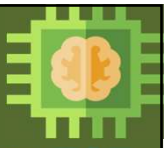
Elective Course

Course Code: CS4103

Autumn 2025-26



Lecture #15

Artificial Intelligence for Data Science

Week-4: PROBLEM SOLVING BY SEARCH

Adversarial Search Problem--- Games [Practice Example]

CONSTRAINT SATISFACTION PROBLEM (CSP)

Course Instructor:

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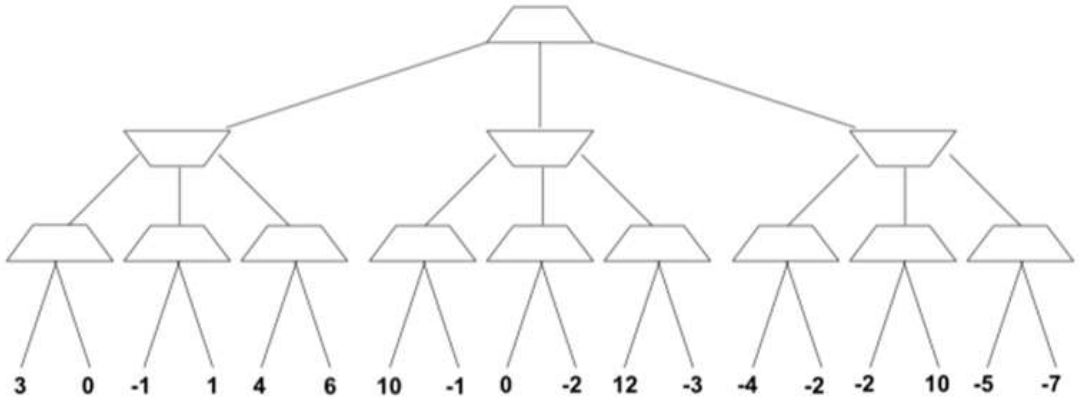
Assistant Professor

Department of Computational and Data Sciences

Indian Institute of Science Education and Research Kolkata, India 741246

Practice Problem

Which leaf nodes are never visited due to pruning?



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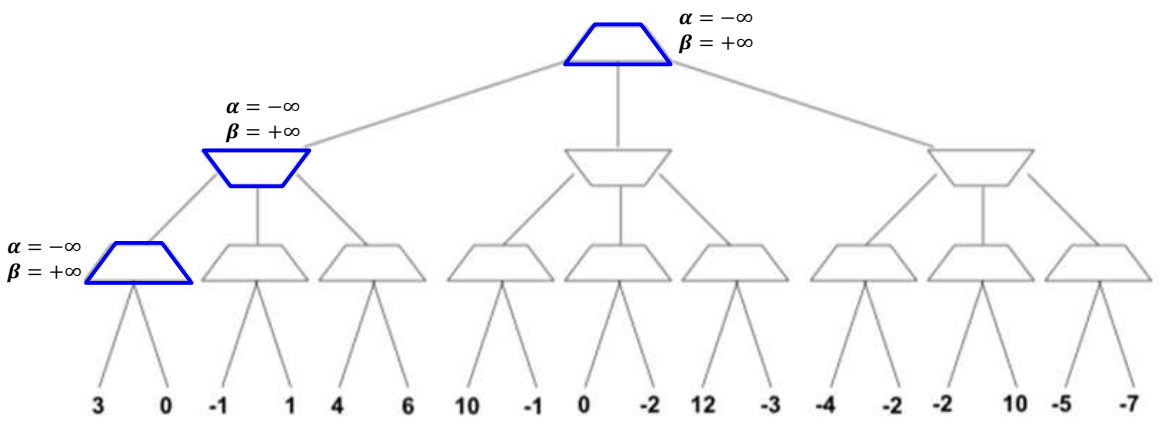

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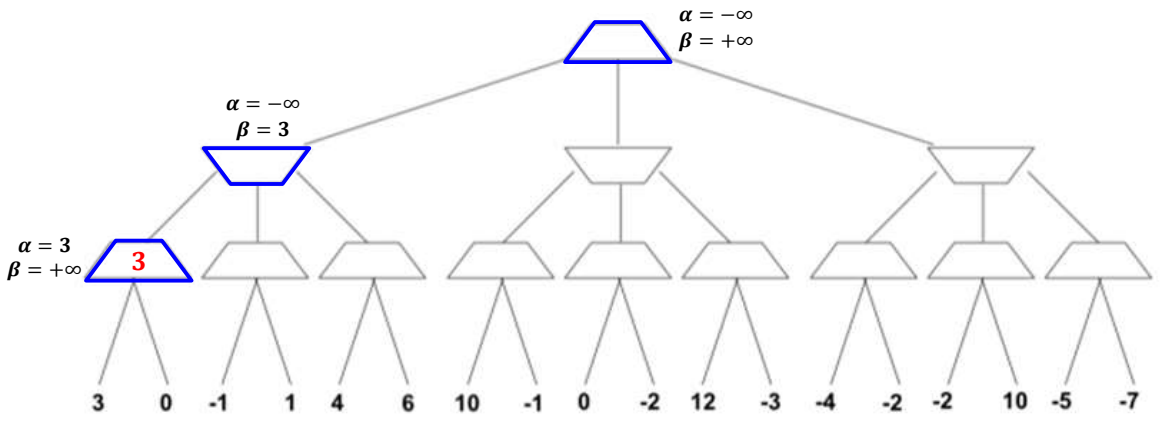

