Centre for
Data Analytics

Insight

CP: What is it good for?

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Acknowledgments

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`http://4c.ucc.ie/~hsimonis/ELearning/index.htm`
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Outline

What is the common element amongst

- The production of Mirage 2000 fighter aircraft
- The personnel planning for the guards in all French jails
- The production of Belgian chocolates
- The selection of the music programme of a pop music radio station
- The design of advanced signal processing chips
- The print engine controller in Xerox copiers

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They all use constraint programming!

Constraint Programming - in a nutshell

- Declarative description of problems with
  - *Variables* which range over (finite) sets of values
  - *Constraints* over subsets of variables which restrict possible value combinations
  - A *solution* is a value assignment which satisfies all constraints
- Constraint propagation/reasoning
  - Removing inconsistent values for variables
  - Detect failure if constraint can not be satisfied
  - Interaction of constraints via shared variables
  - Incomplete
- Search
  - User controlled assignment of values to variables
  - Each step triggers constraint propagation
- Different domains require/allow different methods

Constraint Satisfaction Problems (CSP)

- Different problems with common aspects
  - Planning
  - Scheduling
  - Resource allocation
  - Assignment
  - Placement
  - Logistics
  - Financial decision making
  - VLSI design

Characteristics of these problems

- There are no general methods or algorithms
  - NP-completeness
  - Different strategies and heuristics have to be tested.
- Requirements are quickly changing:
  - Programs should be flexible enough to adapt to these changes rapidly.
- Decision support required
  - Co-operate with user
  - Friendly interfaces

Benefits of CP Approach

- Short development time
  - Fast prototyping
  - Refining of modelling
  - Same tool used for prototyping/production
- Compact code size
  - Ease of understanding
  - Maintenance
- Simple modification
  - Changing requirements
  - No need to understand all aspects of problem
- Good performance
  - Fast answer
  - Good results
  - Optimal solutions rarely required

Outline

Why these stories, and not others?

- Companies are not always eager to share
- Tool providers are not keen either
- Information only available under NDA
- Can be difficult to publish
- Either personal experience
- ..or published description
- Big difference between paper and fielded system

Overview

- Production sequencing
- Production scheduling
- Satellite tasking
- Maintenance planning
- Product blending
- Time tabling
- Crew rotation
- Aircraft rotation
- Transport
- Personnel assignment
- Personnel requirement planning
- Hardware design
- Compilation
- Financial problems
- Placement
- Cutting problems
- Stand allocation
- Air traffic control
- Frequency allocation
- Network configuration
- Product design
- Production step planning

Five central topics

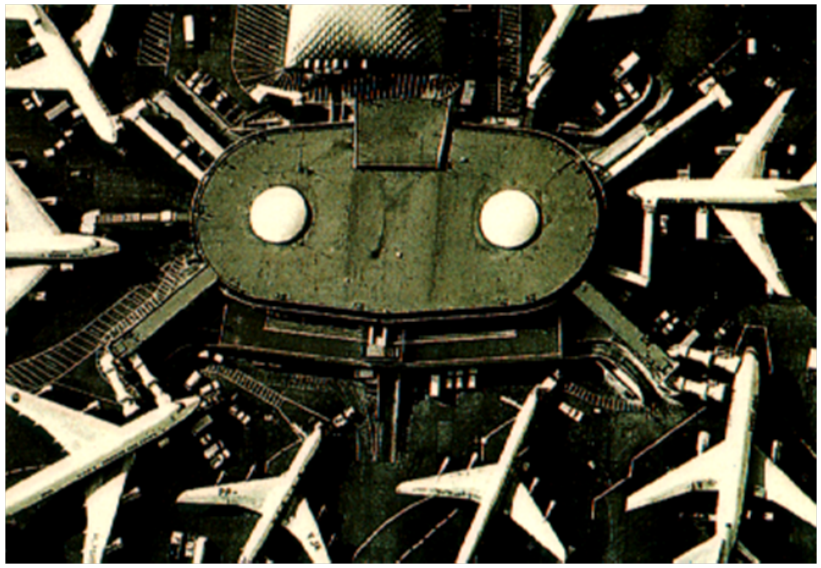
- Assignment
  - Parking assignment
  - Platform allocation
- Network Configuration
- Scheduling
  - Production scheduling
  - Project planning
- Transport
  - Lorry, train, airlines
- Personnel assignment
  - Timetabling, Rostering
  - Train, airlines

Stand allocation

- HIT (ICL)
  - Assign ships to berths in container harbor
  - Developed with ECRC's version of CHIP
    - Then using DecisionPower (ICL)
    - Early version of ECLiPSe
  - First operational constraint application (1989-90)
- APACHE (COSYTEC)
  - Stand allocation for airport
- Refinery berth allocation (ISAB/COSYTEC)
  - Where to load/unload ships in refinery

APACHE - AIR FRANCE (COSYTEC)

