Chapter 3: Application Overview

Helmut Simonis
Cork Constraint Computation Centre
Computer Science Department
University College Cork
Ireland

ECLiPSe ELearning
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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
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
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
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)
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
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
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
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
- Installed in 5 mills
By Air
- AirPlanner (PT)
- Daysy (Lufthansa)
- Pilot (SAS)

By Road
- Wincanton (IC-Parc)
- TACT (SunValley)
- EVA (EDF)

By Rail
- CREW (Servair)
- COBRA (NWT)
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
- 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
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
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.

Helmut Simonis.
Building industrial applications with constraint programming.