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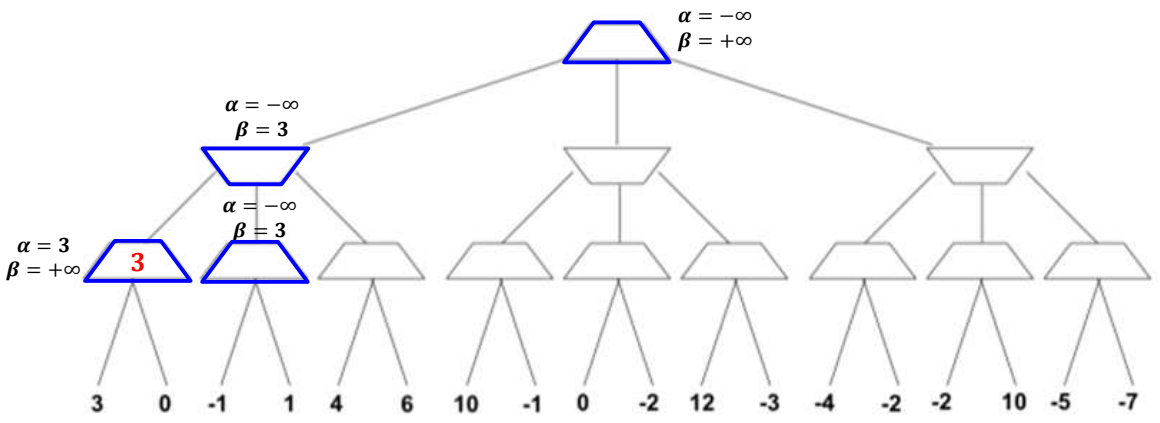

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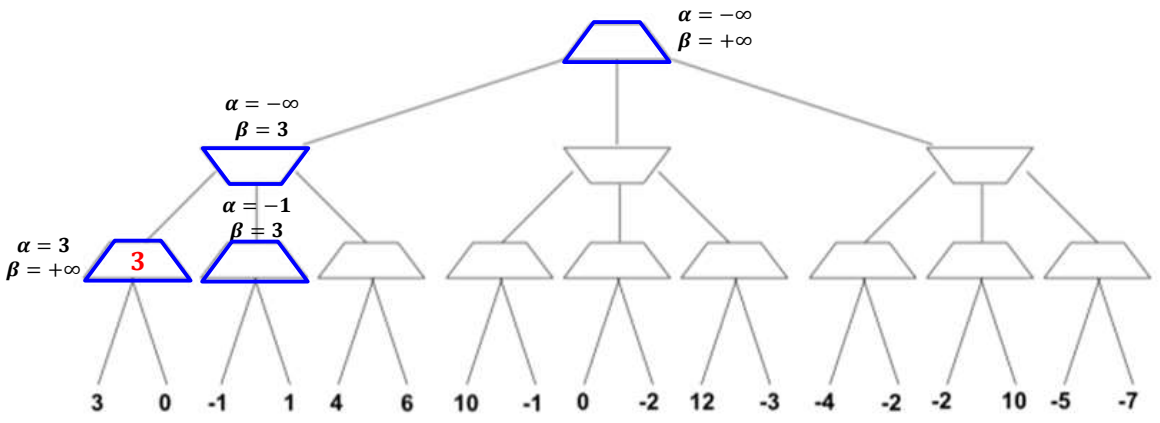

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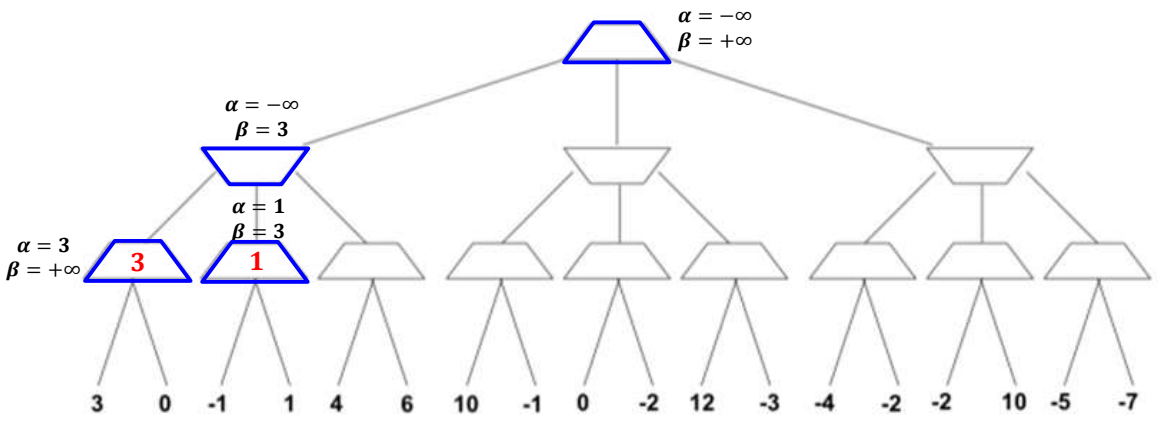

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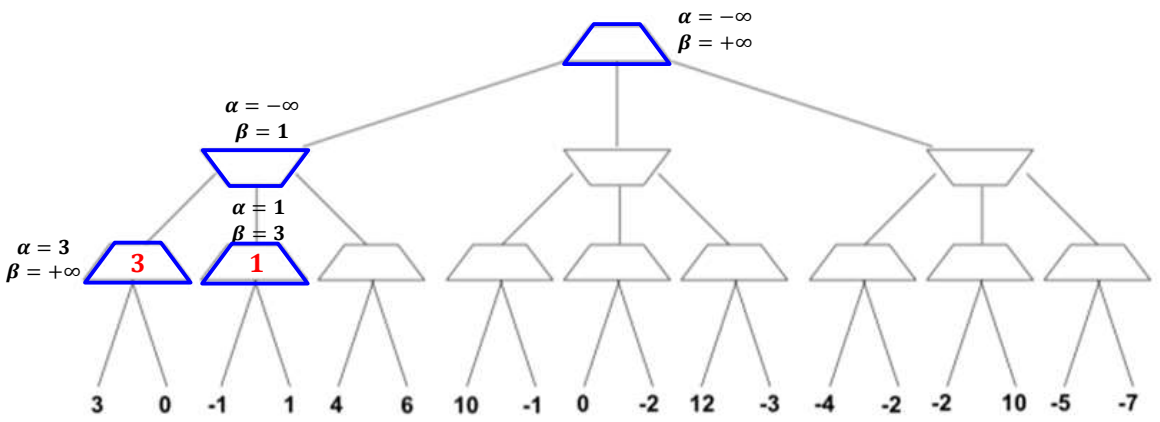

