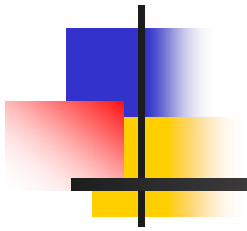
Summer School Course, Xi'an Jiaotong University, July 2009



Constraint Programming

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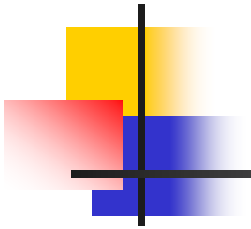
Overview of the Course

The University of Nottingham

ASAP Group, The University of Nottingham

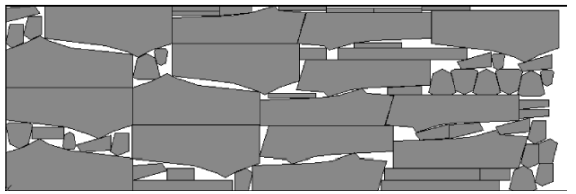


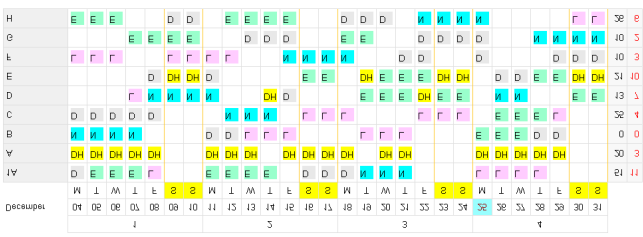
Research in ASAP Group

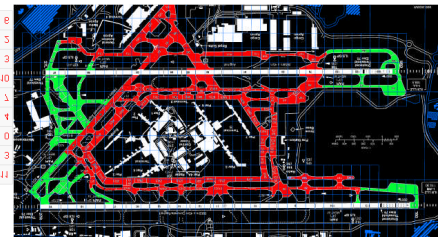
- Meta-heuristics
  - evolutionary algorithm, tabu search, simulated annealing, variable neighbourhood search, particle swarm optimization, immune systems, hyper-heuristics, etc
  - multi-objective, fitness landscape analysis
- Decision support systems
  - case based reasoning, knowledge based systems, etc
- Constraint Programming
- OR optimization
  - integration of IP/ILP/MIP with meta-heuristics
  - modelling

Research in ASAP Group

- Personnel scheduling (nurse rostering, etc)
- Educational timetabling
- Bin packing
- Multicast network routing
- Computational finance (portfolio optimization)
- Graph colouring
- Job shop scheduling
- Space allocation
- ...







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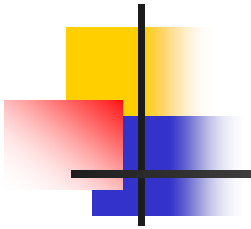
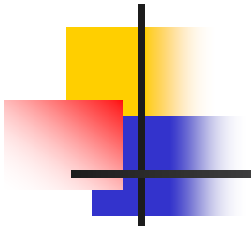


Research in ASAP Group

- **M**ulti-Disciplinary **I**nternational **S**cheduling conference: **T**heory and **A**pplications (MISTA bi-annual conferences)
- **P**ractice and **T**heory of **A**utomated **T**imetabling (PATAT bi-annual conferences)
- EURO **W**orking Group on **A**utomated **T**ime-**T**abling (WATT)

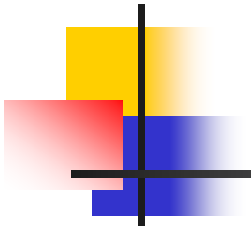
- ***Journal of Scheduling***, impact factor: 1.0

- IEEE Congress on Evolutionary Computation (CEC'2010), Barcelona
- 2011 IEEE Symposium on Computational Intelligence in Scheduling, Singapore



