & \emptyset \\ \emptyset & \emptyset & \emptyset & \emptyset \\ \emptyset & \emptyset & \emptyset & \{(A, S); (S, S_1)\} \\ \emptyset & \emptyset & \{(A, S); (S, S_1)\} & \emptyset \end{pmatrix}$$

$V =$

$$\begin{pmatrix} \emptyset & \emptyset & \{(B, S); (S_1, S)\} & \emptyset \\ \{(B, S); (S_1, S)\} & \emptyset & \emptyset & \emptyset \\ \emptyset & \{(B, S); (S_1, S)\} & \emptyset & \emptyset \\ \emptyset & \emptyset & \emptyset & \emptyset \end{pmatrix}$$

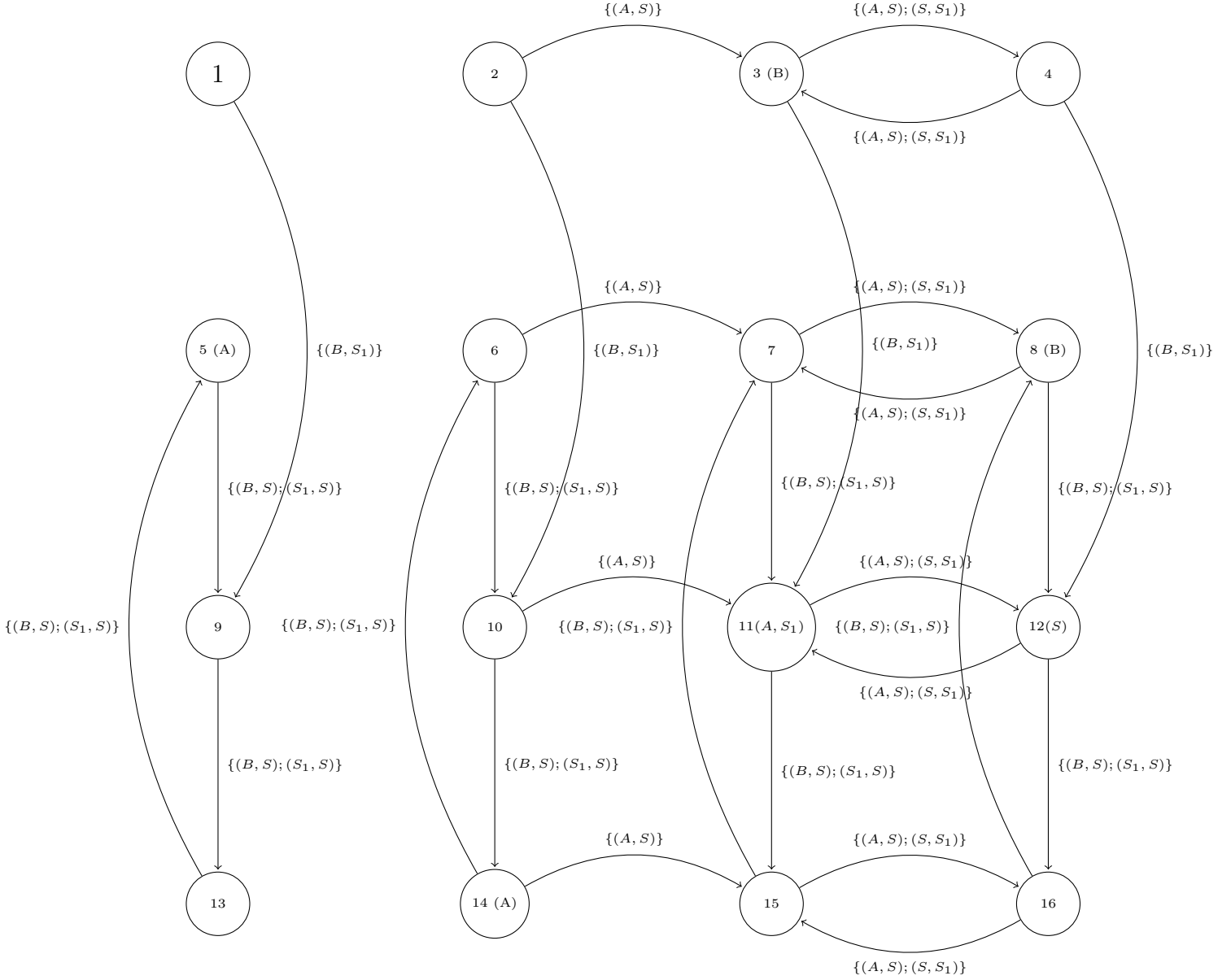
D_1 is “from column to row” $D_1 =$

$$\begin{pmatrix} \emptyset & \emptyset & \emptyset & \emptyset \\ \emptyset & \emptyset & \emptyset & \emptyset \\ \{(A, S); (S, S_1)\} & \{(A, S); (S, S_1)\} & \{(A, S); (S, S_1)\} & \{(A, S); (S, S_1)\} \\ \{(A, S); (S, S_1)\} & \{(A, S); (S, S_1)\} & \{(A, S); (S, S_1)\} & \{(A, S); (S, S_1)\} \end{pmatrix}$$

