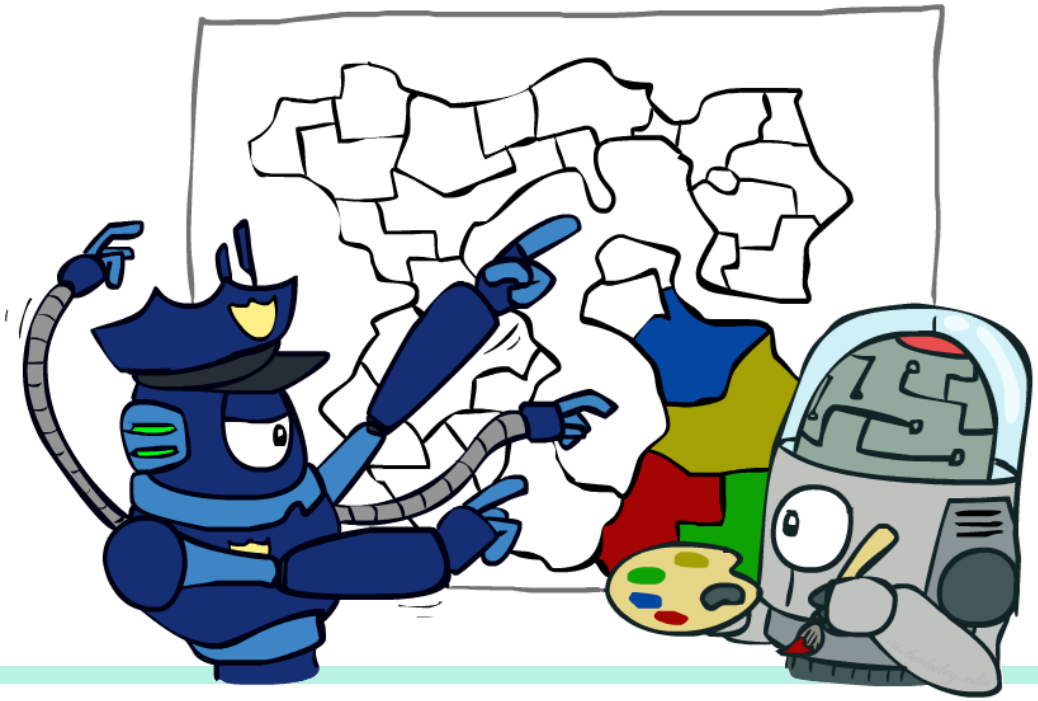
Advanced Topics in AI

Examples of CSPs



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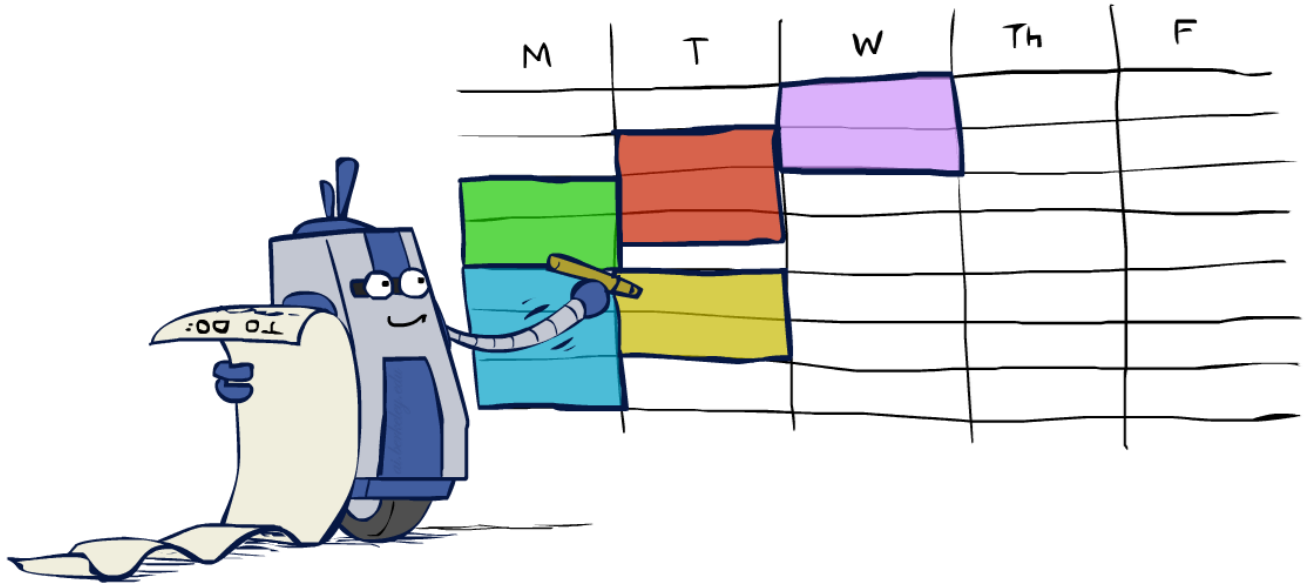
[These slides were created by Dan Klein and Pieter Abbeel for CS188 Intro to AI at UC Berkeley. All materials are available at http://ai.berkeley.edu.]

