The DMCS Solver for Distributed Nonmonotonic Multi-Context Systems

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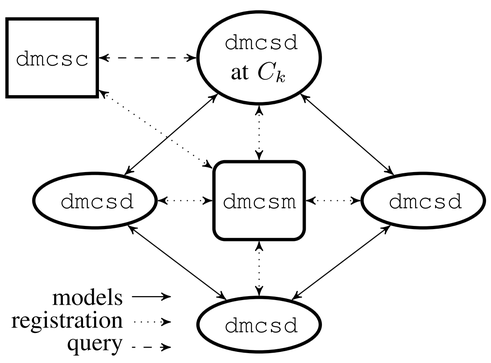
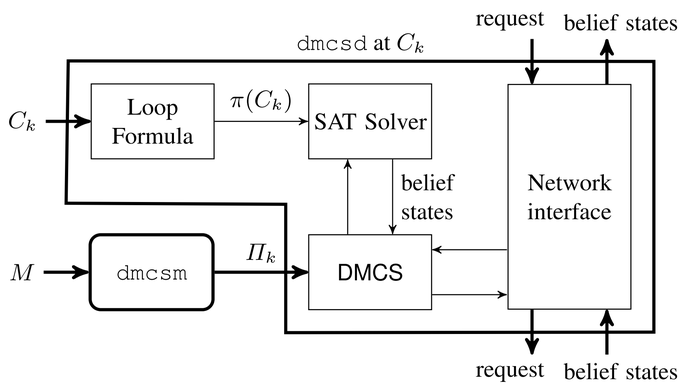
Multi-Context Systems

- A collection of contexts $(C_1, \ldots, C_n)$, interlinked by bridge rules
- Context $C_k = (kb_k, br_k)$: abstraction for knowledge based systems
  core notions: knowledge base kb_k, bridge rules br_k, accept. belief set
  hosts, e.g., default logic, classical logic, ASP, etc.
- Bridge rule adds information to context C_k
  ...depending on belief sets at other contexts.
- Example MCS $M = (C_1, C_2, C_3, C_4)$ with
  - $C_1 = (kb_1, br_1)$: $kb_1 = \emptyset$ and $br_1 = \{a \leftarrow (2:b), (3:c)\}$
  - $C_2 = (kb_2, br_2)$: $kb_2 = \emptyset$ and $br_2 = \{b \leftarrow (4:g)\}$
  - $C_3 = (kb_3, br_3)$: $kb_3 = \{c \leftarrow d; d \leftarrow c\}$ and $br_3 = \{c \vee e \leftarrow not\ (4:f)\}$
  - $C_4 = (kb_4, br_4)$: $kb_4 = \{f \vee g \leftarrow\}$ and $br_4 = \emptyset$
- Semantics in terms of equilibria of form $(S_1, \ldots, S_n)$:
  i.e., a belief set S_k for each context C_k which is compliant with applicable bridge rules.
- E.g., we get three equilibria for M
  - $(\{a\}, \{b\}, \{c, d, \neg e\}, \{\neg f, g\})$
  - $(\{\neg a\}, \{b\}, \{\neg c, \neg d, e\}, \{\neg f, g\})$
  - $(\{\neg a\}, \{\neg b\}, \{\neg c, \neg d, e\}, \{f, \neg g\})$

DMCS System Overview



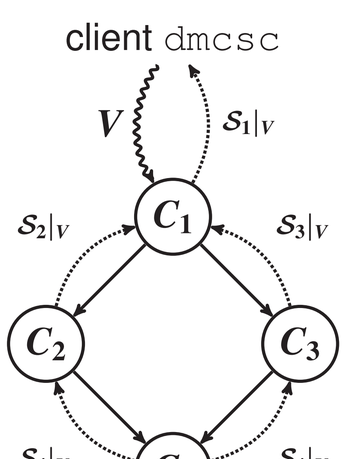


- Input language for declarative MCS specification
- Support for contexts formalized in ASP and SAT
- Computation of (partial) equilibrium semantics
- Sourcecode and Examples available at:

  `http://www.kr.tuwien.ac.at/research/systems/dmcs/`

Basic Evaluation of Distributed Multi-Context Systems

DMCS algorithm overview:



- Bridge rules generate a topology of M
- Upon query variables V, a context C_k:
  - checks if M is cyclic and guesses local beliefs wrt. V, otw. it
  - asks neighbors for partial equilibria
  - combines local belief sets with neighbor beliefs
- returns result S_k projected to V

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Loop Formulas for Multi-Context Systems