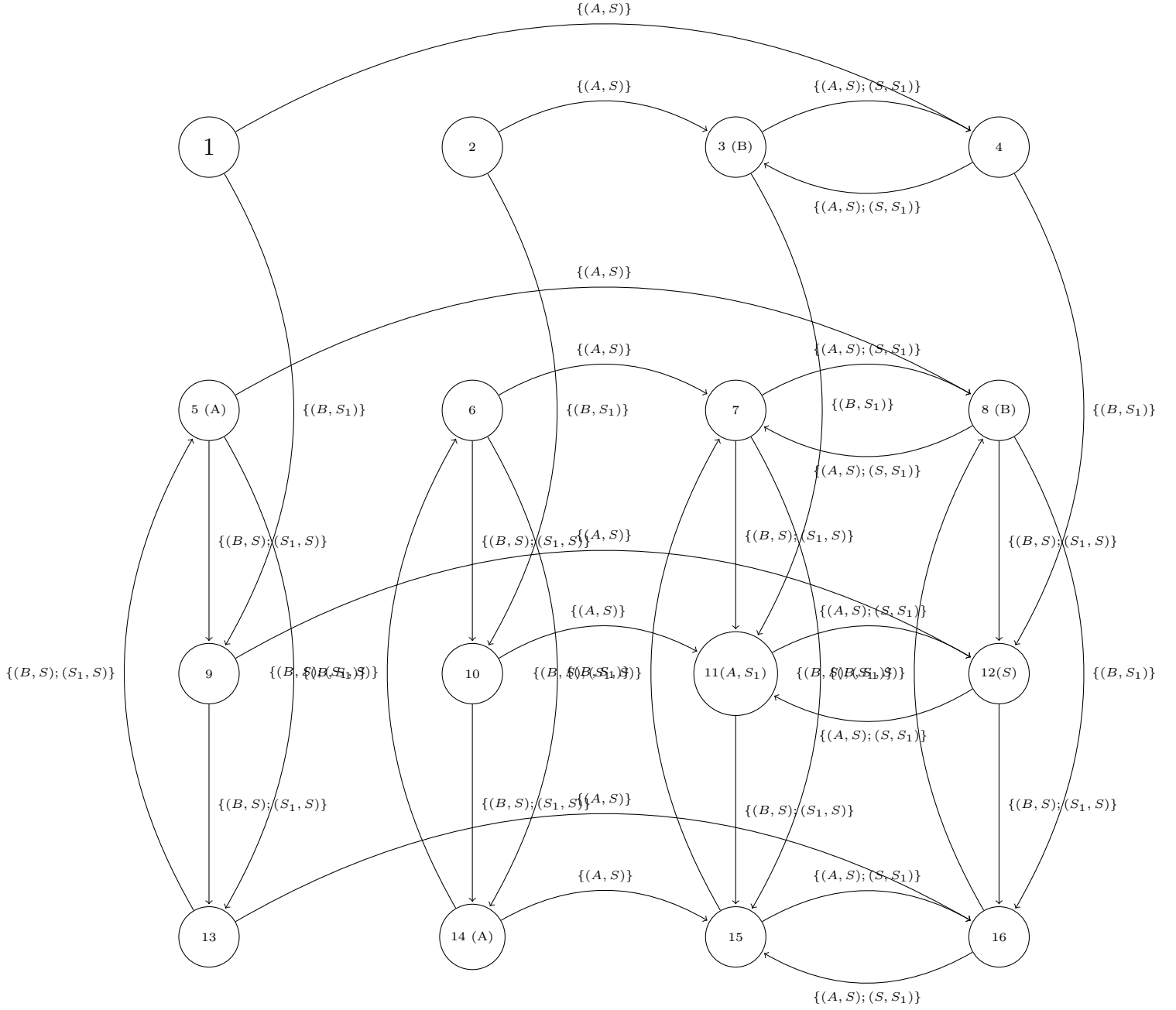
D_2 is “from row to column” $D_2 =$

$$\begin{pmatrix} \emptyset & \emptyset & \emptyset & \emptyset \\ \{(B, S_1); (S_1, S_1)\} & \{(B, S_1); (S_1, S_1)\} & \{(B, S_1); (S_1, S_1)\} & \{(B, S_1); (S_1, S_1)\} \\ \{(B, S_1); (S_1, S_1)\} & \{(B, S_1); (S_1, S_1)\} & \{(B, S_1); (S_1, S_1)\} & \{(B, S_1); (S_1, S_1)\} \\ \{(B, S_1); (S_1, S_1)\} & \{(B, S_1); (S_1, S_1)\} & \{(B, S_1); (S_1, S_1)\} & \{(B, S_1); (S_1, S_1)\} \end{pmatrix}$$

Grid:



Grid:



References

- [1] Krishnendu Chatterjee, Bhavya Choudhary, and Andreas Pavlogiannis. 2017. *Optimal Dyck reachability for data-dependence and alias analysis*. Proc. ACM Program. Lang. 2, POPL, Article 30 (December 2017), 30 pages. DOI: <https://doi.org/10.1145/3158118>