Real-World CSPs

- Assignment problems: e.g., who teaches what class
- Timetabling problems: e.g., which class is offered when and where?
- Hardware configuration
- Transportation scheduling
- Factory scheduling
- Circuit layout
- Fault diagnosis
- … lots more!



- Many real-world problems involve real-valued variables…

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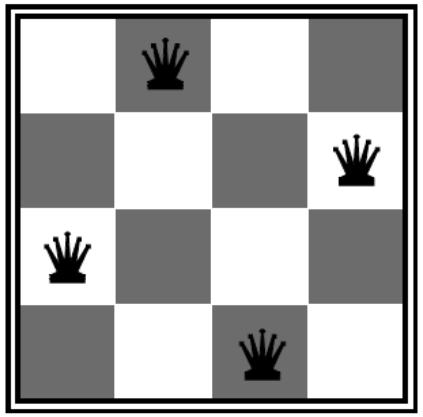
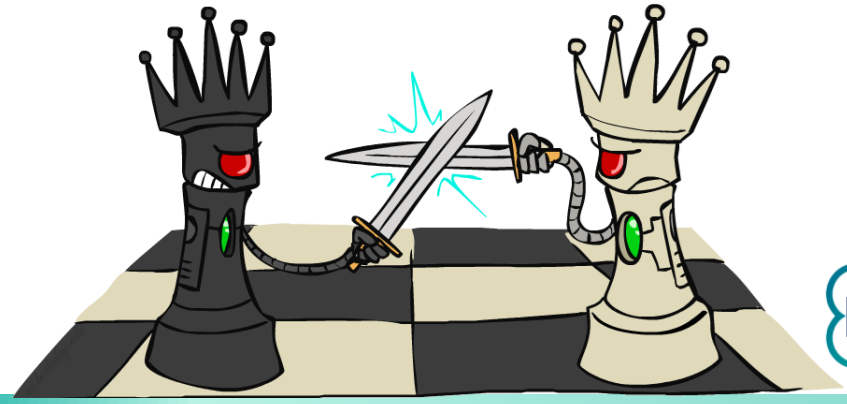
Example: N-Queens

- Formulation 1:
  - Variables: X_{ij}
  - Domains: $\{0, 1\}$
  - Constraints
    - $\forall i, j, k \left(X_{ij}, X_{ik}\right) \in \{(0,0), (0, 1), (1, 0)\}$
    - $\forall i, j, k \left(X_{ij}, X_{kj}\right) \in \{(0,0), (0, 1), (1, 0)\}$
    - $\forall i, j, k \left(X_{ij}, X_{i+k,j+k}\right) \in \{(0,0), (0, 1), (1, 0)\}$
    - $\forall i, j, k \left(X_{ij}, X_{i+k,j-k}\right) \in \{(0,0), (0, 1), (1, 0)\}$
    - $\sum_{i,j} X_{ij} = N$





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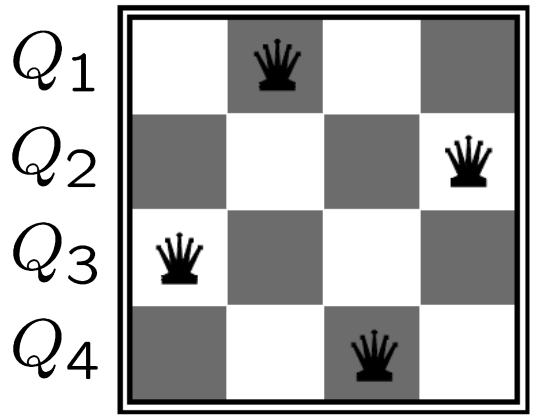
Example: N-Queens

