Modeling Processes Using Transaction Logic

A presentation for RuleML 2013 Doctoral Consortium

Reza Basseda

Stony Brook University (SUNY)

rbasseda@cs.stonybrook.edu

July 13, 2013

Motivation

- Procedural knowledge in scientific knowledge bases
- Given a scientific knowledge base including processes
  - Example: A biological knowledge base including cell development processes
  - How to specify and query the procedural knowledge
  - Example Queries:
    - A researcher treats cells with a chemical that prevents DNA synthesis from starting. This treatment traps the cells in which part of the cell cycle?
    - How many chromosomes does a rat cell have when it is formed?
    - In mitosis, what step follows Metaphase?
  - Changing states while a process is being executed

Background

- Integration of dynamic behavior and static components
- Declarative programming languages and Imperative specification languages
- Different frameworks can represent processes
  - Process Algebra
  - Action Modeling Languages
  - Semantic Web Frameworks
- Different challenges for above mentioned frameworks
  - Not a knowledge representation language
  - Lack of proper implementations

Transaction Logic ($\mathcal{TR}$)

- $\mathcal{TR}$
  - A general logic of state changes
  - A Horn-like fragment: supports logic programming
- Every transaction: A sequence of knowledge base state changes(execution path)
- Executional entailment: $P, D_0, \cdots, D_n \models \psi$

Types of Transactions

- Elementary updates: $P, D_1, D_2 \models u$
  - A truth value
  - A side effect on the knowledge base
  - Example: $P, D_1, D_2 \models u$
- Complex transaction:
  - $\mathcal{TR}$ connectives
  - Example: Serial conjunctions $(\psi \otimes \phi)$
    - $P, D_2, D_3 \models v$
    - $P, D_1, D_2, D_3 \models u \otimes v$
- Executional entailment: $P, D_0, \cdots, D_n \models \psi$

Semantics and Oracles

- Data oracle ($\mathcal{O}^d$)
    - *Static* semantics of states
- Transition oracle ($\mathcal{O}^t$)
    - Specifies a set of primitive knowledge base updates

Example: A simple financial database system

- $balance(Act, Amt)$
- Elementary updates:
  - $balance.ins(Act, Amt)$
    - $balance.ins(c_1, m_1) \in \mathcal{O}^t(D_0, D_0 \cup \{balance(c_1, m_1)\})$
  - $balance.del(Act, Amt)$
    - $balance.del(c_1, m_1) \in \mathcal{O}^t(D_0, D_0 - \{balance(c_1, m_1)\})$
- Complex transaction:
  - $balance.change(Act, Bal, Bal')$
  - $withdraw(Amt, Act)$
  - $deposit(Amt, Act)$
  - $transfer(Amt, Act, Act')$
- If we have two accounts: c_1 and c_2, with balance amount of m_1 and m_2 respectively, then $D_0 = \{balance(c_1, m_1), balance(c_2, m_2)\}$ is a valid state

Example: A simple financial database system (Cont.)

$$
\begin{aligned}
transfer(Amt, Act, Act') &\longleftarrow withdraw(Amt, Act) \otimes deposit(Amt, Act') \\
withdraw(Amt, Act) &\longleftarrow balance(Act, B) \otimes B \geq Amt \otimes \\
&\quad\; balance.change(Act, B, B - Amt) \\
deposit(Amt, Act) &\longleftarrow balance(Act, B) \otimes \\
&\quad\; balance.change(Act, B, B + Amt) \\
change(Act, B, B') &\longleftarrow balance.del(Act, B) \otimes balance.add(Act, B')
\end{aligned}
$$

Types of Processes

- Complex processes:
  - A sequence of complex processes
- Primitive processes:
  - A single step of execution

Example

$$complex\_process(p).$$
$$complex\_process(p_2).$$
$$primitive\_process(p_1).$$
$$primitive\_process(p_3).primitive\_process(p_{2_1}).$$
$$primitive\_process(p_{2_2}).$$
$$primitive\_process(p_{2_3}).$$
$$first\_step(p, p_1).$$
$$first\_step(p_2, p_{2_1}).$$
$$next\_step(p, p_1, p_2).$$
$$next\_step(p, p_2, p_3).$$
$$next\_step(p_2, p_{2_1}, p_{2_2}).$$
$$next\_step(p_2, p_{2_2}, p_{2_3}).$$