Course Schedule

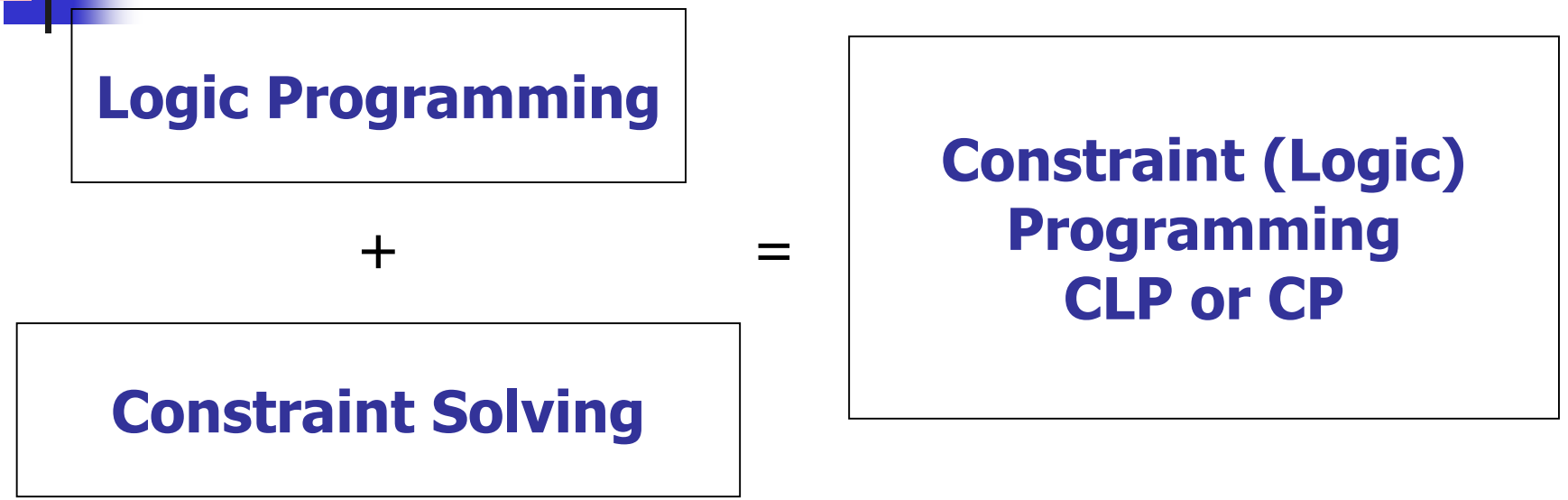
- Lectures 1 & 2 **Introduction**
  - Introduction to constraint programming, constraint satisfaction problems, and constraint based scheduling
- Lectures 3 & 4 **Basics**
  - Modelling scheduling problems in CP, basic techniques
- Lectures 5 & 6 **Constraint Propagation**
  - Constraint propagation and its application in constraint based scheduling
- Lectures 7 & 8 **Advanced techniques**
  - Consistency checks, search strategies, ordering heuristics



Course Schedule

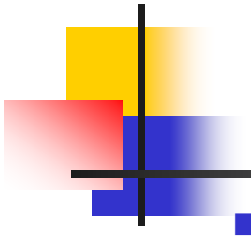
- Lectures 9 & 10 **Research in CBS**
  - Search in constraint based scheduling, current research
- Lectures 11 & 12 **Modeling & COP**
  - Modelling AI puzzles, demos, and constraint optimization problems
- Course web page
  - http://www.cs.nott.ac.uk/~rxq/xjtu.htm
  - Lecture slides
  - Textbooks
  - Extra reading materials

Constraint Logic Programming



These ideas were unified under a common conceptual and practical framework, constraint programming

Constraint programming is not restricted to CLP



Logic Programming

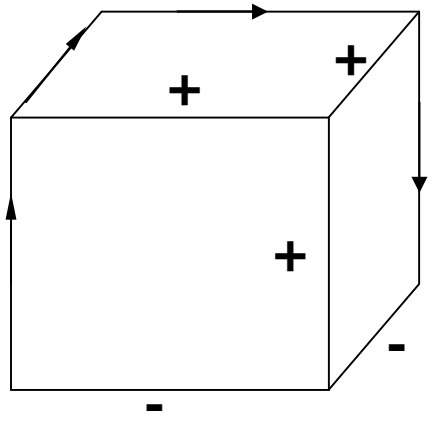
- Procedural: Sequences of instructions
  - how problem is solved and what the solution is
  - languages: C; Pascal; C++
- Declarative: State the logic of the problem
  - interested in only what the solution is
  - languages: Logic (Prolog); CP

- PROgramming in LOGic: PROLOG
  - brings logic into computer programs
  - express specifications for *problem solving* in formal logic: relations + logical variables
  - problems expressed in terms of high level descriptions;
  - emphasis on "what is true", "what needs to be done" rather than "how to do"

Constraint Solving

- Arose from AI & computer graphics in 1960s, 1970s

- Constraint satisfaction
  - Solve problems by exploring constraints which must be satisfied by the solution
  - Set of variables taking values within domains satisfying constraints



Constraint Logic Programming

- 1987 **CLP** Jaar & Lassez
  - Realised that logic programming is a type of constraint programming
- 1990 **CHIP** (Constraint Handling in Prolog)
  - First commercial tool
- 1990 **Prolog III** Colmerauer
- 1994 **ILOG Solver**
  - C++ library
  - Millions dollars revenue in 2005

```
  SEND
+ MORE
-------
 MONEY
```