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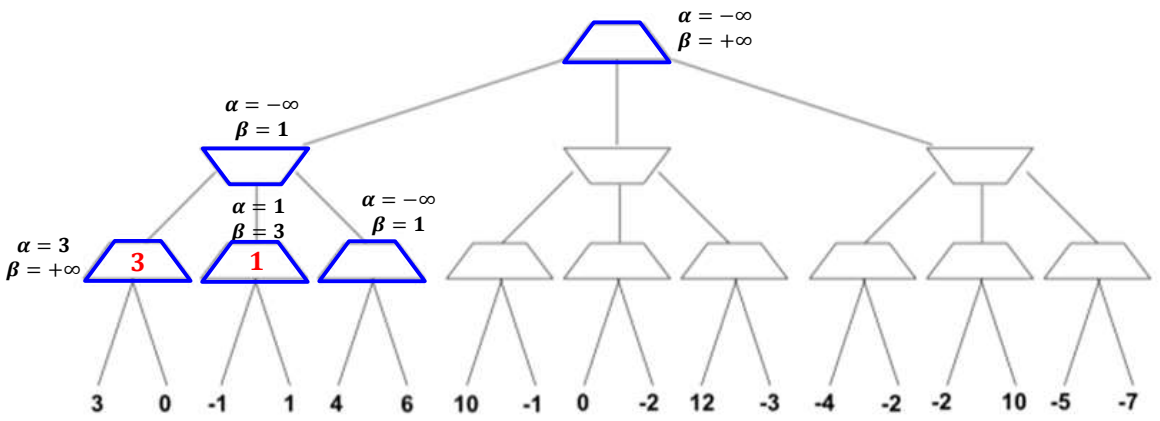

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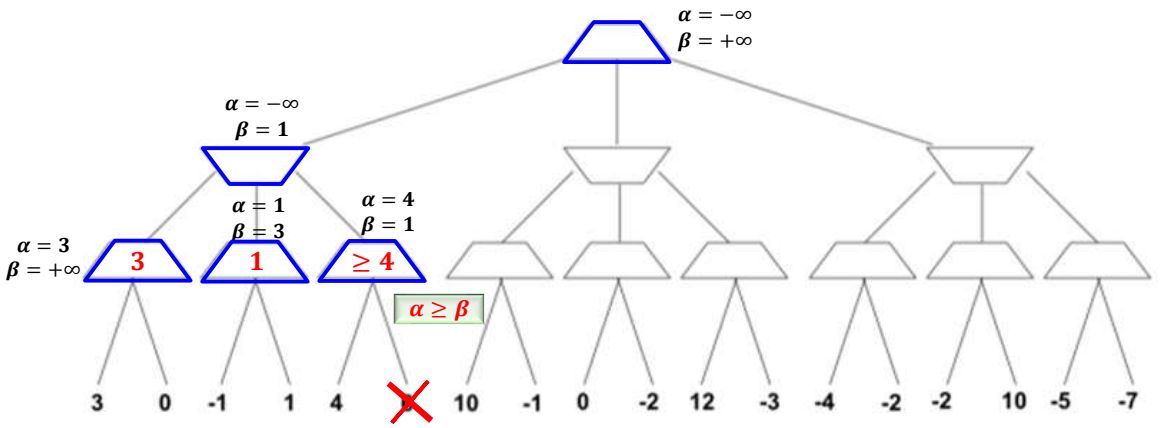

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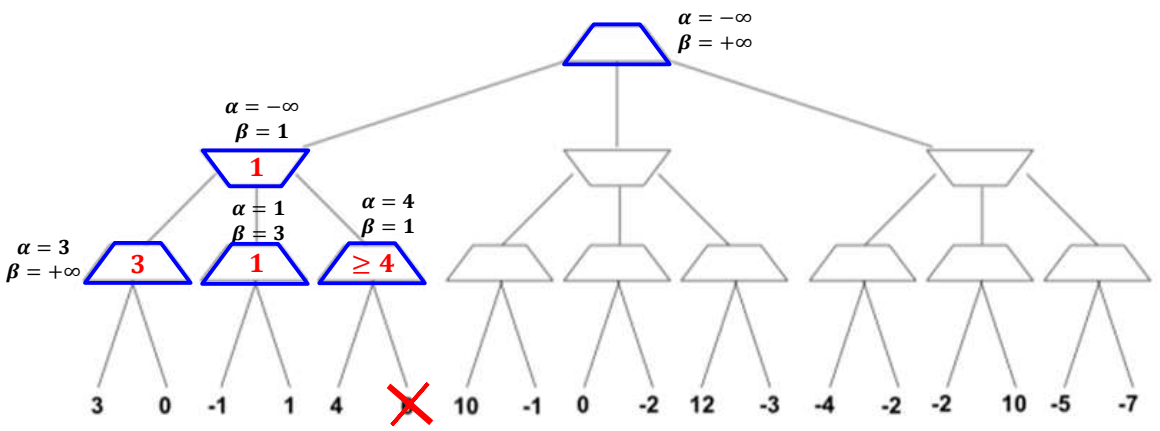

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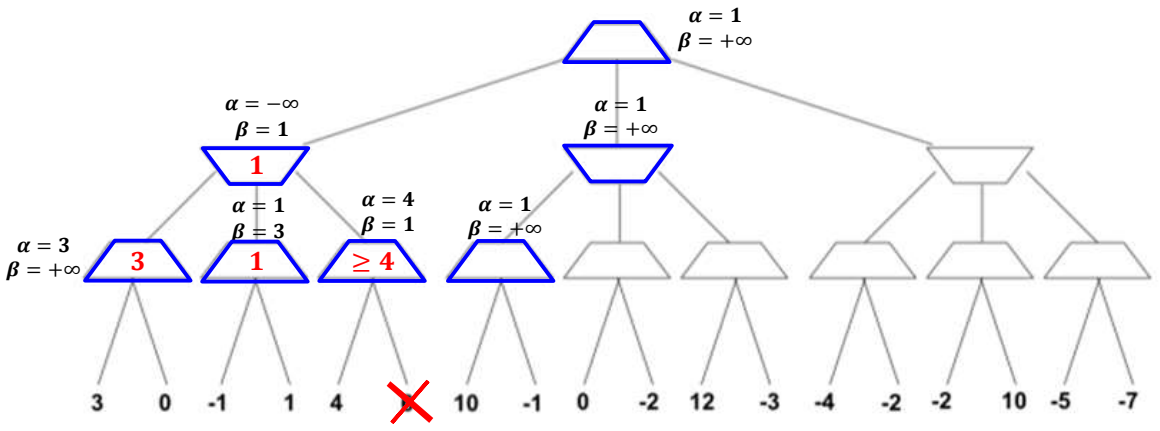