- Formulation 2:
  - Variables: Q_k
  - Domains: $\{1, 2, 3, \dots, N\}$
  - Constraints:
    - Implicit:
      - $\forall i, j \text{ non} - \text{threatening}(Q_i, Q_j)$
    - Explicit:
      - $(Q_1, Q_2) \in \{(1,3), (1,4), \dots\}$
      - …



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Example: Cryptarithmetic

- Variables:

$$F\ T\ U\ W\ R\ O\ X_1\ X_2\ X_3$$

- Domains:

$$\{0, 1, 2, 3, 4, 5, 6, 7, 8, 9\}$$

- Constraints:

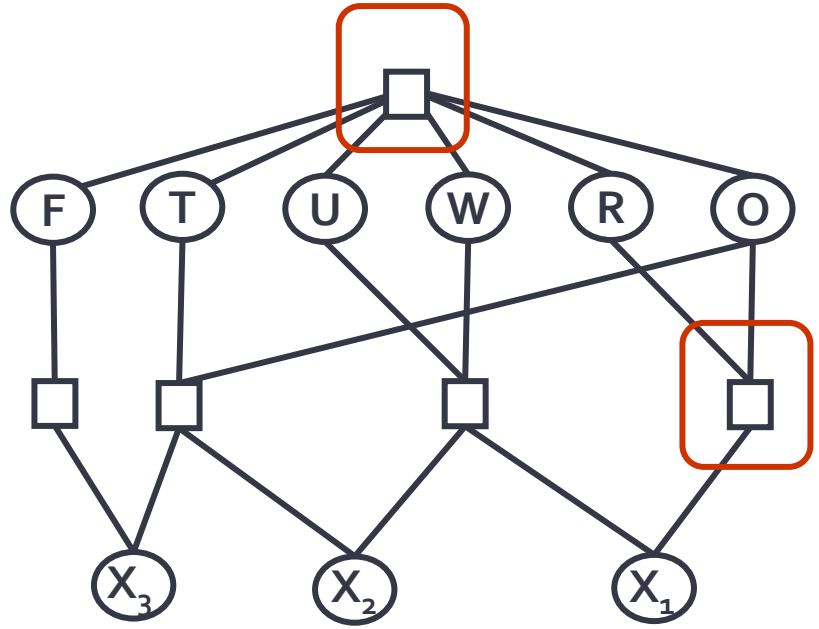
$$\text{alldiff}(F, T, U, W, R, O)$$

$$O + O = R + 10 \cdot X_1$$

...

X_1

```
  T W O
+ T W O
-------
F O U R
```



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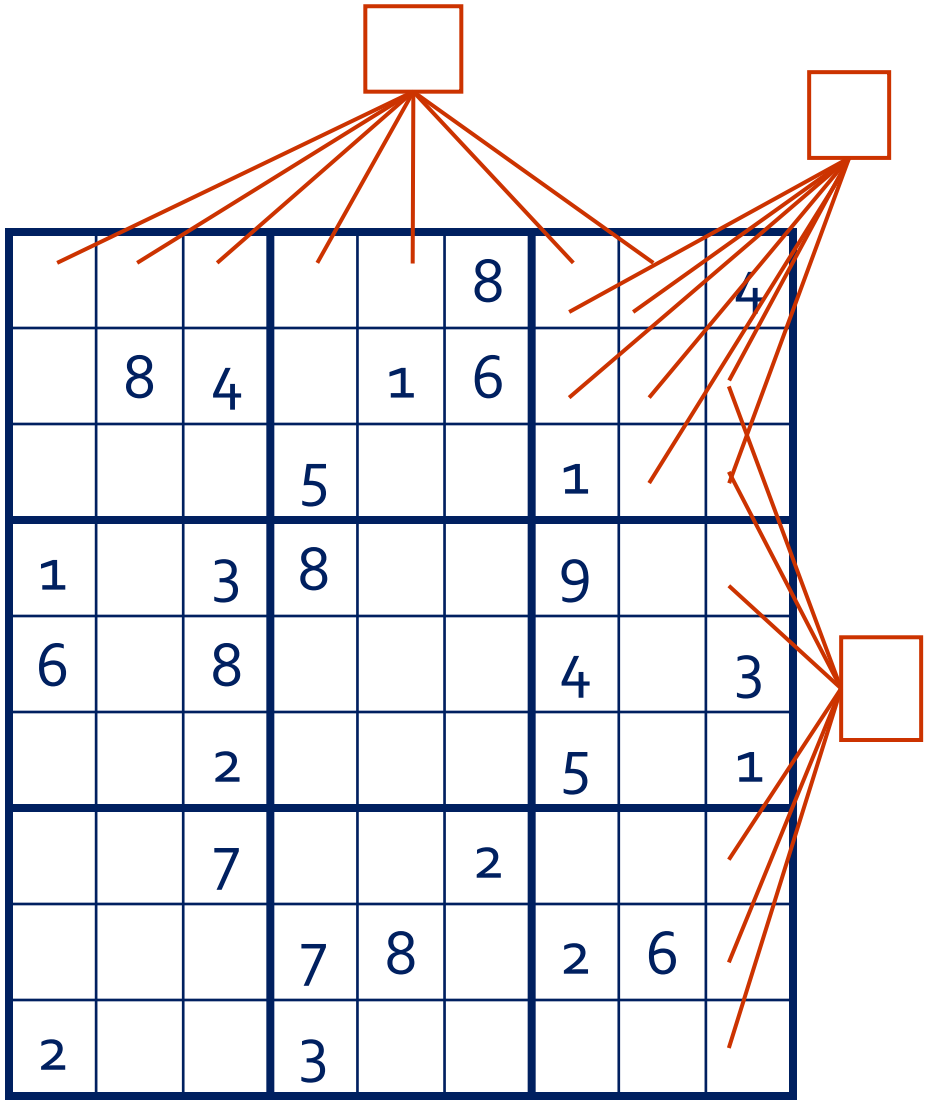
Example: Sudoku