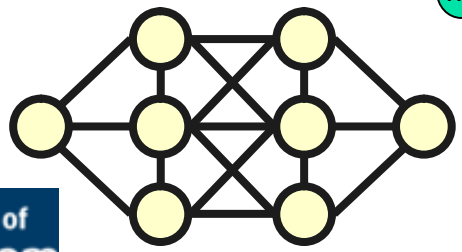
```
enum Letters {S, E, N, D, M, O, R, Y};

var int l[Letters] in 0..9;

solve {
   alldifferent(l) onDomain;
   //l[S] <> 0;
   //l[M] <> 0;

      1000*l[S] + 100*l[E] + 10*l[N] + l[D]
   +  1000*l[M] + 100*l[O] + 10*l[R] + l[E]
   =  10000*l[M] + 1000*l[O] + 100*l[N] + 10*l[E] + l[Y];
};
```

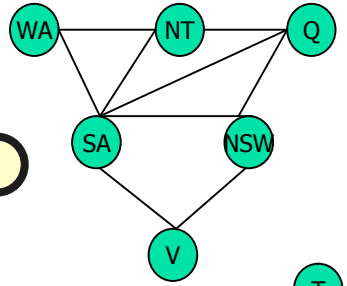
Constraint Programming

"… ***the user states the problem, the computer solves it***."

Eugene C. Freuder

- ***User states the problem***
  - N-queen problem, Sudoku, Cryptarithmetic
  - Graph coloring, Scheduling, Timetabling, Knapsack
  - Real world examples:
    - Lufthansa (Daysy): personnel planning after air traffic disturbances
    - Nokia: automatic configuration of mobile phone software
    - Renult: production planning





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		2	8				9	3
					4		5	
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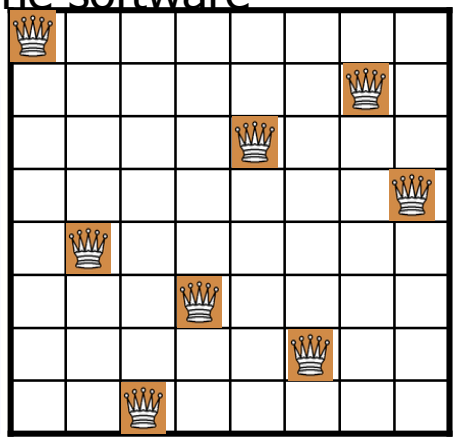
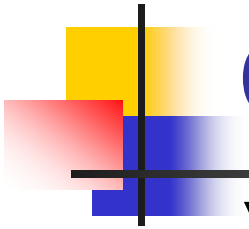




Constraint Programming

"... ***the user states the problem, the computer solves it***."

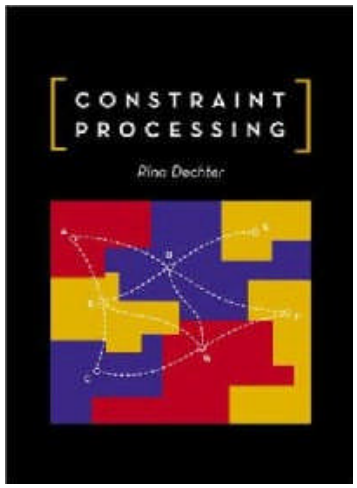
Eugene C. Freuder

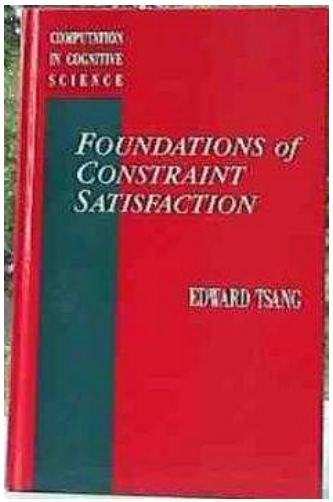
- ***Computer*** uses pre-defined algorithms to ***solve the problem***
  - Understand how algorithms work
  - Aim of this course!
  - Improve the search efficiency
    - Constraint propagation to assist decision making
    - Efficient search techniques, provided by constraint library or language

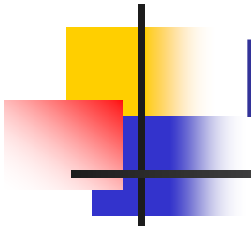
Textbooks

- Foundations of Constraint Satisfaction (Tsang), 1993
  - Online http://www.bracil.net/edward/FCS.html
  - Well written & easy to read

- Constraint Processing (Dechter), 2003
  - Online slides http://www.ics.uci.edu/~dechter/books/
  - Good for both beginners and advanced readers







References/Resources

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