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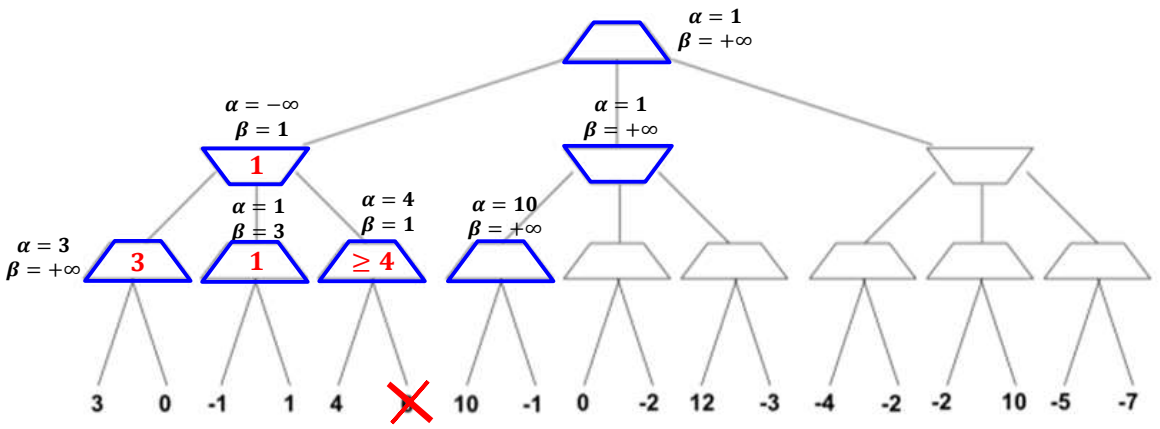

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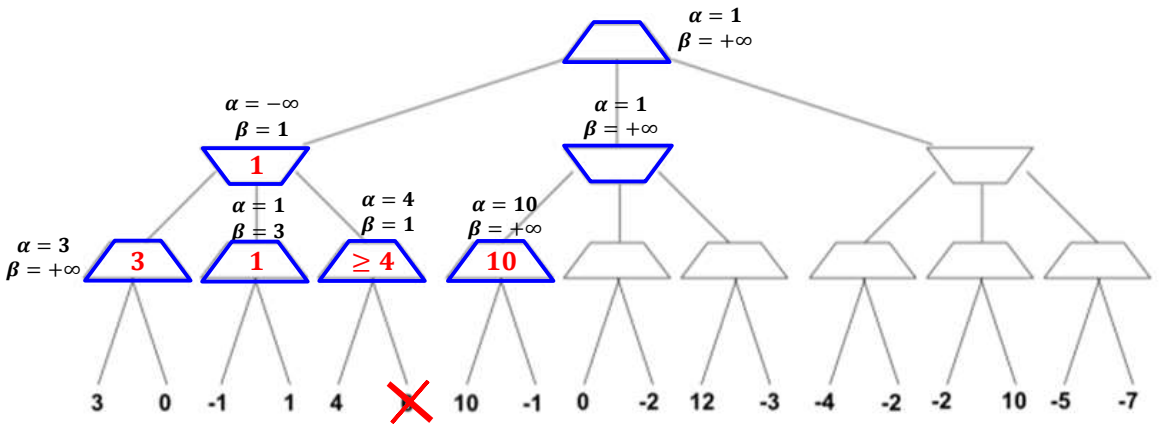

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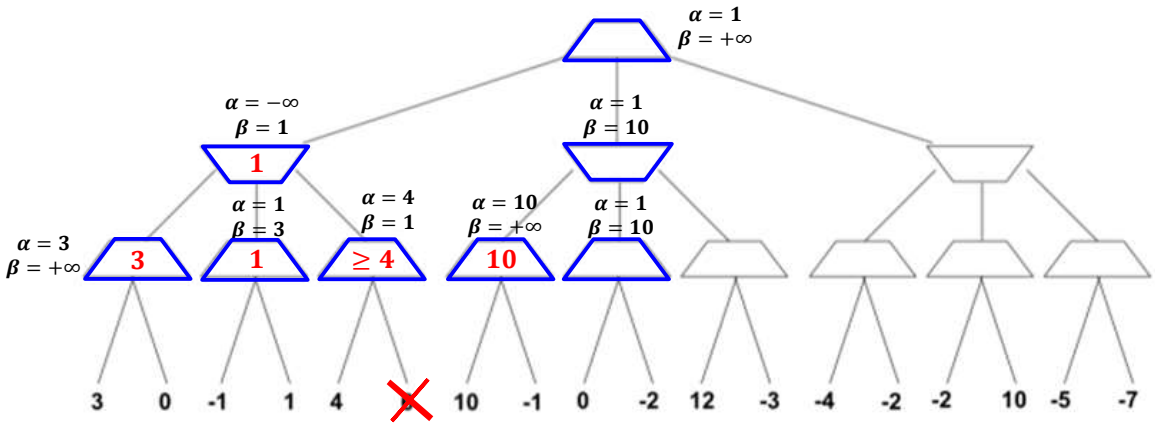