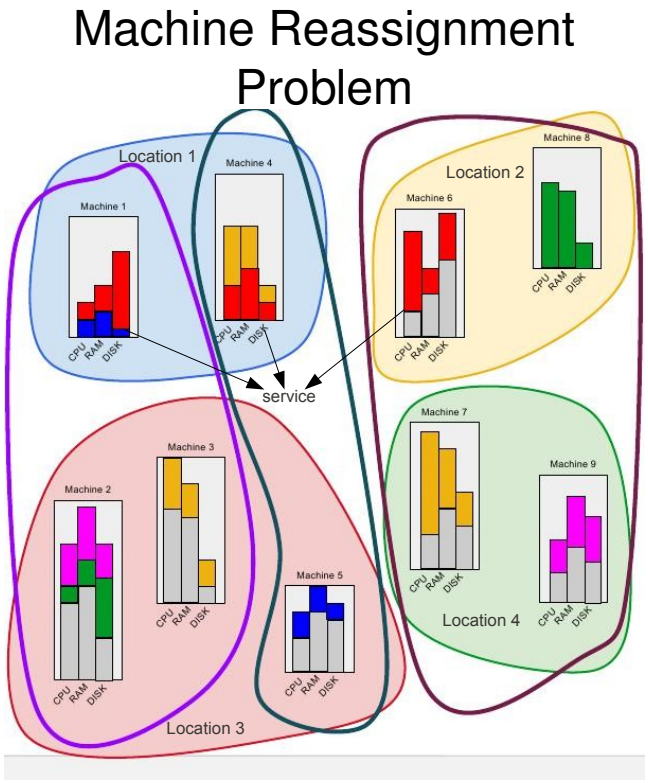
- Stand allocation system
  - For Air Inter/Air France
  - Roissy, CDG2
  - Packaged for large airports
- Complex constraint problem
  - Technical constraints
  - Operational constraints
  - Incremental re-scheduler
- Cost model
  - Max. nb passengers in contact
  - Min. towing, bus usage
- Benefits and status
  - Quasi real-time re-scheduling
  - KAL, Turkish Airlines



Current Example: Data Centre VM Reassignment

- ROADEF Challenge 2012
- Reassign VMs in data centres
- Reduce hotspots
- Preserve redunancy
- Our soluton uses LNS
- Second place overall

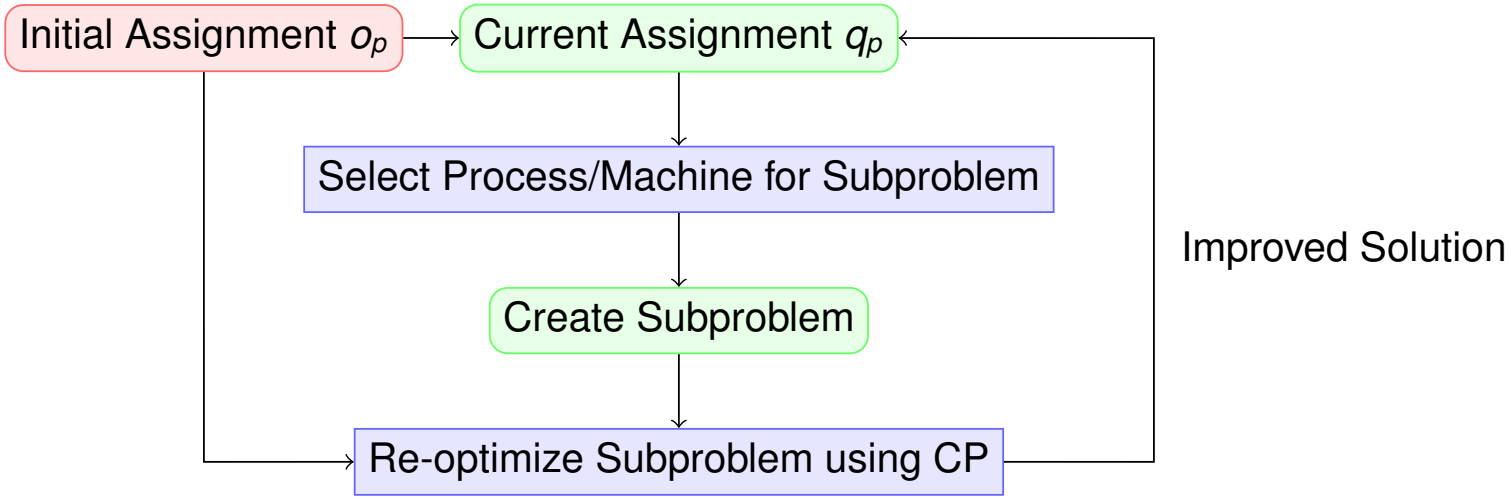
Roadef Challenge



Challenge Specific

No. of Machines	**5000**
No. of Processes	**50000**
No. of Resources	**20**
No. of Services	5000
No. of Locations	1000
No. of Neighborhoods	1000
No. of Dependencies	5000
Time limit	**300 seconds**
space limit	4GB RAM

