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ARTIFICIAL & NATURAL INTELLIGENCE TOULOUSE INSTITUTE

Knowledge Compilation

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An introductory example

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- A product configuration problem: designing a T-shirt
- Parameters:
  - Picture Men in Black (MiB) or Save the Whales (StW)
  - Color blue, red, black
  - Size S,M,L
  - Sleeves with or without
- Rules:
  - the MiB T-shirts must be black
  - the StW cannot be printed on size S
  - Size L T-shirts have sleeves
- The options proposed by the machine must be consistent with the rules

Formalizing the problem

- Configurable product
  $\rightarrow$ Constraint Satisfaction Problem (CSP)

  - The variables correspond to the choices points (Color, Picture, Size, Sleeves)
  - Constraints $\begin{cases} Picture = MiB & \Longrightarrow & Color = black \\ Picture = StW & \Longrightarrow & size > S \\ Size = L & \Longrightarrow & sleeves = yes \end{cases}$
  - A solution of the CSP = an admissible configuration

Formalizing the problem

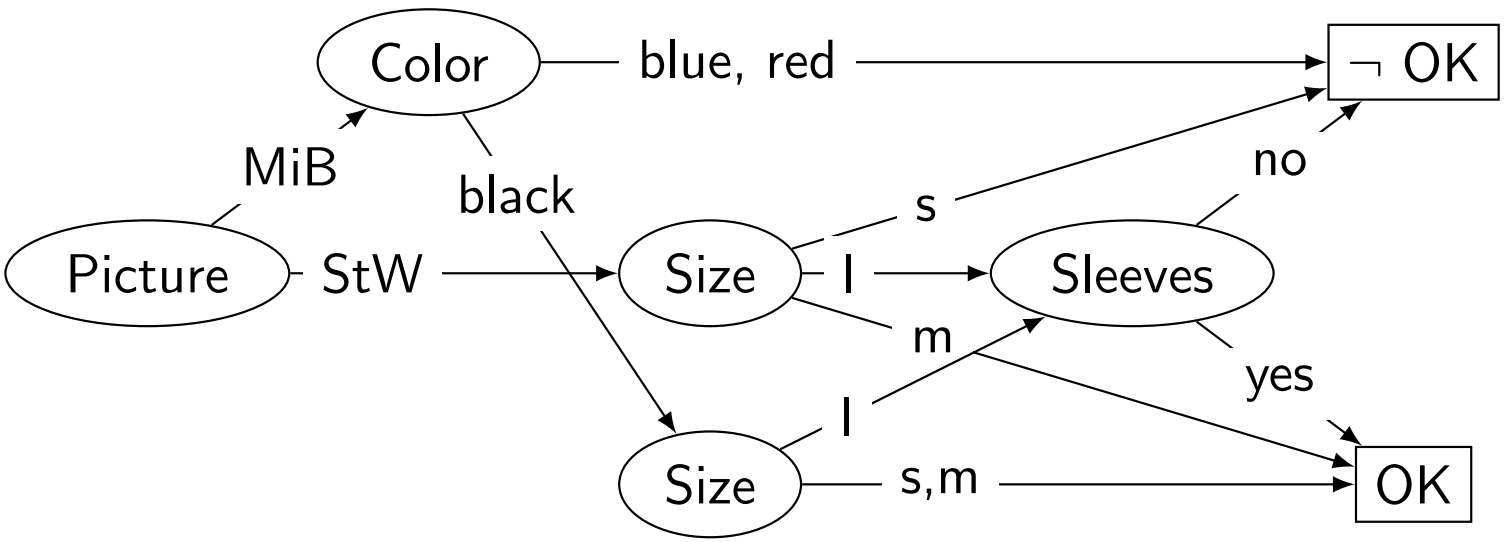
$$\begin{cases} Picture = MiB & \Longrightarrow & Color = black \\ Picture = StW & \Longrightarrow & size > S \\ Size = L & \Longrightarrow & sleeves = yes \end{cases}$$

- Interactive resolution of the CSP:
  - The user selects the next variable
  - The machine proposes values which guarantee the consistency at the next step (Color = blue $\Longrightarrow$ size L,M)
  - The user selects a value

- The second step is NP hard ... but the user cannot wait too long after each action

Compile!

The CSP is static, known in advance
Compile (off line !) the CSP into a more efficient data structure
(here, a decision diagram / deterministic automaton)



The detection of the globaly consistent values is linear in the size of the automaton

Knowledge Compilation

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Knowledge compilation consists in pre-processing some pieces of the available information in order to improve the computational efficiency (especially, the time complexity) of *some* tasks.