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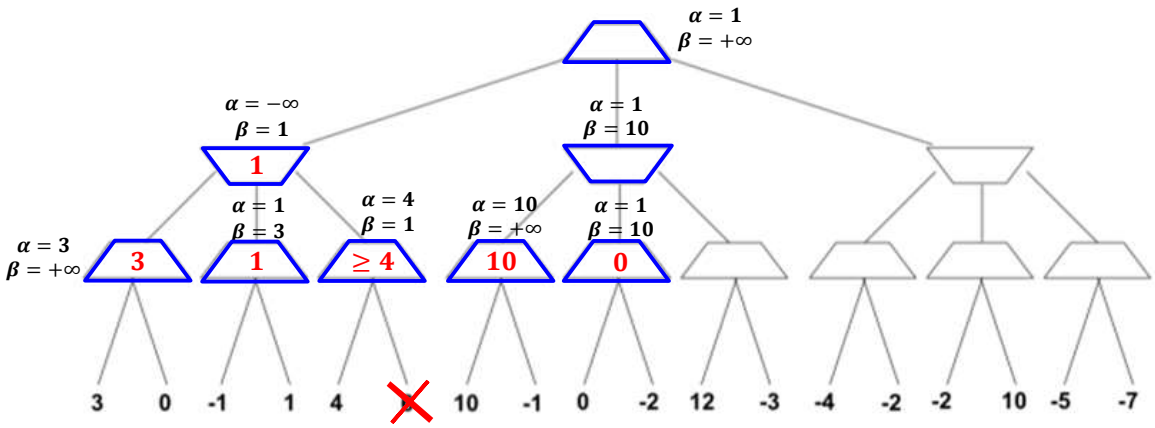

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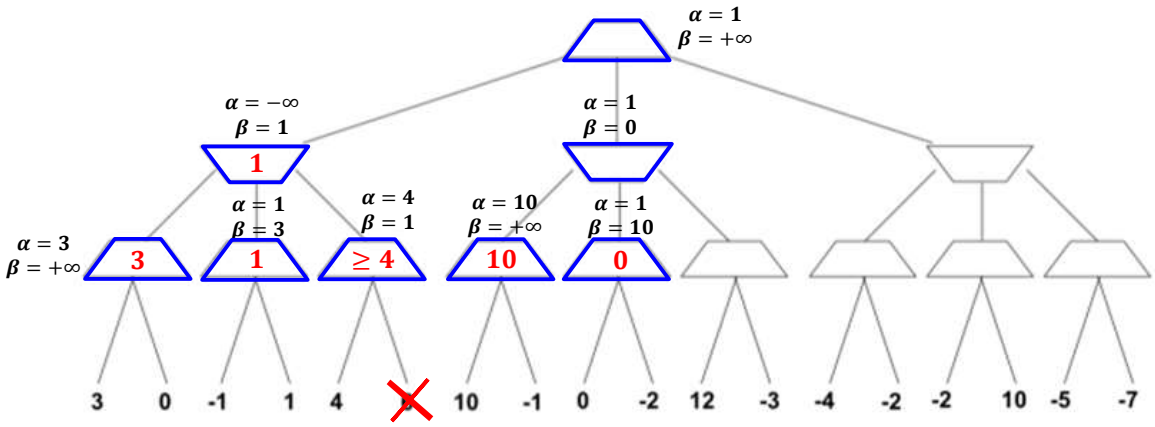

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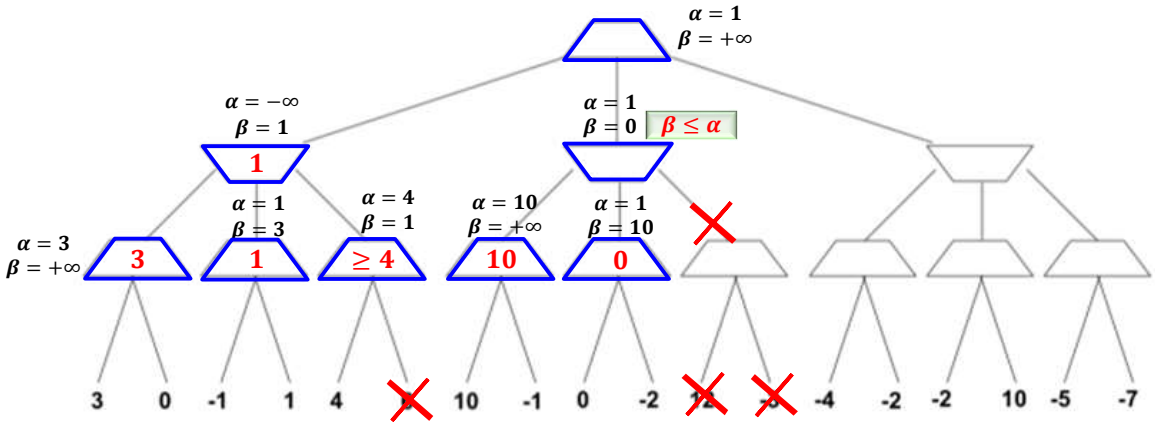

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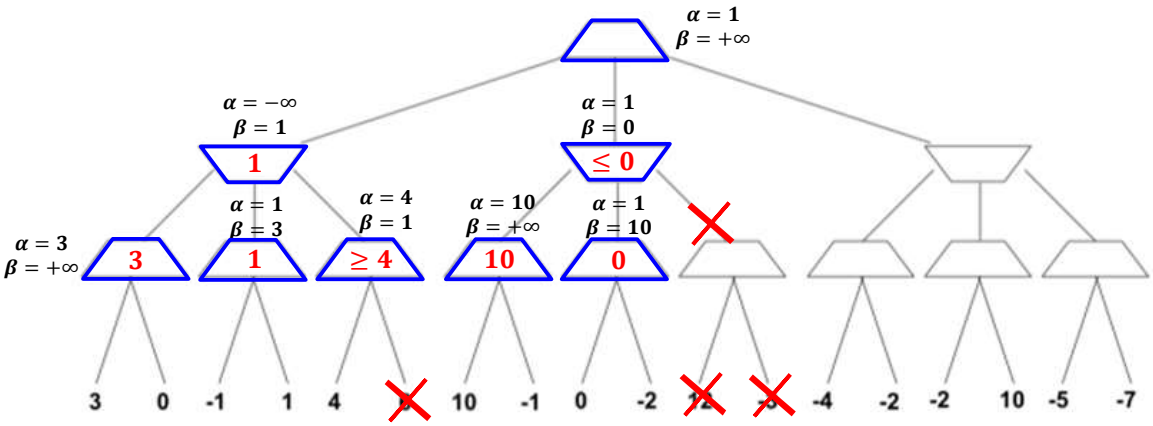