Sequential execution of subprocesses

To keep the track of a complex process execution, we need a structure maintaining the execution status of the complex process. The current step of a process, $current\_step(P, SP)$, is an example of such a structure keeping execution status. A primitive process does not have structure and it only updates the knowledge base state based on its definition.

$$\begin{aligned} execute(P) \longleftarrow & complex\_process(P) \wedge current\_step(P, CS) \otimes \\ & execute(CS) \otimes advance(P, CS) \otimes execute(P). \end{aligned}$$

$$\begin{aligned} execute(P) \longleftarrow & complex\_process(P) \wedge \\ & current\_step(P, CS) \wedge \sim next\_step(P, CS, \_). \end{aligned}$$

$$\begin{aligned} advance(P, CS) \longleftarrow & complex\_process(P) \wedge current\_step(P, CS) \\ & \wedge next\_step(P, CS, NS) \otimes current\_step.delete(P, CS \\ & \otimes current\_step.insert(P, NS). \end{aligned}$$

Primitive Processes

- Execution
  - Defined in terms of *insert* and *delete*
  - Extend the transition oracle and define a specific primitive process execution as a elementary transaction
- Conditional statements

Fault-tolerant execution

- If transaction $execute(CS)$ fails and returns false, the transaction $execute(P)$ also fails and returns false.
- Hypothetical reasoning:

$$execute(P) \longleftarrow complex\_process(P) \wedge current\_step(P, CS) \otimes \\ \sim \diamond execute(CS) \otimes failed(CS) \otimes \\ advance(P, CS) \otimes execute(P).$$

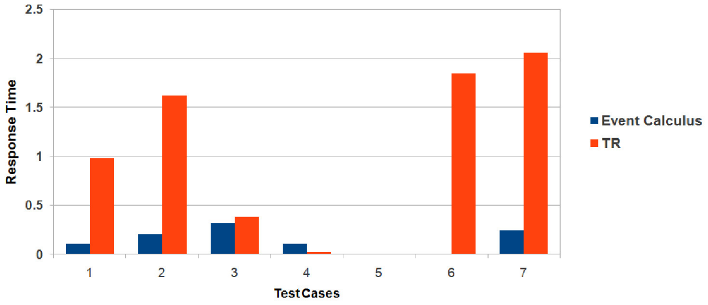
A cell mitosis division process

- A simple implementation of mitosis cell division process
  - Flora-2
  - An object oriented knowledge base language and application platform
- Comparision of
  - $\mathcal{AL}_d$ in SILK
  - An implementation based on the event calculus concepts in Flora2
  - $\mathcal{TR}$ in Flora2

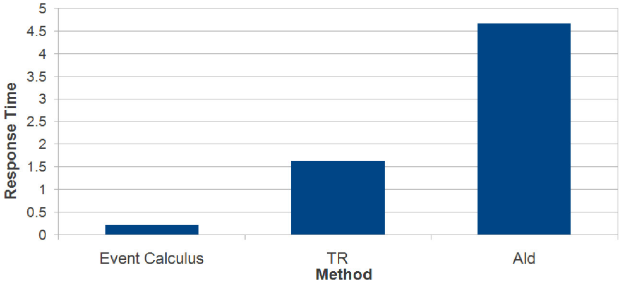
Lines of code

Method	Lines of Code
event calculus	1196
$\mathcal{AL}_d$	707
$\mathcal{TR}$	490

Response Time



Response Time (Cont.)



Conclusion

- $\mathcal{TR}$
  - Allows definitions of processes as first class entities
  - Simplifies programs and makes them more extensible and reusable
  - Improves the response time of queries
- Future Directions
  - $\mathcal{TR}$
    - Scalability in terms of size and complexity of process descriptions
    - Expansion of elementary updates to domain specific updates
  - Consider other capabilities of $\mathcal{TR}$ as a process representation tool
    - Concurrent behaviors???
    - Encode other process specification conventions such as process algebra.

Thank you