# Dancing links package

## Exact cover problem

남수진

2018년 2월 3일 토요일

2018 한국텍학회 학술대회 및 정기총회
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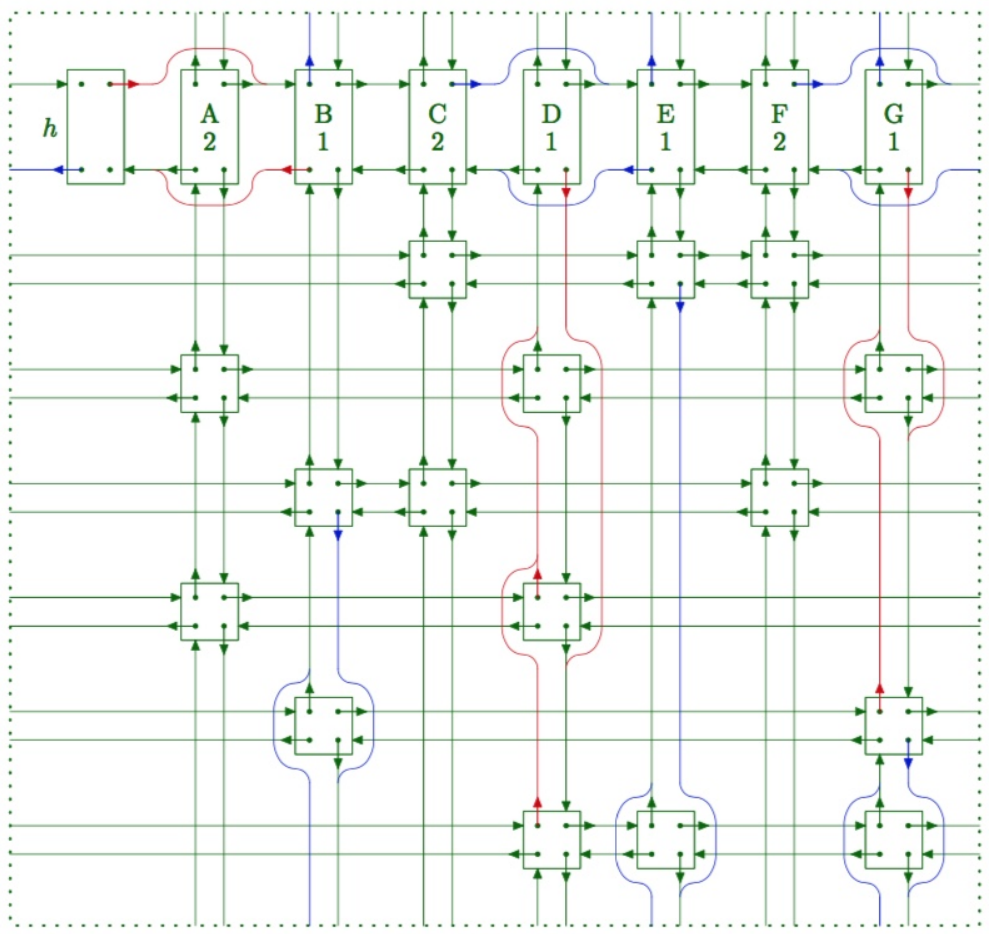
# Dancing links

# Dancing links

- Exact cover 문제를 해결하는 알고리즘에 사용되는 기법
- 백트래킹을 효율적으로 구현하는 방법 (*do*, *undo* 연산)



# Exact cover problem

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0과 1로만 구성된 행렬에서 각 열이 정확히 하나의 1만 갖도록 하는 행들의 집합을 구하라.

$$\begin{pmatrix} 0 & 0 & 1 & 0 & 1 & 0 & 0 \\ 1 & 0 & 0 & 1 & 0 & 0 & 1 \\ 0 & 1 & 1 & 0 & 0 & 1 & 0 \\ 1 & 0 & 0 & 1 & 0 & 1 & 0 \\ 0 & 1 & 0 & 0 & 0 & 0 & 1 \\ 0 & 0 & 0 & 1 & 1 & 0 & 1 \end{pmatrix}$$

# Exact cover problem

0과 1로만 구성된 행렬에서 각 열이 정확히 하나의 1만 갖도록 하는 행들의 집합을 구하라.

$$\begin{pmatrix} 0 & 0 & 1 & 0 & 1 & 0 & 0 \\ 1 & 0 & 0 & 1 & 0 & 0 & 1 \\ 0 & 1 & 1 & 0 & 0 & 1 & 0 \\ 1 & 0 & 0 & 1 & 0 & 1 & 0 \\ 0 & 1 & 0 & 0 & 0 & 0 & 1 \\ 0 & 0 & 0 & 1 & 1 & 0 & 1 \end{pmatrix}$$