Large Neighborhood Search



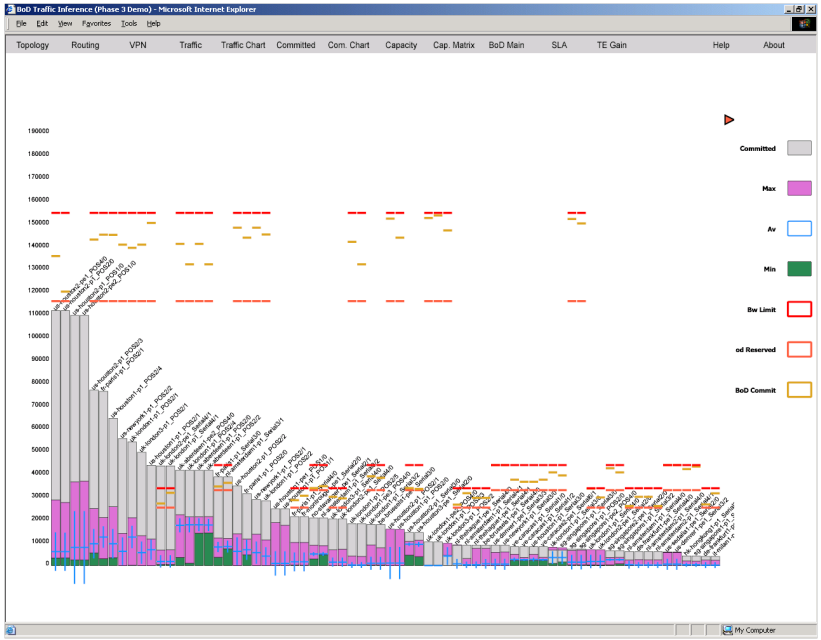
Current Example: Container Ship Loading

- CP 2009 (Delgado et al)
- Stack containers in ship to allow loading unloading in different ports
- Balance ship during loading/unloading
- Requirements for cooling/electricity supply
- No random access to stacks
- Weight/size limits on stacking

Network configuration

- BoD (PTL)
- Locarim (France Telecom, COSYTEC)
  - Cabling of building
- Planets (UCB, Enher)
  - Electrical power network reconfiguration
- Load Balancing in Banking networks (ICON)
  - Distributed applications
  - Control network traffic
- Water Networks (UCB, ClocWise)

BoD - Schlumberger (IC-Parc/PTL)



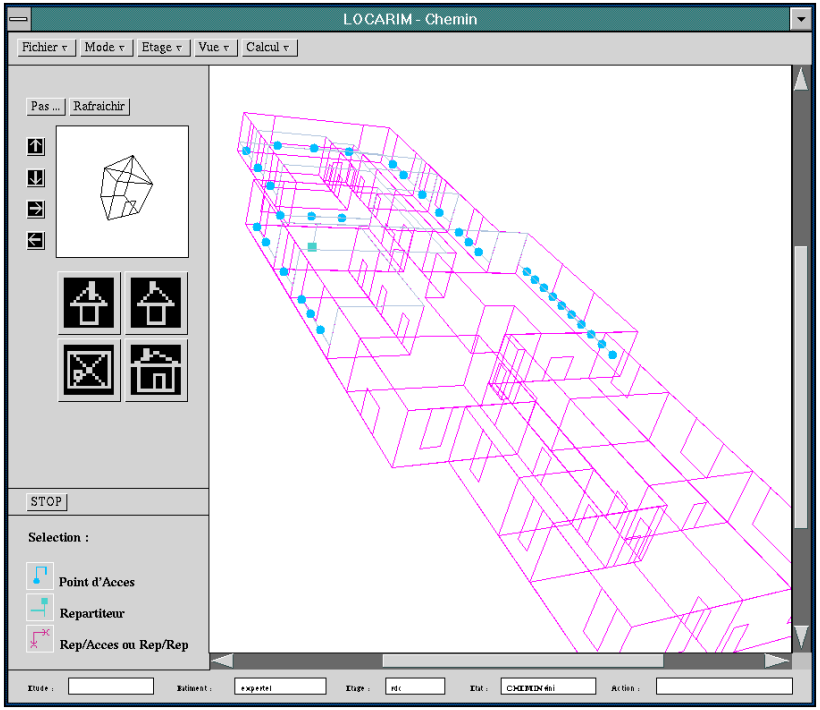
- Bandwidth on Demand
  - Provide guaranteed QoS
  - For temporary connections
  - Video conferences
  - Oil well logging
- World-wide, sparse network
- Bandwidth limited
- Do not affect existing traffic
- Uses route generator module for MPLS-TE
  - Model extended with temporal component
- First version delivered February, 2003

ISC-TEM - Cisco Systems

- Traffic Engineering in MPLS
- Find routes for demands satisfying bandwidth limits
- Path placement algorithm developed for Cisco by PTL and IC-Parc (2002-2004)
- Internal, competitive selection of approaches
- Strong emphasis on stability
- Written in ECLiPSe
- PTL bought by Cisco in 2004
- Part of team moved to Boston

