Industrial Applications of Constraint Satisfaction

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Decision Making in Industrial Applications

- "Industry" has vast numbers of problems to solve.
- We shall define an Industrial Application as;
  - "a commercial application involving a degree of non-trivial complexity which can be addressed using software"
- Added dimension here: it should be suitable for CS techniques.

What is Does Industry Need?

- 5 Important Goals
  - Reduce Costs -> fewer resources
  - Increase Utilisation ->more business
  - Lower Management overhead
  - Increase Creativity -> new business models/processes
  - Reduce any environmental impact
- Constraint-based systems can help
  - Possible?
  - Optimal?
  - Real-time?
  - New Insight?

Examples of Inefficiency

- Container-based transport
  - 40% empty running in UK!
- Transport – routes planned manually
  - Costly to produce and inefficient (sub-optimal) outcomes
- Wine bottles – 500g each on average

Why is CS suited to solving Some Industrial Applications?

- Discrete domains
- Fast response times
- Logical & simple to implement
- Industrial standard toolkits available
  - ILOG CP Optimizer (see www.ilog.com)
- Bespoke algorithms which implement CS algorithms.
  - From simplest algorithms – BT & ACLA
  - To most complex stochastic hybrids
- Can use ***domain independent*** algorithms
  - Layered architectures which are important for software engineering

Example Application Domains

- HR Management
- Mobile Workforce Planning
- Configuration
- Production Line Scheduling
- Logistics

Human Resource Management

- Professional Services – e.g. accountancy
  - Tasks – e.g. VAT return, company audit
    - Requires resources, timescales, durations, multiple skill levels
  - As a CSP
    - Variables: <Resource, Time> tuples
    - Domains: tasks
    - Constraints: Time restrictions e.g. HMRC deadlines
  - Different views of the problem
    - More work with same staffing levels
    - Optimal size of the workforce
    - Minimize chargeable staffing for given tasks

Timetabling

- Timetabling
  - Course/Lecturer, Room, Time
  - Can formulate as CSP in many ways e.g.
    - Course is variable
    - <Room, Time> is domain
    - Constraints to prevent clashes
    - Constraints to prevent too many courses on a given day

Mobile Workforce Planning

- Task is to assign jobs to units of mobile workforce
  - Telephone engineers,
  - White goods engineers
  - Farm service providers
- Formulated as a CSOP:
  - Variables: Jobs at farms
  - Domains: Trucks
  - Constraints: Time windows
  - Optimisation criterion: Distance Travelled
- Demonstration

Logistics – A Journey Through the Supply Chain

- Supply chain;
  - "the network of retailers, distributors, transporters , storage facilities that participate in the sale, delivery and production of a particular product" (*investorwords.com*)
- Beginning to End there are many opportunities for using CS techniques
- Inbound vs Outbound
  - How to optimise products & materials coming in?
  - How to optimise products going out?
- Going to trace journey from buyer decisions in UK to Product arrival

The Base Journey

- Product – Stereo System
- Source (China) -> Destination (UK)

Stage 1: Assortment Planning

- A big issue for retailers
  - What to stock?
  - When to stock?
  - How much to stock?
  - What is the lead time?
  - What are the prices?

Stage 2: Manufacture

- Production Line Scheduling
  - Different models may have common operations
  - How to sequence production efficiently to fulfil orders
- Warehouse Management
  - Where to put what, efficient movement of stock
    - E.g. tescos & picking for home deliveries
- Shift Management
  - Staffing needs to be acceptable to employees and satisfy rules and regulations.

Stage 3: Outbound Logistics

- How to pack pallets? (Manufacturer)
  - E.g. Cape Pack (capesystems.com)
  - Maximise items on a pallet
    - Size/weight/orientation?
  - Speed of loading on pallets
- How to load containers – FCL/LCL
  - 20ft vs 40ft
  - From perspective of freight forwarder or the Logistics Service Provider
  - Plan now for unloading later – to warehouse or direct to customer?

Stage 4: Transportation to Port

- Route planning
- Haulage Company scheduling trucks
  - Plan the allocation of loads/routes
  - Schedule the trucks
  - Planning horizon etc.
  - Time windows to pick/drop
- Drive times (http:www.opsi.gov.uk/si/si2005/20050639.htm)
- Do we schedule all three together?
  - Would take much longer
- Uncertainty!
  - Puncture/sick driver – how robust are the plans?

Stage 5: At the Port I

- Ship Planning
  - Where to put a given container – a ship may have several stops
- Tugs on the docks used to move containers around the port
  - Route planning
  - Staff scheduling
- Crane scheduling
- Demurrage optimisation & Ship Scheduling
  - How much detail – too much makes intractable and fragile plans
  - Coarse plan with experience based margins gives a practical and robust solution

Stage 6: At the Port II

- When the ship arrives at the destination, many similarities
  - Main difference is planning of the use of space to store containers.

Stage 7: Transport to Warehouse

- Use of rail mode
- Train Timetabling
- Train crew shift planning
- Wagon Planning
  - Rules on weight, configuration of 20ft/40ft containers
  - 60ft per wagon

Stage 8: Arrival of goods

- Warehouse management
- Delivery – e.g. DHL, CityLink, UPS…

What to Solve and Why?

- Micro vs. macro planning
- Resilience
- Dynamic planning & scheduling
- How much time have we to solve it?

And there are many more!

- Satellite Operations Planning
- Airport Gate Planning
- Airport planning!
- Financial applications
- Games
  - See The Times supplements!
    - Solving and generation - Sudoku,KenKen...

Summary

- CS an important tool to any business solutions practitioner.
- It makes some solutions possible that would otherwise not have been
- Constraint-based element is often a key part of the overall system
- The problems are out there – get solving!