# Exact cover problem

$$\begin{pmatrix} 0 & 0 & 1 & 0 & 1 & 0 & 0 \\ 1 & 0 & 0 & 1 & 0 & 0 & 1 \\ 0 & 1 & 1 & 0 & 0 & 1 & 0 \\ 1 & 0 & 0 & 1 & 0 & 1 & 0 \\ 0 & 1 & 0 & 0 & 0 & 0 & 1 \\ 0 & 0 & 0 & 1 & 1 & 0 & 1 \end{pmatrix} \Rightarrow$$

| $A$ | $B$ | $C$ | $D$ | $E$ | $F$ | $G$ |
|---|---|---|---|---|---|---|
| $C$ | $E$ | | | | | |
| $A$ | $D$ | $G$ | | | | |
| $B$ | $C$ | $F$ | | | | |
| $A$ | $D$ | $F$ | | | | |
| $B$ | $G$ | | | | | |
| $D$ | $E$ | $G$ | | | | |

# Exact cover problem

| $A$ | $B$ | $C$ | $D$ | $E$ | $F$ | $G$ |
|---|---|---|---|---|---|---|
| $C$ | $E$ | | | | | |
| $A$ | $D$ | $G$ | | | | |
| $B$ | $C$ | $F$ | | | | |
| $A$ | $D$ | $F$ | | | | |
| $B$ | $G$ | | | | | |
| $D$ | $E$ | $G$ | | | | |

# Exact cover problem

| A | B | C | D | E | F | G |
|---|---|---|---|---|---|---|
| C | E | | | | | |
| A | D | G | | | | |
| B | C | F | | | | |
| A | D | F | | | | |
| B | G | | | | | |
| D | E | G | | | | |

# Exact cover problem

| $A$ | $B$ | $C$ | $D$ | $E$ | $F$ | $G$ |
|---|---|---|---|---|---|---|
| $C$ | $E$ | | | | | |
| $A$ | $D$ | $G$ | | | | |
| $B$ | $C$ | $F$ | | | | |

# Exact cover problem

| $A$ | $B$ | $C$ | $D$ | $E$ | $F$ | $G$ |
|---|---|---|---|---|---|---|
| $C$ | $E$ | | | | | |
| $A$ | $D$ | $G$ | | | | |
| $B$ | $C$ | $F$ | | | | |

# Exact cover problem

| $A$ | $B$ | $C$ | $D$ | $E$ | $F$ | $G$ |
|---|---|---|---|---|---|---|
| $C$ | $E$ | | | | | |
| $A$ | $D$ | $G$ | | | | |

# Exact cover problem

| *A* | *B* | *C* | *D* | *E* | *F* | *G* |
|---|---|---|---|---|---|---|
| *C* | *E* | | | | | |
| *A* | *D* | *G* | | | | |
| *B* | *C* | *F* | | | | |
| *A* | *D* | *F* | | | | |
| *B* | *G* | | | | | |
| *D* | *E* | *G* | | | | |

# Exact cover problem

| *A* | *B* | *C* | *D* | *E* | *F* | *G* |
|---|---|---|---|---|---|---|
| *C* | *E* | | | | | |

| *A* | *D* | *F* |
|---|---|---|
| *B* | *G* | |

# Exact cover problem

| $A$ | $B$ | $C$ | $D$ | $E$ | $F$ | $G$ |
|---|---|---|---|---|---|---|
| $C$ | $E$ | | | | | |
| $A$ | $D$ | $F$ | | | | |
| $B$ | $G$ | | | | | |

