

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 is that it should be suitable for CS techniques.

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What 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?

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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

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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 architecture which are important for software engineering

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Example Application Domains

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

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Frequency Allocation

- Telecommunications industry
- Radio links in a network
- Task is to assign communication frequencies, F , to each link such that we avoid interference
 - $|F_i - F_j| > k_{ij}$ - These are the constraints
 - Variables: Radio links
 - Domains: the set of frequencies available to a given link
- Can be expressed as a simple CSP problem, but more useful:
 - Minimise number of frequencies used
 - Minimise maximum frequency used
- Well suited to CS techniques

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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

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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

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Mobile Workforce Planning

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

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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

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The Base Journey

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

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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?

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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. tesco's & picking for home deliveries
- Shift Management
 - Staffing needs to be acceptable to employees and satisfy rules and regulations.

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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?

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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?

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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

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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.

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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

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Stage 8: Arrival of goods

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

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What to Solve and Why?

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

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And there are many more!

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

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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!

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