LOCARIM - France Telecom

- Intelligent cabling system
  - For large buildings
  - Developed by
    - COSYTEC
    - Telesystemes
- Application
  - Input scanned drawing
  - Specify requirements
- Optimization
  - Minimize cabling, drilling
  - Reduce switches
  - Shortest path
- Status
  - Operational in 5 Telecom sites
  - Generates quotations

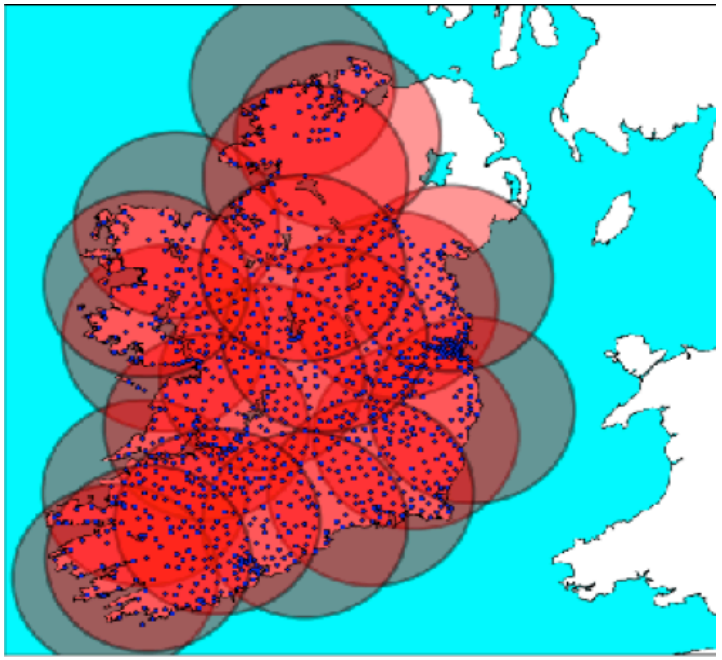


Current Example: Future Internet Design

- FP7 project DISCUS
- O'Sullivan et al
- End-to-end optical networks for future Internet design
- Two key problems
  - Metro node placement
  - Core network topology

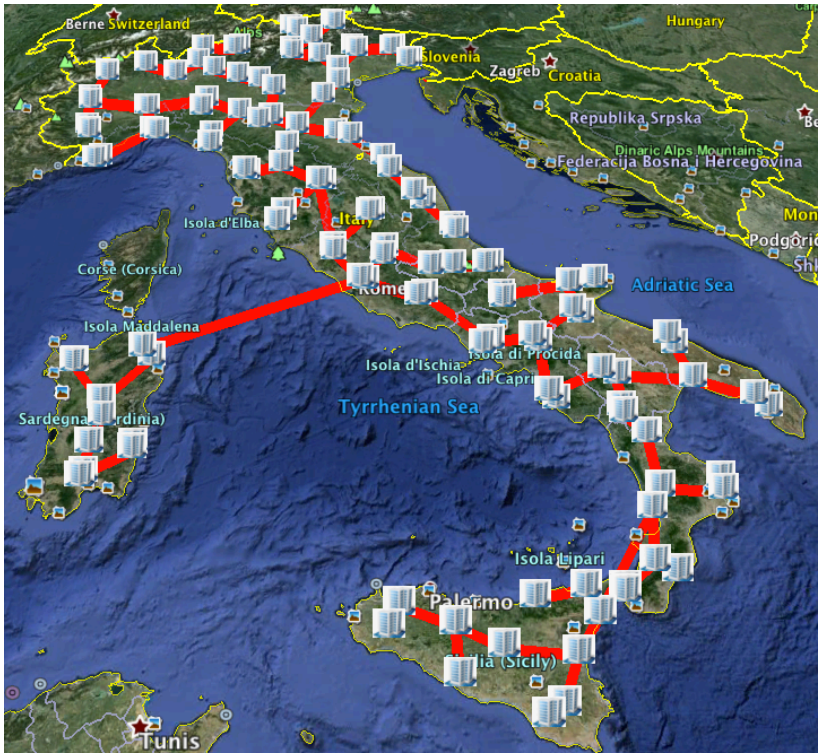
Metro node placement

- Fibre to the premise
- Cover country by metro nodes
- Distance to end-users limited to achieve high throughput
- Redundant connection of each customer to two metro nodes



Topology Design

- Select links to form connected topology
- Starting with minimum spanning tree
- Limited diameter (fibre/speed constraints)
- Add extra links to improve throughput

