Chapter 3: Application Overview

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ECLiPSe ELearning

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This work is licensed under the Creative Commons Attribution-Noncommercial-Share Alike 3.0 Unported License. To view a copy of this license, visit http://creativecommons.org/licenses/by-nc-sa/3.0/ or send a letter to Creative Commons, 171 Second Street, Suite 300, San Francisco, California, 94105, USA.
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

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**

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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 CLP 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
Introduction

Success Stories for Constraint Programming

Conclusions

Assignment
Network Management
Scheduling
Transport
Personnel Planning

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

Tools Used (Prolog Based Constraint Languages)

- CHIP
  - 1986-1990 ECRC, Munich, Germany
  - 1990-today COSYTEC, Orsay, France
- ECLiPSe
  - 1984-1996 ECRC
  - 2004-today Cisco Systems
  - a.k.a. Sepia (ECRC)
  - a.k.a. DecisionPower (ICL)
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

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)
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**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

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**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

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 → Processing → 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
  - 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

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%

Personnel Planning

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

Assignment of technical staff
  Overseas radio/TV network
  Radio France Outre-mer
  Joint development:
    GIST and COSYTEC
    250 journalists and technicians
Features
  Schedule manually,
  Check, Run automatic
  Rule builder to specify cost formulas
  Minimize overtime, temporary staff
  Compute cost of schedule
Status
  Operational since 1997
  Installed worldwide in 8 sites
  Developed into generic tool
Nurse Scheduling

- GYMNSTA
e - 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

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

- 3D camera control in movie animation
- Finding instable control states for robots
- Optimized register allocation in gcc

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
Mark Wallace.  
Practical applications of constraint programming.  

Helmut Simonis.  
Building industrial applications with constraint programming.  

Helmut Simonis.  
Models for global constraint applications.  