Some domains of application: configuration, diagnosis, reasoning, planning

Which Target Language ?

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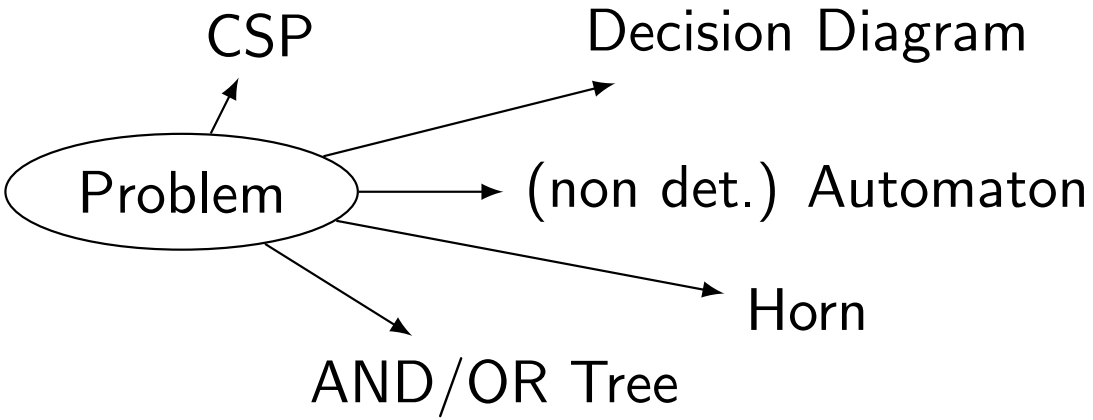
Which is the best target language for my application ?



- Draw a Compilation Map = compare the languages w.r.t.
  - the complexity of the operations
  - the succinctness of the languages
  - their expressivity

A compilation map (MDDs)

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Results about queries and transformations; $\surd$ means "satisfies" (polytime algo), $\bullet$ means "does not satisfy", and $\circ$ means "does not satisfy, unless P = NP". Brackets [·] denote a conjecture.

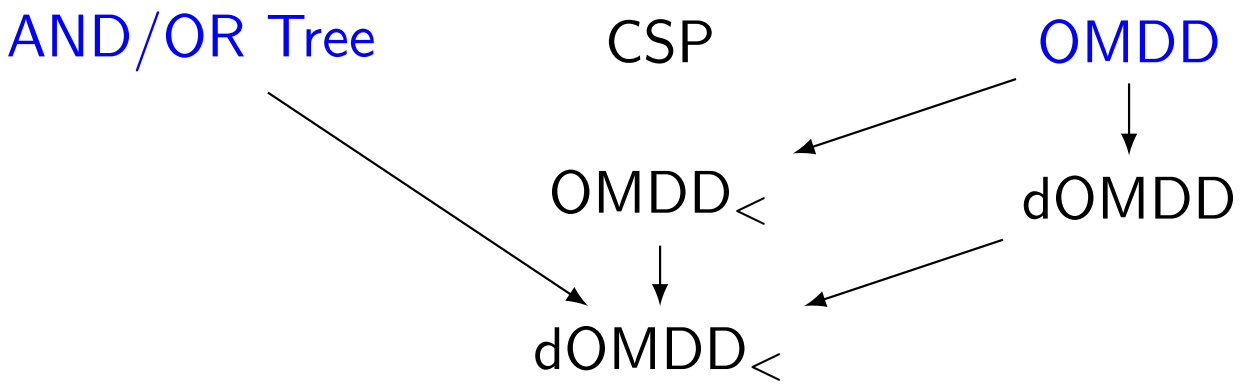
	CO	VA	MC	CE	IM	EQ	SE	MX	CX	CT	ME
CSP	$\circ$	$\circ$	$\surd$	$\circ$	$\circ$	$\circ$	$\circ$	$\circ$	$\circ$	$\circ$	$\circ$
Horn CSP	$\surd$	$\surd$	$\surd$	$\surd$	$\surd$	$\surd$	$\surd$	$\surd$	$\surd$	$\circ$	$\surd$
dOMDD$_<$	$\surd$	$\surd$	$\surd$	$\surd$	$\surd$	$\surd$	$\surd$	$\surd$	$\surd$	$\surd$	$\surd$
OMDD$_<$	$\surd$	$\circ$	$\surd$	$\surd$	$\circ$	$\circ$	$\circ$	$\surd$	$\surd$	$\circ$	$\surd$
OMDD	$\surd$	$\circ$	$\surd$	$\surd$	$\circ$	$\circ$	$\circ$	$\surd$	$\surd$	$\circ$	$\surd$
dOMDD	$\surd$	$\surd$	$\surd$	$\surd$	$\surd$	$\surd$	$\circ$	$\surd$	$\surd$	$\surd$	$\surd$
AND/OR tree	$\surd$	$\circ$	$\surd$	$\surd$	$\circ$	$\circ$	$\circ$	$\surd$	$\surd$	$\circ$	$\surd$