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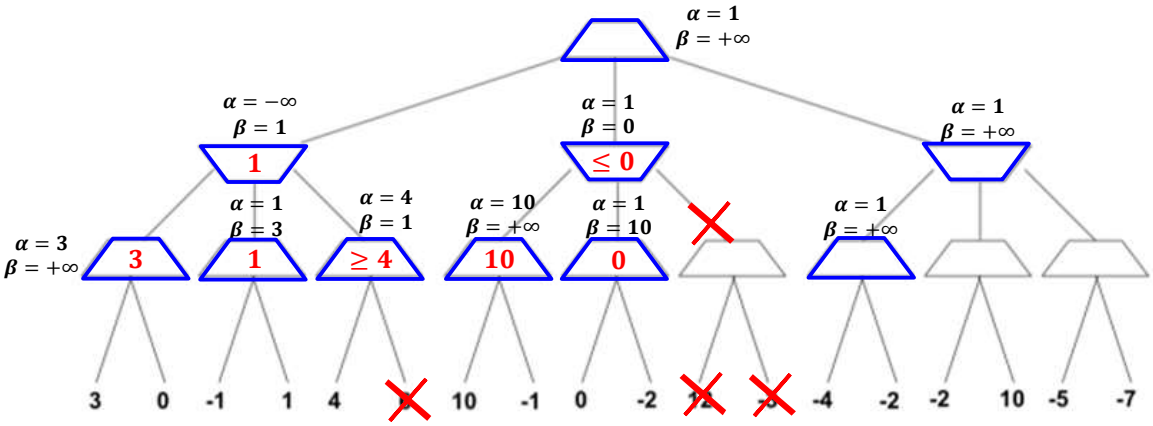

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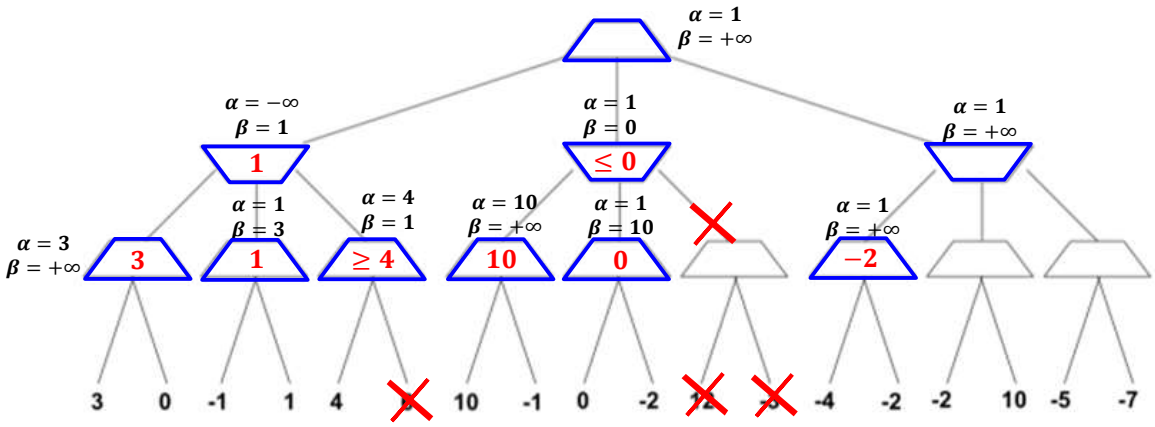

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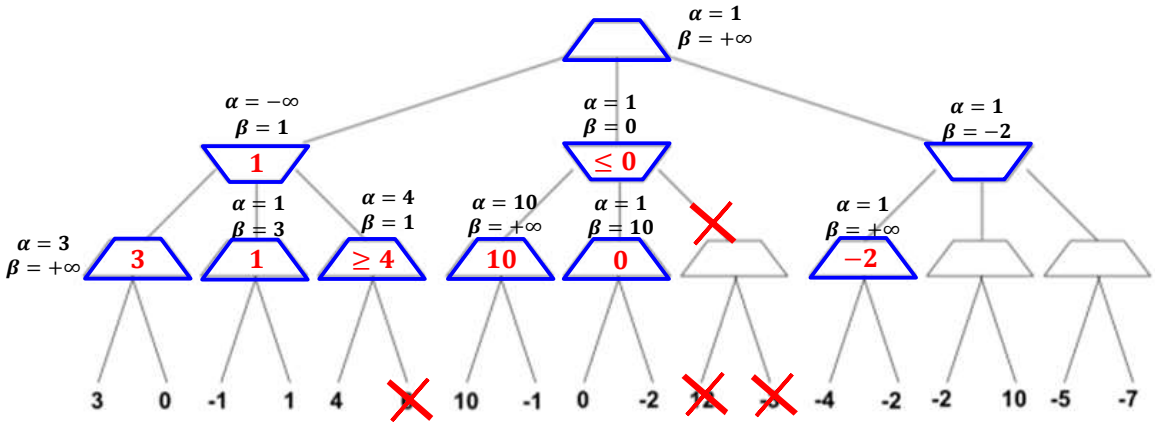

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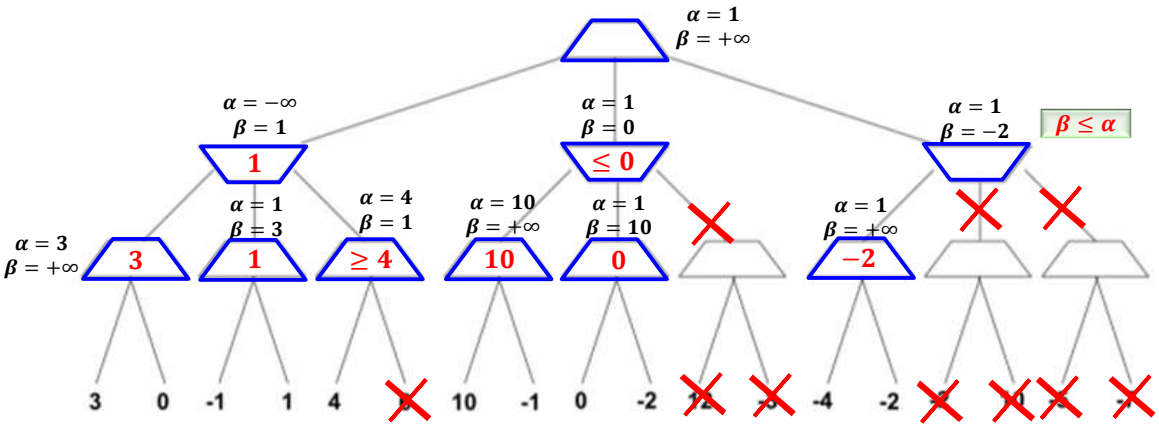