# Exact cover problem

| $A$ | $B$ | $C$ | $D$ | $E$ | $F$ | $G$ |
|---|---|---|---|---|---|---|
| $C$ | $E$ | | | | | |

| $A$ | $D$ | $F$ |
|---|---|---|
| $B$ | $G$ | |

# lua-dancing-links

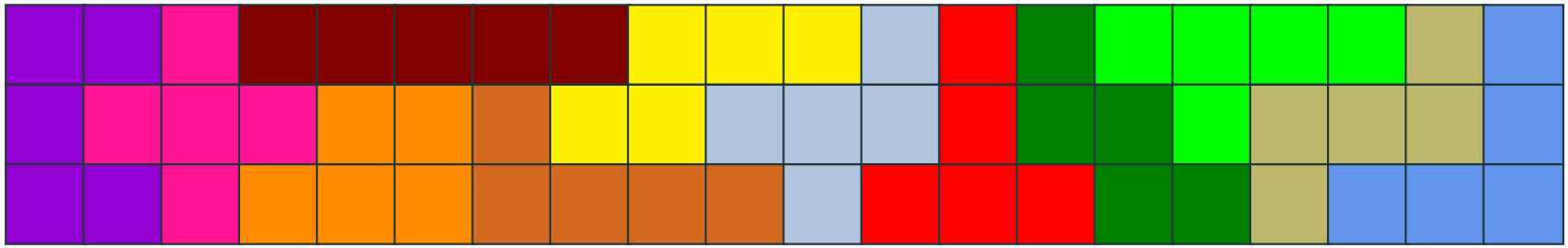
github.com/sjnam/lua-dancing-links

# Exact cover problem

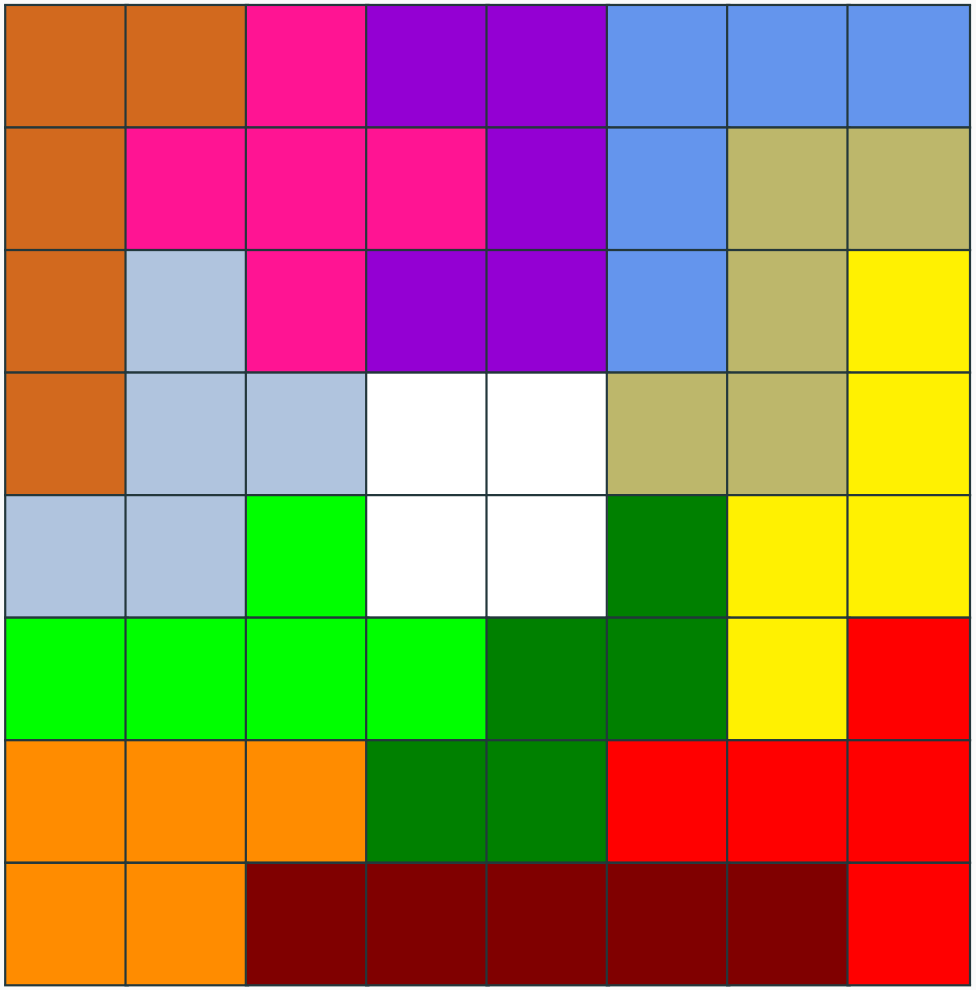
## Pentominoes

# Pentominoes

```
\usepackage{pentominoes}
\pentominoes{1.4em}{3}{20}.
```



# Pentominoes, 8x8



# Exact cover problem

## Sudoku

# Sudoku

```
\sudoku {9.......6.3.4....9...915.8..8.5..7..%
..3.9.4....2..1.9.32176....6..1.2.3.8...5...1}
```

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 9 | | | | | | | | 6 |
| | 3 | | 4 | | | | | 9 |
| | | | 9 | 1 | 5 | | 8 | |
| | 8 | | 5 | | | 7 | | |
| | | 3 | | 9 | | 4 | | |
| | | 2 | | | 1 | | 9 | |
| 3 | 2 | 1 | 7 | 6 | | | | |
| 6 | | | 1 | | 2 | | 3 | |
| 8 | | | | 5 | | | | 1 |

