Algorithms for Goal Analysis

— ONGOING WORK —

Paolo Giorgini
John Mylopoulos
Eleonora Nicchiarelli
Roberto Sebastiani

SUMMARY

- The problem
- A logical approach
- A numerical approach
- Future work

THE PROBLEM

GOAL dependency graphs

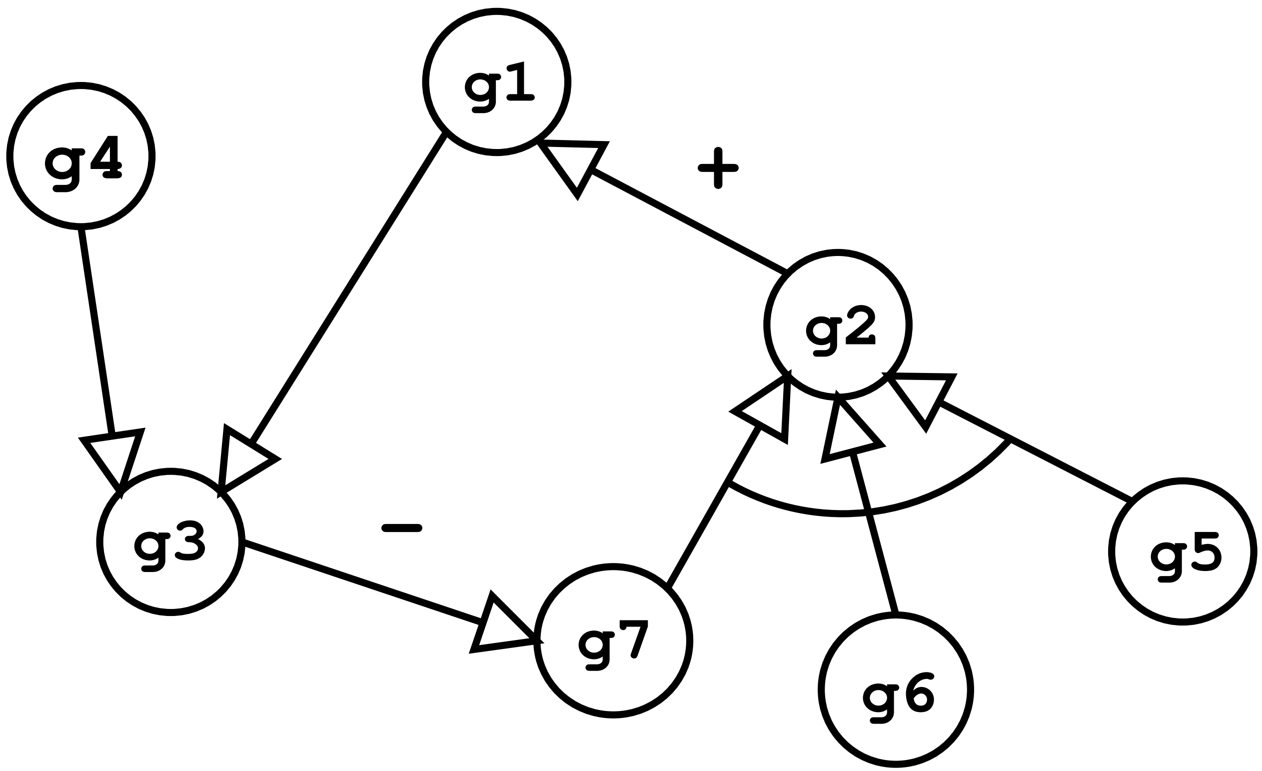
- AND/OR, (+) and (-) contribution arcs $[\overline{(+)}, \overline{(-)}]$
- goals g can be "Satisfied" or "Denied"

THE PROBLEM

Given an initial partial assignment, propagate the values trough the graph and detect conflicts

- AND/OR: Trivial
- (+) and (-)?
- CYCLES possible!

THE PROBLEM: Example



LOGIC APPROACH:

4 TRUTH VALUES: S, D, PS, PD

(Satisfied, Denied, Partially Satisfied, Partially Denied)

- Goal values: $\{S, PS, -\}$, $\{D, PD, -\}$
- Intuition: PS and PD values come from (+) and (-)

Conflict: g can be, e.g., satisfied and partially denied

LOGIC APPROACH: Predicates

4 PREDICATES: $S(g),\ D(g),\ PS(g),\ PD(g)$

- $S(g) \to PS(g)$, $D(g) \to PD(g)$
- $S(g)/PS(g)$ compatible with $D(g)/PD(g)$ (conflict)

LOGIC APPROACH: AND Axioms

$g = AND(g_1, g_2)$:

- $(S(g_1) \wedge S(g_2)) \to S(g)$
- $(PS(g_1) \wedge PS(g_2)) \to PS(g)$
- $D(g_1) \to D(g),\ D(g_2) \to D(g)$
- $PD(g_1) \to PD(g),\ PD(g_2) \to PD(g)$

LOGIC APPROACH: OR Axioms

$g = OR(g_1, g_2)$:

- $S(g_1) \rightarrow S(g),\ S(g_2) \rightarrow S(g)$
- $PS(g_1) \rightarrow PS(g),\ PS(g_2) \rightarrow PS(g)$
- $(D(g_1) \wedge D(g_2)) \rightarrow D(g)$
- $(PD(g_1) \wedge PD(g_2)) \rightarrow PD(g)$

LOGIC APPROACH: (+), (-) Axioms

$g = PLUS(g_1)$:

- $S(g_1) \to PS(g)$
- $PS(g_1) \to PS(g)$

$g = MINUS(g_1)$:

- $S(g_1) \to PD(g)$
- $PS(g_1) \to PD(g)$

[LOGIC APPROACH: $\overline{(+)}$, $\overline{(-)}$ Axioms]

$g = DUAL\_PLUS(g_1)$:

- $D(g_1) \to PS(g)$
- $PD(g_1) \to PS(g)$

$g = DUAL\_MINUS(g_1)$:

- $D(g_1) \to PD(g)$
- $PD(g_1) \to PD(g)$

LOGIC APPROACH

g.S [resp. g.PS, g.D, g.PD] is True if and only if S(g) [resp. PS(g), D(g), PD(s)] can be inferred from the initial assignment and the axioms.

LOGIC APPROACH: ALGORITHM

- assign the initial values
- do
  - for each goal do:
    - infer all new values possible for g
      from the incoming arcs

  until no new value can be inferred (fixpoint).
- detect all conflicts

NUMERICAL APPROACH:

Satisfiability and Deniability represented by real values $S_{val}, D_{val} \in [min, ..., max]$ ("evidence", "criticality",...)

- Intended meaning:

$$
\begin{aligned}
S(g) &\leftrightarrow S_{val}(g) = max, \\
PS(g) &\leftrightarrow S_{val}(g) \in \,]min, max] \\
-(g) &\leftrightarrow S_{val}(g) = min \\
\ldots
\end{aligned}
$$

- Intuition: values in $]min, max[$ come from (+) and (-)

Conflict: $S_{val}(g) \in \,]min, max], D_{val}(g) \in \,]min, max]$.

NUMERICAL APPROACH: Propagation model

2 dual OPERATORS: $\oplus$ and $\otimes$, representing value propagation trough “or” and “and”

- Independent probability model:

  $min = 0, max = 1$

  $v_1 \oplus v_2 = v_1 + v_2(1 - v_1)$

  $v_1 \otimes v_2 = v_1 \cdot v_2$

- Flow model:

  $min = 0, max = +\infty$

  $v_1 \oplus v_2 = v_1 + v_2$

  $v_1 \otimes v_2 = (v_1 \cdot v_2)/(v_1 + v_2)$

- ...

NUMERICAL APPROACH: AND & OR prop. rules

$g = AND(g_1, g_2)$:

- $S_{val}(g) = S_{val}(g_1) \otimes S_{val}(g_2)$
- $D_{val}(g) = D_{val}(g_1) \oplus D_{val}(g_2)$

$g = OR(g_1, g_2)$:

- $S_{val}(g) = S_{val}(g_1) \oplus S_{val}(g_2)$
- $D_{val}(g) = D_{val}(g_1) \otimes D_{val}(g_2)$

NUMERICAL APPROACH: (+), (-) prop. rules

A value in $v \in]min, max[$ is associated to each (+), (-)

$g = PLUS(g_1)$:

- $S_{val}(g) = S_{val}(g_1) \otimes v$

$g = MINUS(g_1)$:

- $D_{val}(g) = S_{val}(g_1) \otimes v$

NUMERICAL APPROACH: $\overline{(+)}$, $\overline{(-)}$ prop. rules

$g = DUAL\_PLUS(g_1)$:

- $S_{val}(g) = D_{val}(g_1) \oplus v$

$g = DUAL\_MINUS(g_1)$:

- $D_{val}(g) = D_{val}(g_1) \oplus v$

NUMERICAL APPROACH: ALGORITHM

- assign the initial values
- do
  - for each goal do:
    - compute the new values for g
      from the incoming arcs

  until no new value can be computed (fixpoint).
- detect all conflicts

FUTURE WORK

- implement a basic version
- test it on real-word cases
- extend the model to handle different sources of goal values