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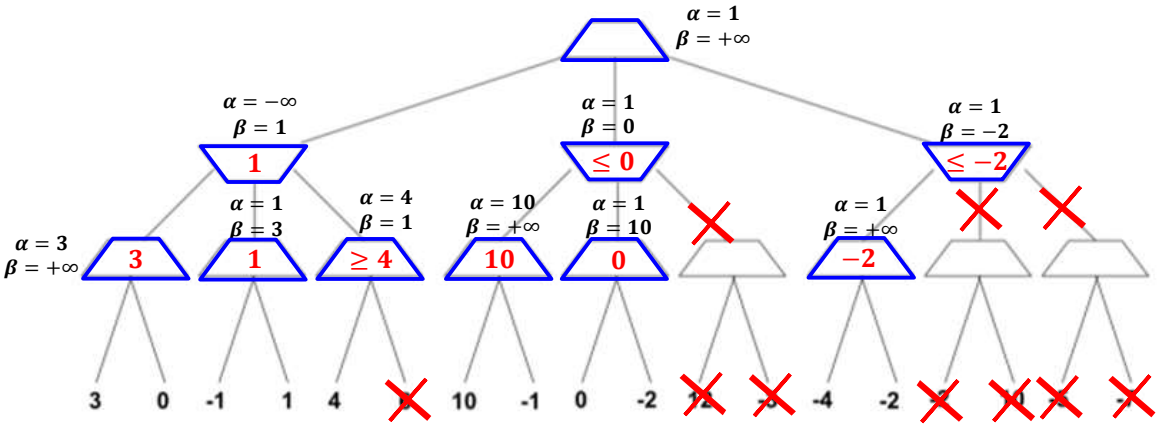

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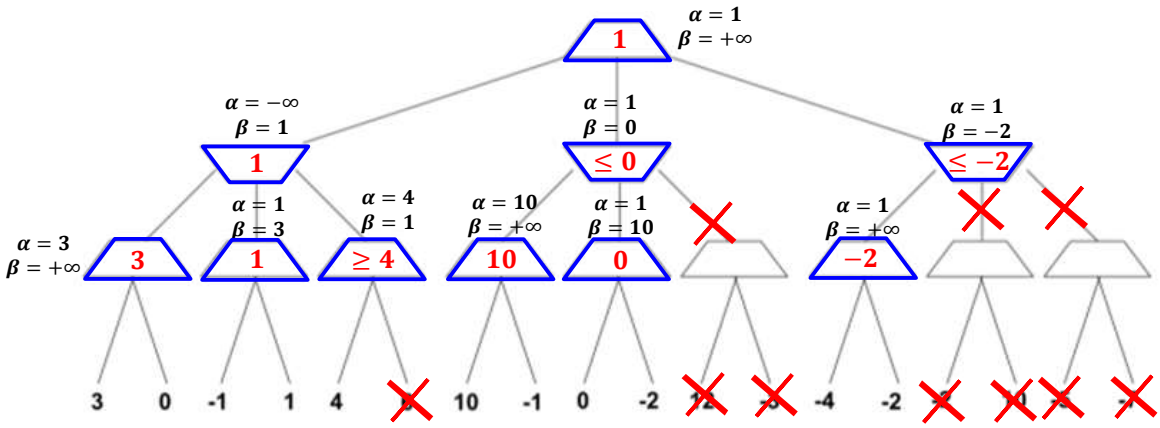

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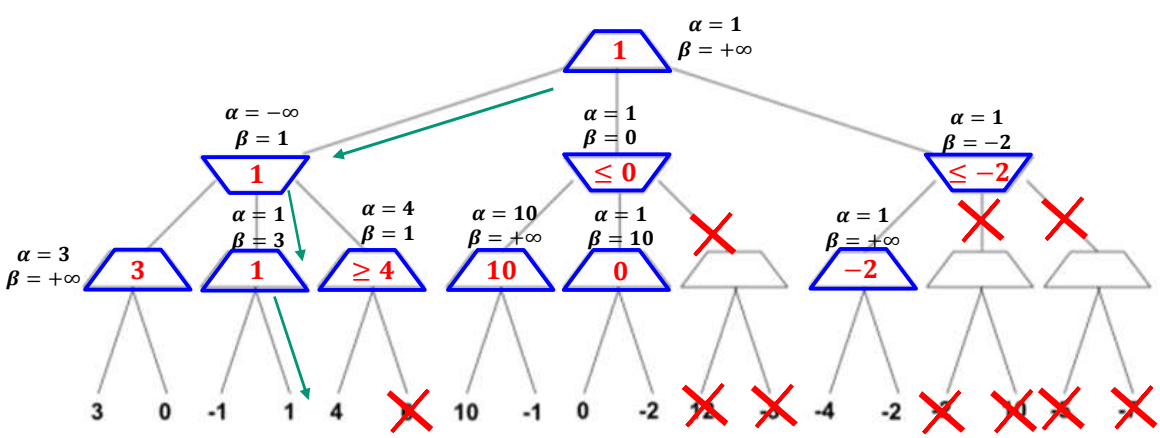

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Constraint Satisfaction Problems (CSPs)

Slides adapted from Prof. Tuomas Sandholm
Carnegie Mellon University, Computer Science Department