DMCS system translates ASP contexts to SAT using loop formulas

But: Equilibrium semantics needs special treatment

For each context C_k, we have

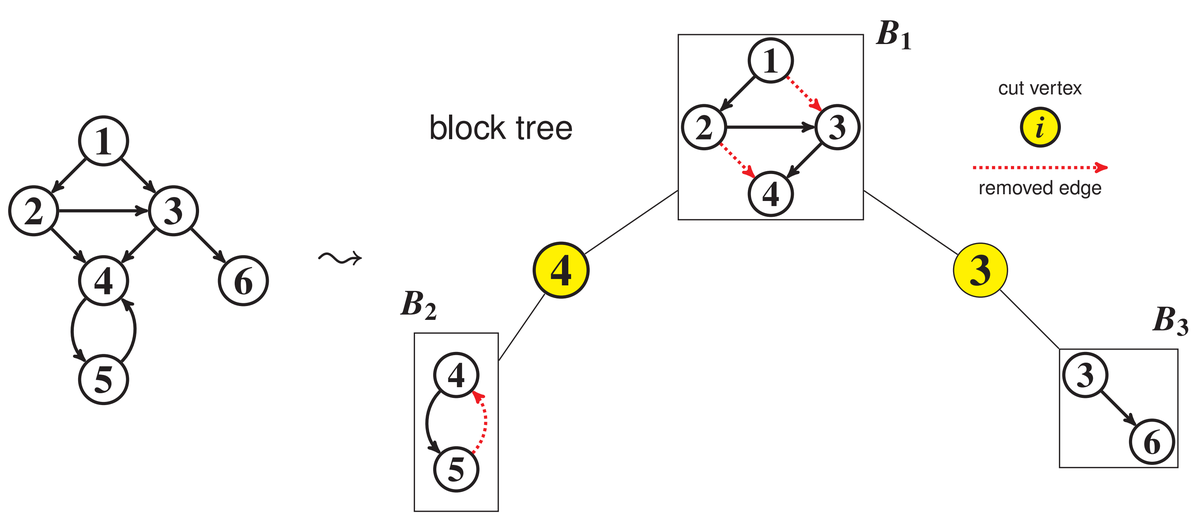
- completion and support formulas as usual
- for a loop $\mathcal{L}$ that is local to C_k, we add the externally supported rules of kb_k and the supported rules of br_k to the antecedent of the loop formula for $\mathcal{L}$

Standard SAT solvers can be used at each context to compute the partial equilibria independently

Decomposition of Multi-Context Systems

Optimization of MCS evaluation using a decomposition into the biconnected components of the topology:

- cut redundant paths in topology: transitive reduction and ear decomposition
- localize projected query variables to the minimum: forget belief sets of contexts below a cut vertex



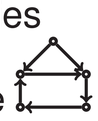
Adapted evaluation strategy using query plans: DMCSOPT

Experimental Results

	n	A_ϕ	$A_\bowtie$	$A_\leftrightarrow$	A_Σ (σ)	# (σ)	B_ϕ	$B_\bowtie$	$B_\leftrightarrow$	B_Σ (σ)	# (σ)
D	13	0.9	0.0	0.0	1.0 (0.2)	28 (17.6)	0.8	8.4	0.0	9.4 (5.5)	3136 (3155.8)
	25	11.2	0.5	0.0	12.8 (1.3)	17 (18.9)	—				
	31	51.1	3.7	0.0	59.5 (8.9)	58 (49.7)	—				
R	10	0.1	0.0	0.0	0.1 (0.0)	3.5 (3.4)	0.1	0.0	0.0	0.2 (0.1)	300 (694.5)
	13	0.1	0.0	0.0	0.2 (0.1)	6 (1.2)	0.1	1.5	1.9	3.9 (5.3)	5064 (21523.8)
	301	4.1	0.1	2.1	10.2 (2.2)	8 (4.9)	—				
Z	13	0.6	0.1	0.0	0.7 (0.2)	34 (41.8)	5.5	4.2	0.0	11.5 (4.0)	3024 (1286.8)
	151	8.9	22.3	0.4	32.2 (7.3)	33 (28.5)	—				
	301	21.6	99.5	1.7	124.3 (20.6)	22 (41.4)	—				
H	9	0.2	0.0	0.0	0.2 (0.0)	28 (44.4)	1.1	0.9	0.0	2.0 (1.3)	684 (1308.0)
	101	1.8	0.3	0.3	3.8 (1.0)	48 (76.6)	—				
	301	7.8	2.0	2.4	25.1 (8.7)	38 (34.2)	—				

Table: Runtime for DMCSOPT (A_x) and DMCS (B_x), timeout 180 secs (—)

Random instances with n contexts and topologies

Diamond  , Ring  , Zig-zag  , House 

Timings: SAT solver (ϕ), Belief state combination ($\bowtie$) and transfer ($\leftrightarrow$); No. of partial equilibria: #

References

- Minh Dao-Tran, Thomas Eiter, Michael Fink, and Thomas Krennwallner. Distributed Nonmonotonic Multi-Context Systems. In *KR*, pp. 60–70, 2010.
- Seif El-Din Bairakdar, Minh Dao-Tran, Thomas Eiter, Michael Fink, and Thomas Krennwallner. Decomposition of Distributed Nonmonotonic Multi-Context Systems. In *JELIA*, pp. 24–37, 2010.