	CD	TR	FO	SFO	EN	SEN	C $>$	BC $>$	C $<$	BC $<$	C $\sqcap$
CSP	$\surd$	$\circ$	$\circ$	$\surd$	$\circ$	$\surd$	$\surd$	$\surd$	$\surd$	$\surd$	?
Horn CSP	$\surd$	?	$\surd$	$\surd$	$\circ$	$\circ$		!	!	!	!
OMDD$_<$	$\surd$	$\surd$	$\surd$	$\surd$	$\circ$	$\circ$	$\surd$	$\surd$	$\circ$	$\surd$	$\circ$
dOMDD$_<$	$\surd$	$\bullet$	$\bullet$	$\bullet$	$\bullet$	$\bullet$	$\bullet$	$\surd$	$\bullet$	$\surd$	$\surd$
OMDD	$\surd$	$\surd$	$\surd$	$\surd$	$\circ$	$\circ$	[$\circ$]	[$\circ$]	$\circ$	$\circ$	$\circ$
dOMDD	$\surd$	$\bullet$	$\bullet$	$\bullet$	$\bullet$	$\bullet$	$\bullet$	$\circ$	$\bullet$	$\circ$	$\surd$
AND/OR tree	$\surd$	?	$\bullet$	$\bullet$	$\circ$	$\circ$	$\bullet$	$\circ$	$\bullet$	$\circ$	$\bullet$

Succinctness

Results about succinctness;

$L \rightarrow L'$ means that L is exponentially more succint than L'.



Algorithms and benchmarks

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- Top-down compilers, bottom-up compilers
- Algos for the exploitation of the compiled form
- Random benchs (bof) $\mapsto$ structured / real life benchs (e.g. Renault's configuration problems, product lines,)

Beyond the Boolean KC map

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- State of the art in KC:
  - mainly boolean languages ($\text{Bool}^n \mapsto \text{Bool}$),
  - reasonning-oriented KC maps
  - off line compilers
- Extend KC to
  - preferences and/or uncertainties ($\text{Bool}^n \mapsto L \subseteq \mathbb{R}$)
  - non boolean languages (e.g. temporal CSPs, scheduling problems)
  - decision and optimization requests
  - fine grain complexity, FTP
  - learning tasks: sample complexity, VC dimension, on-the-fly compilation.

KC@ANITI chair: Objectives

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Develop compilation models and algorithms for the on line optimization of problems dealing with preferences/uncertainties, be the information quantitative (e.g. GAI nets, Bayesian nets, temporal CSPs) or qualitative (e.g. CP nets, logical approaches, point and interval algebra).

Research lines for the KC@ANITI Chair:

- Approximate compilation
- Compilation for involving numerical variables - e.g. temporal problems $\mapsto$ Heterogeneous KC maps
- Learning requests (sample complexity, VC dimension)
- Case studies

KC@ANITI chair: Members

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Helene Fargier (CNRS, PI): interested in extending the KnC approach to broader areas (e.g. preference,uncertainties, continuous domaines, temporal problems) and application domains (e.g. configuration, temporal planning).

Romain Guillaume (UT2J): plans to develop the use of knowledge compilation techniques in planning, logistics and scheduling.

Jerome Mengin (UPS): KC map dedicated to learning problems + compilation of preferences and uncertainties.

Cedric Pralet (ONERA): on-the-fly knowledge compilation and approximate compilation (as a way to enhance the efficiency of incomplete methods); application to problems from the aerospace field.

Associate members at EMAC (KC for design and configuration) ?

KC@ANITI chair: projects

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- Ph. D and Post Doc propositions:
  - KC for Incomplete Combinatorial Optimization Techniques (Ph. D)
  - Constraints Compilation for Satellite Design (Cifre)
  - From Machine Learning to Knowledge Compilation and Back (post doc)
  - Approximate Compilation for Preference and Likelihood Models (post doc)
- In link with:
  - ANR projects CAASC, PING ACK, PER4MANCE
  - Thomas Schiex's and Joo Marques-Silva's chairs (at least)
  - Beyond NP