G53CLP
Constraint Logic Programming

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Introduction to Scheduling Problems
Scheduling – Definition

- Given
  - A number of machines, \( M_i, i = 1, \ldots, M \);
  - A number of jobs, \( J_j, j = 1, \ldots, N \).

  The optimal allocation or assignment of resources, over time, to a set of tasks or activities
  - usually subject to a set of constraints (restrictions)

- Scheduling problems can often be modeled as CSP (or constraint optimization problem, COP)
Scheduling – Example

Given

- 3 machines, \( M_i \), \( i = 1, ..., 3 \);
- 9 jobs, \( J_j \), \( j = 1, ..., 9 \).

The optimal allocation or assignment of jobs to machines over time

- subject to the precedence constraints

Most common objective
- Minimise the completion time of all jobs (i.e. makespan)
Solving CSP/COP – Approaches

- **Constraint programming techniques**
  - Systematic search on search trees + constraint based techniques
  - Content of “Constraint Logic Programming” G53CLP
  - Based on basic search techniques on search tree
    - Part of content of “Introduction to AI” G51IAI

- **Artificial intelligence search algorithms**
  - “move” within search space to promising solutions
  - Content of “Planning & Search” G52PAS
Solving CSP/COP – Approaches

Four criteria to evaluate how good search techniques are

- Completeness
- Time complexity
- Space complexity
- Optimality
Solving CSP/COP – Approaches

AI Search algorithms

- Not complete
- Not guarantee to find (optimal) solution
- Work well on large scale problems (when good enough rather than optimal solutions are needed)
- Usually difficult to evaluate time and space complexity

- Based on *search space* of possible solutions approachable by neighborhood “moves”
  - Partially explored by searching algorithms
Solving CSP/COP – Approaches

AI Search algorithms

- Start (usually) from complete solutions
- Modify the solutions by changing and accepting the new solution
- Return the best/satisfactory solution
Solving CSP/COP – Approaches

- AI Search algorithms
  - Search space
    - all possible solutions approachable by neighborhood moves
  - Neighborhood moves
    - operators that modify values of certain elements in complete solutions
Solving CSP/COP – Approaches

- AI Search algorithms

- Search space
  - all possible neighborhood

- Neighborhood
  - Operators that modify values of certain elements
Solving CSP/COP – Approaches
Solving CSP/COP – Approaches

**AI Search algorithms**

- **Simulated Annealing**
  - accept worse solutions by probability, which is higher at the beginning and lower at the end of the search

- **Tabu Search**
  - use memory to remember previous moves, so as not to go back revisit visited solutions
Solving CSP/COP – Approaches

- AI Search algorithms
  - Genetic Algorithms
    - simulate the evolution process by crossover and mutation within populations of individuals (solutions)
  - Ant Algorithms
    - use pheromone as guidance of search towards promising and better solutions
Solving CSP/COP – Approaches

- Constraint programming techniques
  - It is complete
  - Guarantee to find the (optimal) solution(s) if one exists
  - Computational time and space may be expensive for large scale problems

- Based on systematically organised search tree consists of all solutions
Solving CSP/COP – Approaches

- Constraint programming techniques
  - Search tree
  - All possible solutions systematically organised and explored
Constraint Programming

- We’ll concentrate on CP in this module
  - Theory of CP (lectures)
  - Practical of CP (case study and exercises in ILOG Solver using OPL)
  - Research on constraint based scheduling

- Slight touch on AI search algorithms and scheduling
  - To build the context among different modules in the school

- Recent research
  - hybridise AI search algorithms with constraint based techniques
Summary

- Scheduling problem
  - Definition
  - Approaches
    - CP
    - AI search algorithms