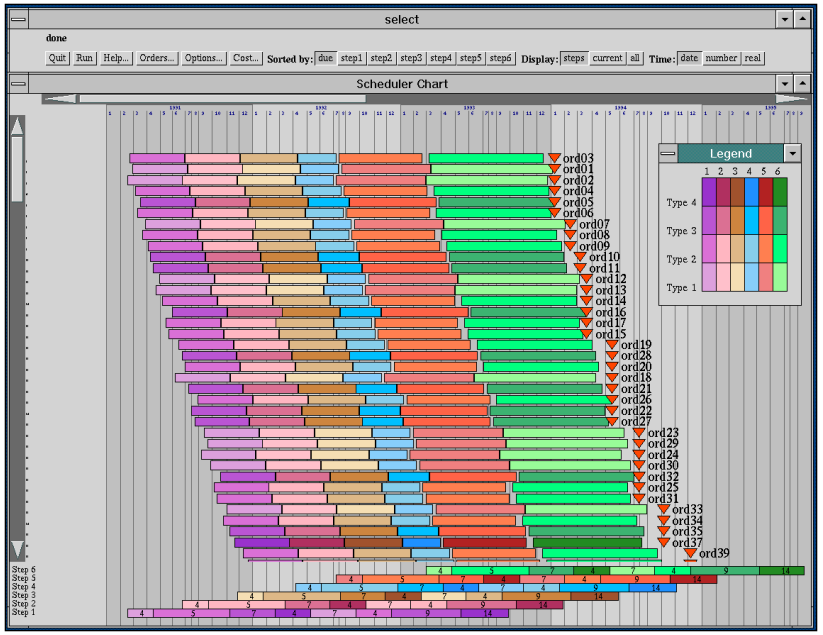


Production Scheduling

- Amylum (OM Partners)
  - Glucose production
- Cerestar (OM Partners)
  - Glucose production
- Saveplan (Sligos)
  - Production scheduling
- Trefi Metaux (Sligos)
  - Heavy industry production scheduling
- Michelin
  - Rubber blending, rework optimization

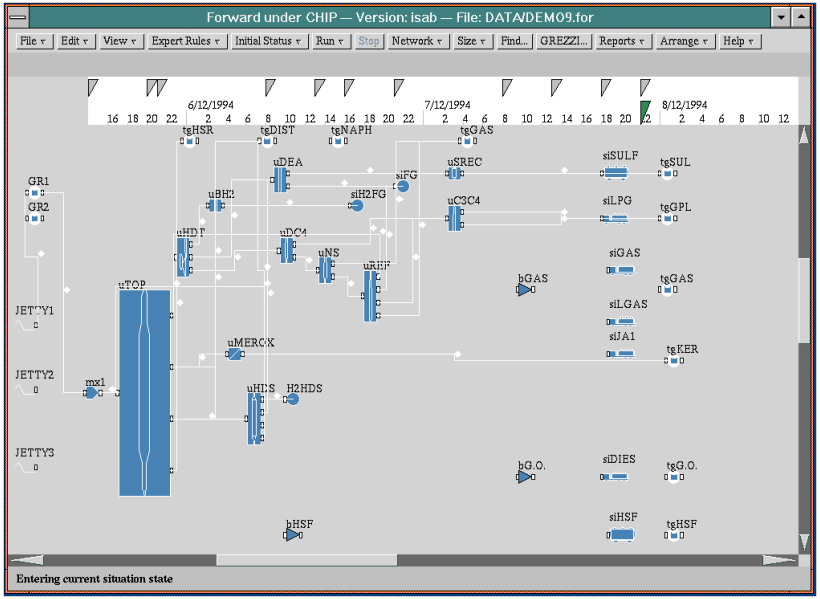
PLANE - Dassault Aviation

- Assembly line scheduling
  - Mirage 2000 Fighter
  - Falcon business jet
- Two user system
  - Production planning 3-5 years
  - Commercial what-if sales aid
- Optimisation
  - Balanced schedule
  - Minimise changes in production rate
  - Minimise storage costs
- Benefits and status
  - Replaces 2 week manual planning
  - Operational since Apr 94
  - Used in US for business jets

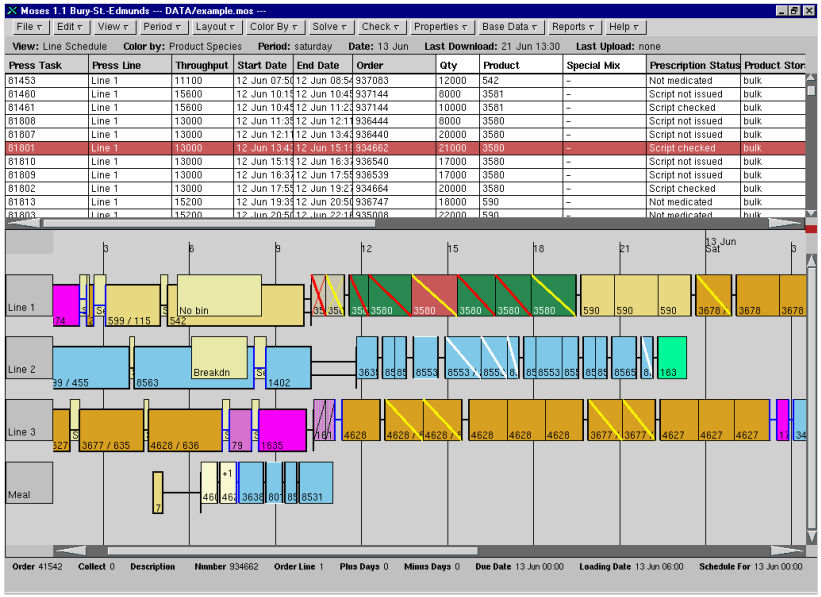


FORWARD - Fina

- Oil refinery scheduling
  - Developed by
    - TECHNIP
    - COSYTEC
  - Uses simulation tool
    - Forward by Elf
- Schedules daily production
  - Crude arrival $\rightarrow$
  - Processing $\rightarrow$ Delivery
  - Design, optimize and simulate
- Product Blending
  - Explanation facilities
  - Handling of over-constrained problems
- Status
  - Operational since June 94
  - Operational at FINA, ISAB, BP