# Sudoku

```
\sudoku*{9.......6.3.4....9...915.8..8.5..7..%
..3.9.4....2..1.9.32176....6..1.2.3.8...5...1}
```

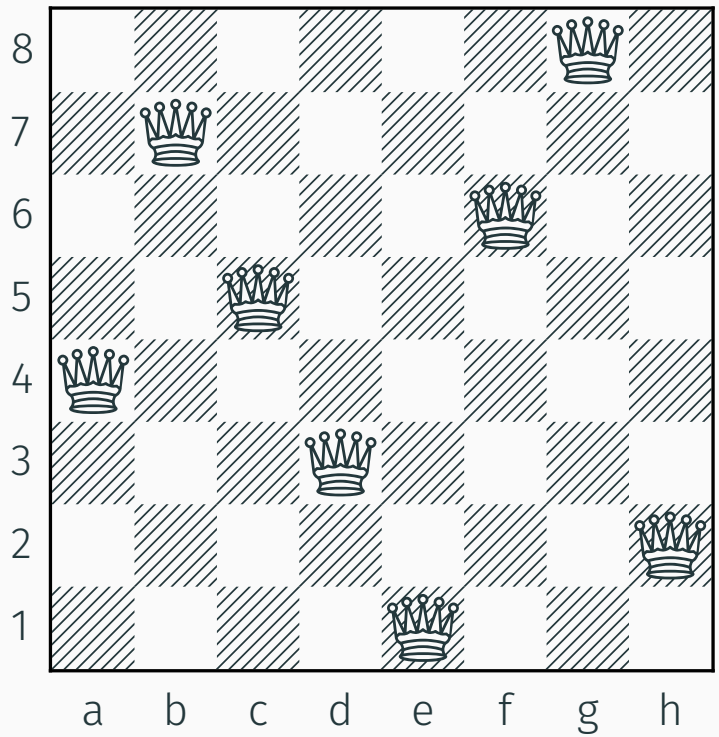
| 9 | 1 | 4 | 8 | 3 | 7 | 2 | 5 | 6 |
|---|---|---|---|---|---|---|---|---|
| 5 | 3 | 8 | 4 | 2 | 6 | 1 | 7 | 9 |
| 2 | 7 | 6 | 9 | 1 | 5 | 3 | 8 | 4 |
| 1 | 8 | 9 | 5 | 4 | 3 | 7 | 6 | 2 |
| 7 | 6 | 3 | 2 | 9 | 8 | 4 | 1 | 5 |
| 4 | 5 | 2 | 6 | 7 | 1 | 8 | 9 | 3 |
| 3 | 2 | 1 | 7 | 6 | 9 | 5 | 4 | 8 |
| 6 | 4 | 5 | 1 | 8 | 2 | 9 | 3 | 7 |
| 8 | 9 | 7 | 3 | 5 | 4 | 6 | 2 | 1 |

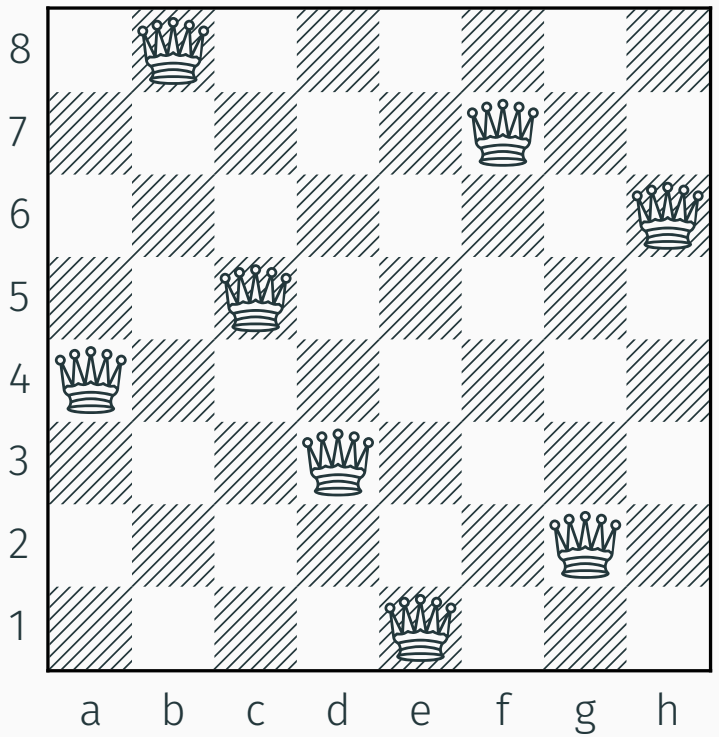
# Exact cover problem

## N-Queens

# N-QUEENS

```
\usepackage{queens}
\queens{8}{2}.
```



# References


- The Art of Computer Programming Pre-Fascicle 5c
- github.com/sjnam/lua-dancing-links

질문?