

Constraint Programming: Introduction

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Constraint programming

- an alternative approach to programming
- interleaves reasoning and computing
- constraint: a relation on variables and their domains
- Constraint Satisfaction Problem (CSP): a set of constraints together with a set of variable domains

Constraint programming process

- modelling: formulate the problem with constraints as a CSP
- resolution: solve the CSP using constraint solvers
 - domain specific methods (Simplexe, Gröbner bases, ...),
 - generic methods (constraint propagation),
 - or a combination of methods (solver cooperation)

programming=modelling
focus on WHAT and not on HOW

Programming (modelling)

Different programming paradigms(host languages):

- imperative programming
Pascal, C,...
- functional programming
Lisp, Caml,...
- object-oriented programming
C++, Java,...
- logic programming
Prolog, Mercury,...

constraint programming

⇒ orthogonal to the programming paradigm

Solving

Solving CSPs can be:

- compute whether the CSP has a solution (is the CSP consistent?)
- find A solution
- find ALL solutions
- find THE optimal solution (global optimum)
- find A good solution (local optimum)

Constraint solvers: domain specific methods

Algorithms devoted to specific variables and specific constraints

- program for solving systems of linear equations,
- package for linear programming,
- implementation of the unification algorithm,
- Gröbner bases computation,
- Simplexe like techniques,
- local search methods (borderline)
- Gaussian elimination, ...

Constraint solvers: generic methods

general methods that can be adapted to several types of constraints and several types of variables

- constraint propagation algorithms
to repeatedly remove inconsistent values from domains of variables
- search methods
to explore the search space

Constraint programming: characteristics

- declarative programming: modelling
- flexible representation:
constraints can be added, removed, or modified
- a two phase programming process:
 - generation of a problem representation as a CSP
 - solution of it
- support in the form of built-in mechanisms:
 - features to declare/define objects
 - features to set/generate constraints over these objects
 - constraint solvers
 - constraint propagation algorithms
 - search techniques

Constraint programming: summary

"Constraint programming represents one of the closest approaches computer science has yet made to the Holy Grail of programming: the user states the problem, the computer solves it."

Eugene C. Freuder, CONSTRAINTS, Avril 1997

Constraint programming = 2 level architecture:

- a language component
(independant of the paradigm)
⇒ add/remove constraints to the constraint store
- a constraint solver component
solution of the problem by considering constraints in the store

Constraint programming: applications (1/2)

- operation research problems (optimization problems such as: scheduling, sequencing, resource allocation, timetabling, job-shop, traveling salesman, ...)
- electrical engineering (location of faults in circuits, circuit layout, verification of circuit design, ...)
- business applications (option trading)
- graphic systems (to maintain consistency of moving objects, computer-aided design, ...)
- molecular biology (search for patterns, 3D models of proteins, ...)

Constraint programming: applications (2/2)

- natural language (efficient parsers, speech recognition with semantics, ...)
- numerical computation (computation with guaranteed precision for chemistry, engineering, design, ...)
- internet (constrained web queries)
- ...