MOSES - Dalgety



- Animal feed production
  - Feed in different sizes
  - For different species
  - Human health risk
    - Contamination
    - BSE
  - New strict regulations
- Constraints
  - Avoid contamination risks
  - Machine setup times
  - Machine choice (quality/speed)
  - Limited storage of finished products
  - Very short lead times (8-48 hours)
  - Factory structure given as data
- Status
  - Operational since Nov 96, still running in 2010

Current Example: Long Term Investment Strategy

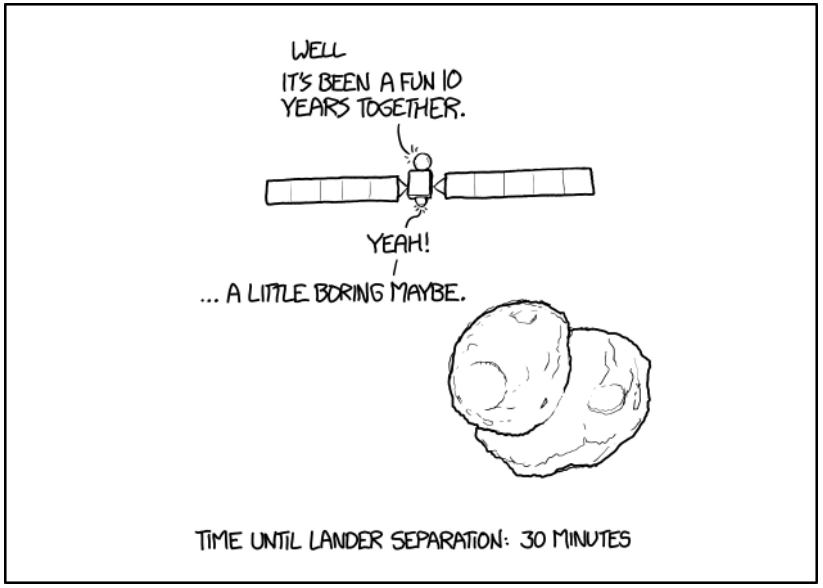
- CP 2012, CPAIOR 2012
- Australian mining companies
- Resource-constrained project scheduling over 10-20 years
- Discounting investment choices

Current Example: Hunter Valley Coal Chain

- CPAIOR 2014
- Port of Newcastle, NSW
- Trains deliver coal to harbour
- Picked up by large bulk carriers
- Stockyard management

Scheduling Rosetta/Philae Experiments

- CP 2012, best application paper
- Simonin et al
- Which experiments to run when on philae lander
- Limited data storage, two stage transmission to earth
- Limited power
- Dependant on exact orbit of Rosetta
- Communications lag



Transport

- By Air
  - AirPlanner (PT)
  - Daysy (Lufthansa)
  - Pilot (SAS)
- By Road
  - Wincanton (IC-Parc)
  - TACT (SunValley)
  - EVA (EDF)
- By Rail
  - CREW (Servair)
  - COBRA (NWT)

AirPlanner (IC-Parc)

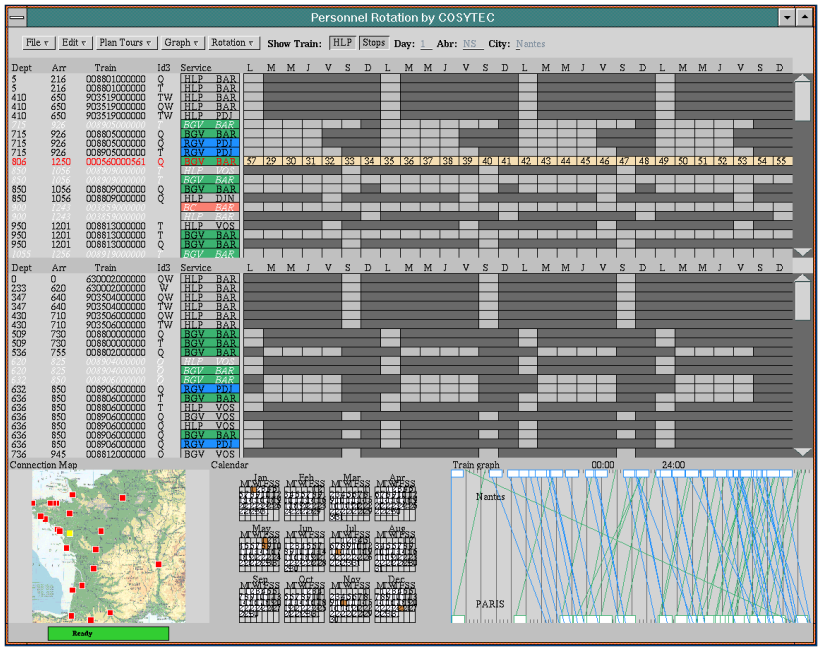
- Based on the Retimer project for BA
- Consider fleet of aircraft
- Shifting some flights by small amount may allow better use of fleet
- Many constraints of different types limit the changes that are possible