- Variables:
  - Each (open) square
- Domains:
  - {1,2,…,9}
- Constraints:
  - 9-way alldiff for each column
  - 9-way alldiff for each row
  - 9-way alldiff for each region
    - (or can have a bunch of pairwise inequality constraints)

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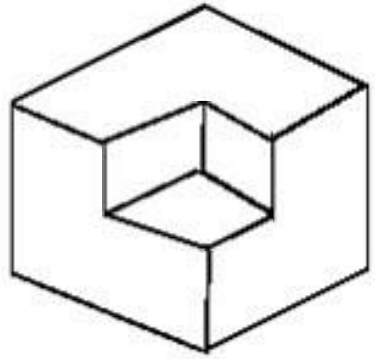
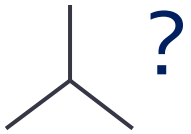
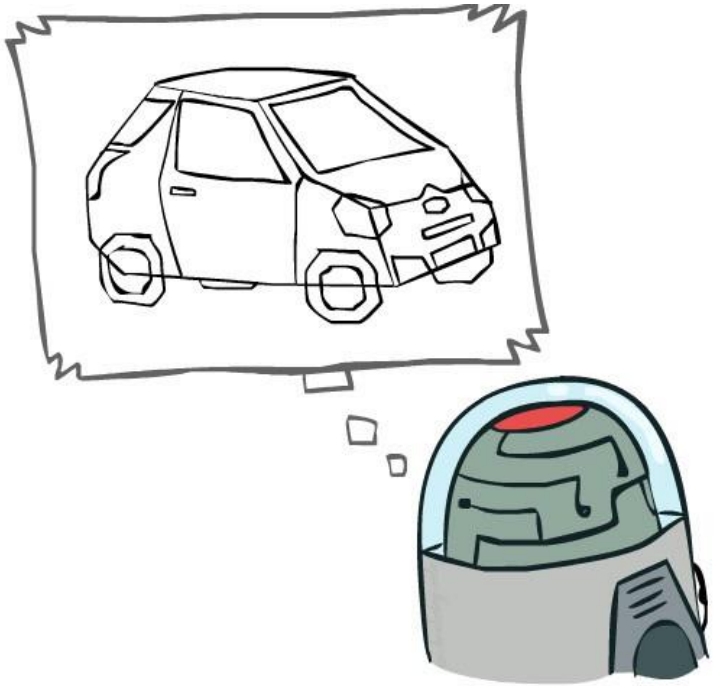
Example: The Waltz Algorithm

- The Waltz algorithm is for interpreting line drawings of solid polyhedra as 3D objects
- An early example of an AI computation posed as a CSP







- Approach:
  - Each intersection is a variable
  - Adjacent intersections impose constraints on each other
  - Solutions are physically realizable 3D interpretations

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Next: Solving CSPs

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