Course Structure/Syllabus

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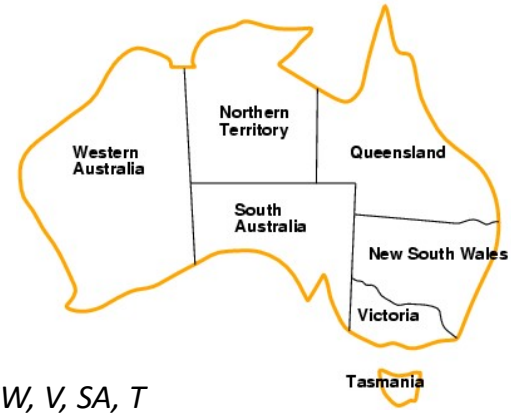
Syllabus	
Timeline	**Topics to be Covered**
Week 1	**INTRODUCTION TO AI:** Artificial Intelligence Introduction, Brief History, Intelligent Agents, Types of agents ***Python Primer for AI***
Week 2-4	**PROBLEM SOLVING BY SEARCH:** Problem formulation, Concept of state space search Introduction to Uninformed Search Techniques: *Breadth First Search, Depth First Search, Depth First Search with Iterative Deepening, Uniform Cost Search* Introduction to Informed/Heuristic search techniques: *Greedy Best First Search, A* search, Hill Climbing search, Simulated Annealing search* Introduction to GA, GA Operations: *Selection, Crossover, Mutation* ***Solving N-Queen Problem using GA*** Adversarial Search: *Minimax algorithm, Alpha-Beta Pruning* ***Building a bot to play tic-tac-toe/Building 8-puzzle solver***
Week 5	**CONSTRAINT SATISFACTION PROBLEM (CSP):** Introduction to CSP, Constraint Graph, Binary and Higher order CSP, Backtracking Search, MRV heuristic, Degree heuristic, Least Constraining-value heuristic, Forward Checking, Arc Consistency, Min-Conflicts Algorithm ***Solving map coloring problem, Solving puzzle***

To be discussed in the first two lectures after the mid-semester exam

Constraint satisfaction problems (CSPs)

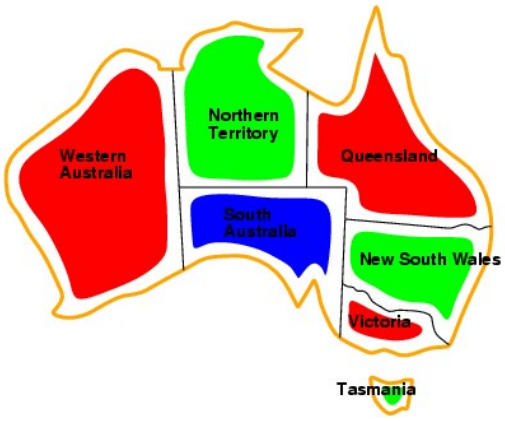
- Standard search problem:
  - **state** is a "black box“ – any data structure that supports successor function and goal test
- CSP:
  - **state** is defined by variables X_i with values from domain D_i
  - A set of constraints specifying allowable combinations of values for subsets of variables
- Allows useful general-purpose algorithms with **more power** than standard search algorithms

Example: Map-Coloring



- Variables: *WA, NT, Q, NSW, V, SA, T*
- Domains: D_i = {red, green, blue}
- Constraints: adjacent regions must have different colors
- e.g., WA ≠ NT, or (WA,NT) in {(red, green),(red, blue),(green, red),(green, blue), (blue, red),(blue, green)}

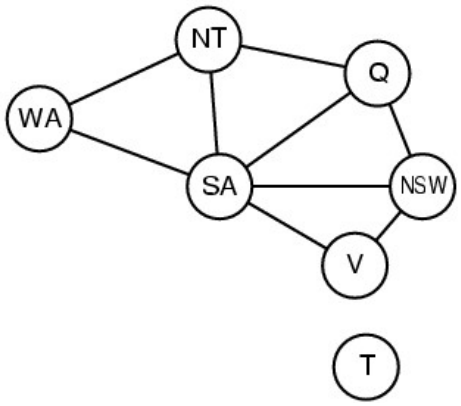
Example: Map-Coloring



- Solutions are complete and consistent assignments
- e.g., WA = red, NT = green, Q = red, NSW = green, V = red, SA = blue, T = green

Constraint graph

- Binary CSP: each constraint relates two variables
- Constraint graph: nodes are variables, arcs are constraints



Varieties of CSPs

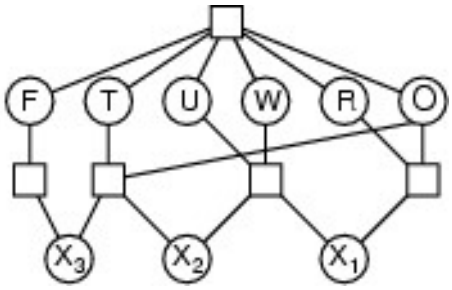
- **Discrete variables**
  - finite domains:
    - n variables, domain size $d \rightarrow O(d^n)$ complete assignments
    - e.g., Boolean CSPs, incl. Boolean satisfiability
  - infinite domains:
    - integers, strings, etc.
    - e.g., job scheduling, variables are start/end days for each job
    - need a constraint language, e.g., $StartJob_1 + 5 \leq StartJob_3$
- **Continuous variables**
  - e.g., start/end times for Hubble Space Telescope observations

Varieties of constraints

- **Unary** constraints involve a single variable,
  - e.g., SA ≠ green
- **Binary** constraints involve pairs of variables,
  - e.g., SA ≠ WA
- **Higher-order** constraints involve 3 or more variables,
  - e.g., cryptarithmetic column constraints

Example: Cryptarithmetic

$$\begin{array}{r} \text{T W O} \\ +\ \text{T W O} \\ \hline \text{F O U R} \end{array}$$



- **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:** *Alldiff (F,T,U,W,R,O)*

$O + O = R + 10 \cdot X_1$
$X_1 + W + W = U + 10 \cdot X_2$
$X_2 + T + T = O + 10 \cdot X_3$
$X_3 = F,\ T \neq 0,\ F \neq 0$

Questions?