Wincanton (IC-Parc)

- Large scale distribution problem
- Deliver fresh products to supermarkets
- Direct deliveries/warehousing
- Combining deliveries
- Capacity constraints
- Tour planning
- Workforce constraints

CREW - Servair

- Crew rostering system
  - Assign service staff to TGV
  - Bar/Restaurant service
  - Joint design COSYTEC/GSI
- Problem solver
  - Generates tours/cycles
  - Assigns skilled personnel
- Constraints
  - Union, physical, calendar
- Status
  - Operational since Mar 1995
  - Cost reduction by 5%

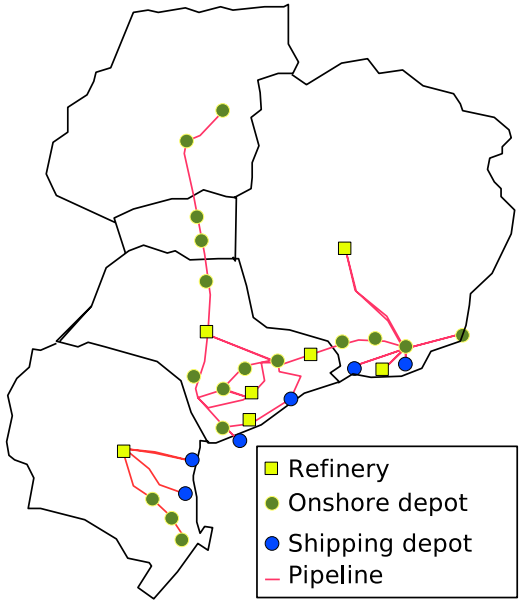


Current Example: Non-preemptive Evacuation Scheduling

- CP 2015 (VanHentenryck et al)
- Plan schedule of evacuation in major flooding
- Part of the road network is disabled by event
- Start evacuations in different zones at different times
- Avoid bottlenecks and delays
- Suggest new road connections to build

Current Example: Petrobras Oil Pipeline Network

- CP 2008, best application paper
- Moura et al
- Distribute oil products over pipeline network
- Physical transport, content of pipes
- Change of direction
- Some buffer storage available



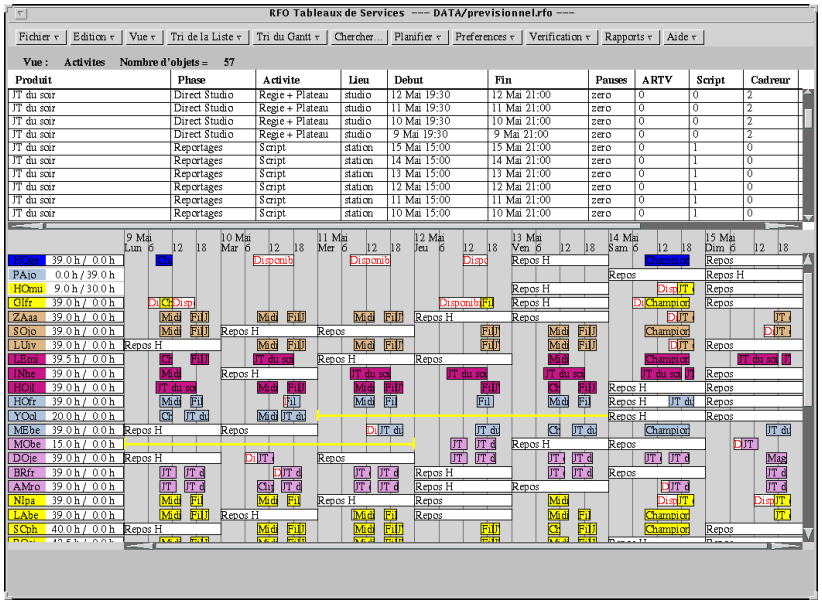
Personnel Planning

- RAC (IC-Parc)
- OPTISERVICE (RFO)
- Shifter (ERG Petroli)
- Gymnaste (UCF)
- MOSAR (Ministère de la JUSTICE)

RAC

- Personnel dispatching
- On-line problem
  - Change plan as new requests are phoned in
- Typical constraints for workforce
  - Duty time
  - Rest periods
  - Max driving time
  - Response time
- Operational/Strategic use

