An introduction to Choco 3.0
an Open Source Java Constraint Programming Library

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16th September 2013
Outline

1. The Choco constraint solver
2. Inside Choco
3. Dealing with real world problems
4. The future of Choco
A solver for teaching and research

History

1999  a first CLAIRE impl. within the OCRE project
      an national initiative for an open constraint solver for both teaching
      and research (Nantes, Montpellier, Toulouse, Bouygues, ONERA)

2003  Choco 1.0 : a first Java implementation
      Portability, ease of use for newcomers, etc.
      Guillaume Rochart (Bouygues), Hadrien Cambazard (Grenoble INP)

2008  Choco 2.0 : a user-oriented version
      Separation between modeling and solving, more constraints.
      Charles Prud’homme (EMN), Hadrien Cambazard, Arnaud Malapert (Univ. Nice)

2013  Choco 3.0 : towards efficiency and reliability !
      Deep code refactoring, easy-to-use (and to maintain)
      Charles Prud’hui, Jean-Guillaume Fages (EMN), Xavier Lorca (EMN)
The Choco constraint solver

An open constraint solver

- Open (online source repository\(^a\), BSD license)
- Readable and flexible (designed for teaching and research)
- Efficient and reliable (solves real world problems)
- More than 60000 DL (2003-2013), worldwide
- Code: > 60k LOC, > 700 Classes

\(^a\) github.com/chocoteam/choco3
Academic users

- **In France:**
  - Universities: Nantes, Montpellier, Paris, Rennes, Toulouse, Clermont-Ferrand
  - Engineering schools: ENSTA, ENAC, École des Mines de Nancy, École des Mines de Nantes, ISIMA

- **Around the world:**
  - UK: University of Glasgow
  - Ireland: University of Cork
  - Canada: École Polytechnique de Montreal
Industrial users

- Big companies: Safran, Dassault, PSA
- Research agencies: ONERA, NASA
- Software and Integrators: Kls-Optim, alfaplan GmbH, Easyvirt, Hedera Technology, etc.
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A wide **variety of variable** paradigms:

- Integer variables
- Boolean variables
- Set variables
- Graph variables
- Real variables
More than **80 available constraints** in Choco:

- **Classical arithmetic constraints**: $=, \neq, <, \leq, >, \geq$.
- A large set of useful **global constraints**: AllDifferent, GlobalCardinality, NValue, Cumulative, Diffn, Occurrence, Element, Regular, Circuit . . .
- **Exclusive** constraints: Tree, CostRegular, Ibex . . .
- **Reified** constraints: any constraint can be reified.
Discrete-continuous hybridization

The Ibex global constraint:

- Handles numerous **non linear continuous expressions**
  
  $+, -, *, /, =, <, >, \leq, \geq, \min, \max, \text{abs, sqr, sqrt, exp, log, pow, cos, sin, tan, acos, asin, atan} \ldots$

- Can mix **integer and real** variables.
Choco natively supports explained constraints.

- Both generic and *ad hoc* explanations schemas
- Asynchronous and lazy computation, flattened or unflattened storage
- **Improve** resolution (CBJ, DBT, path repair, LNS)

Next steps:
- Providing **feedback** to the user
- Nogood recording / SAT Solver interaction
Search-related tools

Different kinds of use:
- Get a solution,
- Enumerate all solutions,
- Find an optimal solution

Predefined search methods:
- Built-in search strategies (DomWDeg, ABS, IBS, etc.)
- and some optimization procedures (LNS, fast restart, Last Conflict, etc.).
An intuitive user interface

Use of Factories to build a model:
- Variables: VariableFactory,
- Constraints: IntConstraintFactory, LogicalConstraintFactory, SetConstraintsFactory...
- Strategies: IntStrategyFactory, SetStrategyFactory...
Contestant within the MiniZinc Challenge (2012, 2013)
JSR-331 implementation (in progress)
CP-Viz interface
One-sheet documentation, teaching materials, articles, demo material (> 60 examples), etc.
The problem is to arrange \( k \) sets of numbers 1 to \( n \) so that each appearance of the number \( m \) is \( m \) numbers on from the last.

Ex: \( L(k = 3, n = 9) = 3 \ 4 \ 7 \ 8 \ 3 \ 9 \ 4 \ 5 \ 3 \ 6 \ 7 \ 4 \ 8 \ 5 \ 2 \ 9 \ 6 \ 2 \ 7 \ 5 \ 2 \ 8 \ 1 \ 6 \ 1 \ 9 \ 1 \)

```java
Solver s = new Solver("Langford");

IntVar[] p = VF.enumeratedArray("p", n*k, 0, k*n-1, s);
for (int i = 0; i < n; i++) {
    for (int j = 0; j < n*(k - 1); j+=n) {
        s.post(ICF.arithm(VF.offset(p[i+j], i+2), "=" , p[i+(j+n)]));
    }
}

s.post(ICF.arithm(p[0], "<", p[n*k-1]));
s.post(ICF.allDifferent(position, "AC"));

s.set(ISF.firstFail_InDomainMax(position));
s.findSolution();
```
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Dealing with real world problems

Attacking real world problems

- Entropy, Easyvirt, Hedera: data center management (VM placement),
- Vaberlin, GSD lab: software development, code generation,
- Safran, Dassault Aviation: mission planning,
- KLS Optim, Optilogistic: loading plans for vehicles and palettes,
- Biotrial, Maif: personal scheduling,
- Kosmos: timetabling for secondary schools,
- PSA: online car configuration (prototype),
They like

- Modeling (declarative, reliable),
- *Ad hoc* constraints (simplicity),
- Scalability (more than 100,000 VMs).

Issues

- Clear problem statement,
- Unaware of NP-hardness,
- Discrete-continuous hybridization,
- Multi-objective resolution.
Dealing with real world problems

Discussion

Few feedbacks from users
- only when they have trouble modeling a problem,
- or when there is a bug.
⇒ BSD license

Academic inconvenience
- Cannot provide professional support (heavy administration),
- Not interested in turnkey project (SQL, HMI) : AIMMS?
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Explanations:
- User-oriented explanations
- SAT Solver interaction
- Discrete-continuous bridge in practice
- Parallelization / distribution
- Robotic applications (Ibex)
Thank you for your attention!

Fathers

- Founding fathers: François Laburthe (Amadeus), Narendra Jussien (EMN, LINA)
- Funding fathers: École des Mines de Nantes, (Bouygues SA, Amadeus SA)