

Task scheduling for dual-arm industrial robots through constraint programming

MiniZinc modeling and solver comparison

Tommy Kvant

Institute of Computer Science
Lund University

February 12, 2015



Outline

1 Introduction

- YuMi®
- Project goal
- Job Shop Problem
- MiniZinc
- Solvers

2 Case Study

3 Model

- Filter

4 Evaluation

- Results



Introduction - YuMi®

- Dual-armed robot
- Flexible
- Fine motor skills



Photo: ABB

Introduction - Project goal



Introduction - Job Shop Problem



Introduction - MiniZinc



Criteria

- FlatZinc parser
- Free



Solvers Tested

- G12/FD
- JaCoP
- Gecode
- or-tools
- Opturion CPX
- Choco3



G12/FD

- G12 Team, NICTA
- Mercury
- Default solver for MiniZinc



JaCoP

- Java Constraint Programming solver
- Open Source
- Developed since 2001 - Krzysztof Kuchcinski & Radoslaw Szymanek
- Silver medal



Gecode

- C++
- Open Source
- Christian Schulte
- Parallel searches - utilising multiple cores
- All gold medals 2008-2012



Task scheduling for dual-arm industrial robots through constraint programming

└ Introduction

└ Solvers

└ Gecode

Gecode

- C++
- Open Source
- Christian Schulte
- Parallel searches - utilising multiple cores
- All gold medals 2008-2012

1. Christian Schulte: lett utvecklingen, många andra som bidragit
2. All gold medals 2008-2012: i alla kategorier

or-tools

- C++
- Google - Operational Research
- Open Source
- Utilising multiple cores
- Gold medals 2013-2014



Task scheduling for dual-arm industrial robots through constraint programming

└ Introduction

└ Solvers

└ or-tools

- C++
- Google - Operational Research
- Open Source
- Utilising multiple cores
- Gold medals 2013-2014

1. Utilising multiple cores: Inte säker om parallel sökning, nämns i dokumentationen som "parallel solving", explicit utesluten ur dokumentationen

Opturion CPX

- Opturion Pty Ltd
- Commercial
- SAT combo
- Gold medals 2013, all silver medals 2014



Task scheduling for dual-arm industrial robots through constraint programming

└ Introduction

└ Solvers

└ Opturion CPX

- Opturion Pty Ltd
- Commercial
- SAT combo
- Gold medals 2013, all silver medals 2014

1. Opturion Pty Ltd: Härstammar från G12
2. Commercial: kostar, akademisk licens
3. SAT combo: FD + SAT, SAT = satslogik, väldigt effektiv på att lösa stora problem, sägs att satslogik -*å* sökning inte slöas ner av stora domäner

Choco3

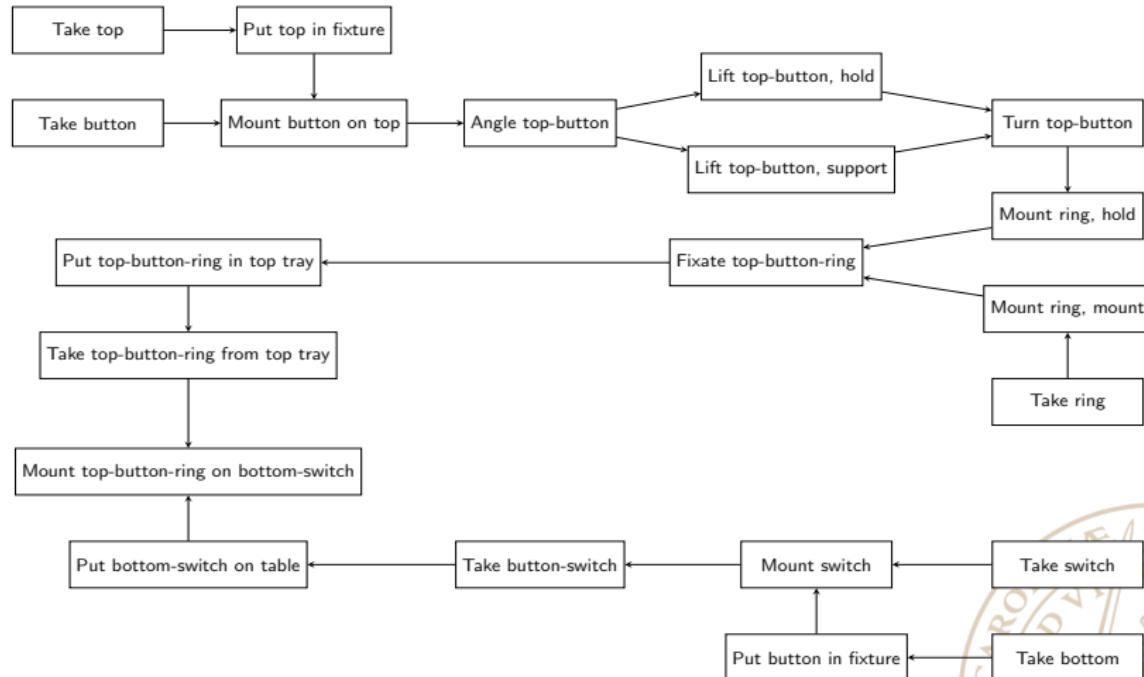
- Java
- Open Source
- Developed since early 2000 - Jean-Guillaume Fages & Charles Prud'homme
- Not same as predecessor Choco2



Case Study



Case Study



Model



Filter



Evaluation



Results

	Pred & Temp		Pred		Temp		None	
	1.6	2.0.1	1.6	2.0.1	1.6	2.0.1	1.6	2.0.1
G12/FD	-	-	-	-	-	-	-	-
JaCoP	658	-	1011156	-	-	-	-	-
Gecode	-	60	-	71761	-	99	-	70925
or-tools	271	!	380	!	302	!	457	!
Opturion CPX	-	!	-	!	-	!	-	!
Choco3	-	-	-	-	-	-	-	-