OPTI SERVICE - RFO



- Assignment of technical staff
  - Overseas radio/TV network
  - Radio France Outre-mer
  - Joint development:
    - GIST and COSYTEC
  - 250 journalists and technicans
- Features
  - Schedule manually,
  - Check, Run automatic
  - Rule builder to specify cost formulas
  - Minimize overtime, temporary staff
  - Compute cost of schedule
- Status
  - Operational since 1997
  - Developed into generic tool
  - Now main product of COSYTEC

Nurse Scheduling

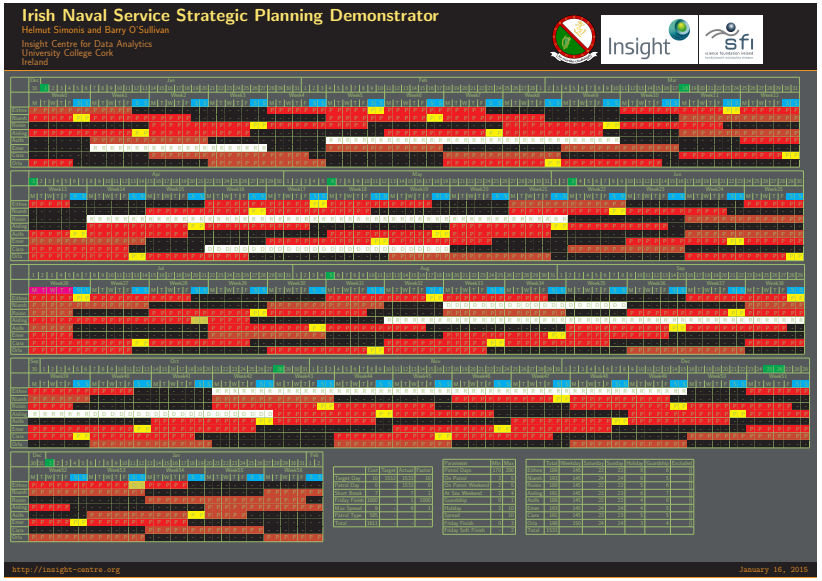
- GYMNASTE
- Time tabling
- Personnel assignment
- Provisional and reactive planning (1-6 weeks)
- Developed by COSYTEC with partners
  - PRAXIM/Université Joseph Fourier de Grenoble
- Pilot site Grenoble
- Also used at hôpital de BLIGNY (Paris)
- Advantages :
  - Plan generation in 5 minutes
  - User/personnel preferences
  - Decrease in days lost

Current Example: IBM Workforce Management

- CP2010, best application paper
- IBM Haifa
- Find the best people to work on all projects of company
- Introduce “somedifferent” constraint
- Deployed with IBM Global Business Services

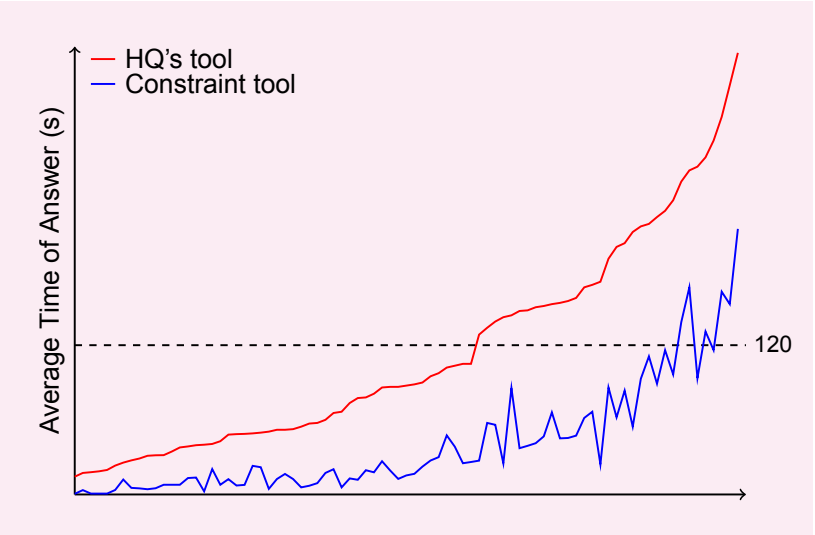
Current Example: Irish Naval Service

- Insight, unpublished
- Yearly rotation plan
- Within financial budget
- Perform required patrols
- Plan maintenance, refit, training
- Balance work load



Hydro-Quebec Callcentre Staffing

- CP 2014 (Pelleau et al)
- Large callcentre operator in Canada
- More diverse activities for staff: chat, email
- Forecasted demand
- Improved call-waiting times



Outline

Conclusions

- Constraint Programming useful for many domains
- Large scale industrial use in
  - Assignment
  - Network Management
  - Production Scheduling
  - Transport
  - Personnel Planning

Good approach for specialized, complex problems

- Disaster evacuation planning
- Power restoration for power grids
- 3D camera control in movie animation
- Finding instable control states for robots
- Test generation and scheduling for spray-paint robot cells
- Optimized register allocation in gcc
- Optimal wine blending

Key advantages

- Easy to prototype/develop
- Using modelling to understand problem
- Expressive power
- Add/remove constraints as problem evolves
- Customized search exploiting structure and knowledge

More Information

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