Towards Verification of a Service Orchestration Language

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Outline

- Background of Orc
- Motivation of Verifying Orc
- Overview of Orc Language
- Verification using PAT
- Future Works

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Background of Orc

- Proposed by Jayadev Misra at University of Texas at Austin (UT Austin) in 2004.
- Orc is a service orchestration language, which can be used as:
  - Executable specification language
    - Web Service Orchestration
    - Workflow process [1]
  - General purpose programming language

Background of Orc

- Process calculus → Full programming language.
- Involve timing aspect.
- Has the structure and feel of a functional programming language, yet it handles many non-functional aspects effectively, including time-outs etc.
- A simulator is created in Java by UT Austin team.

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Motivation of Verifying Orc

- The only related work is [5] which is done by our group
  - Translate Orc to Time-Automata.
  - Verify it using UPPAAL.
- Downside
  - The translation from Orc to Time-Automata takes time.
  - The translated model might be complicated.
  - Furthermore, Orc has evolved over time.
- Our new approach
  - **Direct** Verification of Orc.

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Overview of Orc Language

- Site – Basic service or component

Category of Sites

- Internal Site:
  - +, −, ∗, &&, ||, < =
    - 1+1→(+)(1,1)
  - Rtimer
    - Rtimer(5000)
- External Site: Google Search, MySpace, CNN, ...
  - Google ("Orc")

Overview of Orc Language

- Site call - two steps:
  - Invocation
  - Response with published value, or halt
- Published value can be:
  - Constant – string, boolean, number, list, and so on
  - Signal – A special value which carries no information
- Effects of calling sites:
  - Response
  - Halted
  - Pending – Neither response nor halted

Structure of Orc Expression

- Simple: just a site call, eg. *CNN*(*d*)
  - Publishes the value returned by the site.

- Composition of two Orc expressions:

  f and g can be simple expression like CNN(d), or composite expression like CNN(d) | BBC(d), x is a variable to be bounded.

  f | g Parallel Combinator

  f >x>g Sequential Combinator

  f <x< g Pruning Combinator

  f ; g Otherwise Combinator

- Orc is about the theory of combinators.

Parallel Combinator: *f* | *g*

- Evaluate *f* and *g* independently.
- Publish all values from both.
- No direct communication or interaction between *f* and *g*.

Example: *CNN*(*d*) | *BBC*(*d*)

Calls both *CNN* and *BBC* simultaneously. Publishes values returned by both sites. (0, 1 or 2 values)

Sequential Combinator: *f* >*x*> *g*

For all values published by *f* do *g*.
Publish only the values from *g*.

- *CNN*(*d*) >*x*> *Email*(*address*, *x*)
  - Call *CNN*(*d*).
  - Bind result (if any) to *x*.
  - Call *Email*(*address*, *x*).
  - Publish the value, if any, returned by *Email*.

- (*CNN*(*d*) | *BBC*(*d*)) >*x*> *Email*(*address*, *x*)
  - May call *Email* twice.
  - Publishes up to two values from *Email*.

Notation: *f* >>*g* for *f* >*x*> *g*, if *x* is unused in *g*.

Pruning Combinator: (*f* <x< *g*)

For some values published by *g* do *f* .

- Evaluate *f* and *g* in parallel.
  - Site calls in *f* that need *x* are suspended.
  - see (*M*() | *N*(*x*)) <*x*< *g*
- When *g* returns a (first) value:
  - Bind the value to *x*.
  - Terminate *g*.
  - Resume suspended calls in *f*.
- Values published by (*f* < x < g) are the values returned by f.
- Example:

  Email(*address*, *x*) <*x*< (*CNN*(*d*) | *BBC*(*d*))

Otherwise Combinator (f ; g)

- First executes f
  - If f stops and publishes any value, g is ignored. If f stops and publishes no value, then g executes. f stops if:
    - All site calls in the execution of f have either responded or halted.
    - f will never call any more sites.
    - f will never publish any more values.
  - Example:

    (*CNN*(*d*) ; *BBC*(*d*)) > x > Email(a,x)

Functional subset of Orc

- Constants – true, false, 1, 2, 3, "abc"
  - 1→let(1)
- Conditional – if true then 4 else 5
  - (if(b) >> let(4) | if(~b) >> let(5)) <b< let(true)
- Local variables – val a=1 a
  - let(a)<a<let(1)
- Functions – def A(x ,y)=x+y

Example

```
include "search.inc"
def sum (x, y)= x + y
val a=1
if sum(a,1)=2
then
    Google("Orc Language")
else
    "impossible!"
```

Programming Idioms

- Fork-Join
- Parallel Or
- Timeout
- Priorities
- And so on…

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- Fork-Join
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- Priorities
- Non-deterministic choice
- And so on…

Timeout

```
result < result < (
    Google("impatience")| (Rtimer(5000) >>"Search timed out.")
)
```

- Search for the keyword “impatience" in Google.
- If the result is not returned within 5 seconds, "Search timed out." is published.

Operational Semantics of Orc [2]

$$\frac{[E(x) \;\Delta\; f] \in \mathcal{D}}{E(p) \overset{0,\tau}{\rightarrow} [p/x].f} \quad (\textsc{Def})$$

$$\frac{f \overset{t,a}{\rightarrow} f' \qquad a \neq !m}{f >x> g \overset{t,a}{\rightarrow} f' >x> g} \quad (\textsc{Seq1N})$$

$$\frac{k \in \Sigma(M,m)}{M(m) \overset{0,\tau}{\rightarrow} ?k} \quad (\textsc{Call})$$

$$\frac{f \overset{t,!m}{\longrightarrow} f'}{f >x> g \overset{t,\tau}{\rightarrow} (f' >x> g) \mid [m/x].g} \quad (\textsc{Seq1V})$$

$$\frac{(t,m) \in k}{?k \overset{t,!m}{\rightarrow} \mathbf{0}} \quad (\textsc{Return})$$

$$\frac{f \overset{t,a}{\rightarrow} f'}{f <x< g \overset{t,a}{\rightarrow} f' <x< g^t} \quad (\textsc{Asym1})$$

$$\frac{f \overset{t,a}{\rightarrow} f'}{f \mid g \overset{t,a}{\rightarrow} f' \mid g^t} \quad (\textsc{Sym1})$$

$$\frac{g \overset{t,!m}{\rightarrow} g'}{f <x< g \overset{t,\tau}{\rightarrow} [m/x].f^t} \quad (\textsc{Asym2V})$$

$$\frac{g \overset{t,a}{\rightarrow} g'}{f \mid g \overset{t,a}{\rightarrow} f^t \mid g'} \quad (\textsc{Sym2})$$

$$\frac{g \overset{t,a}{\rightarrow} g' \qquad a \neq !m}{f <x< g \overset{t,a}{\rightarrow} f^t <x< g'} \quad (\textsc{Asym2N})$$

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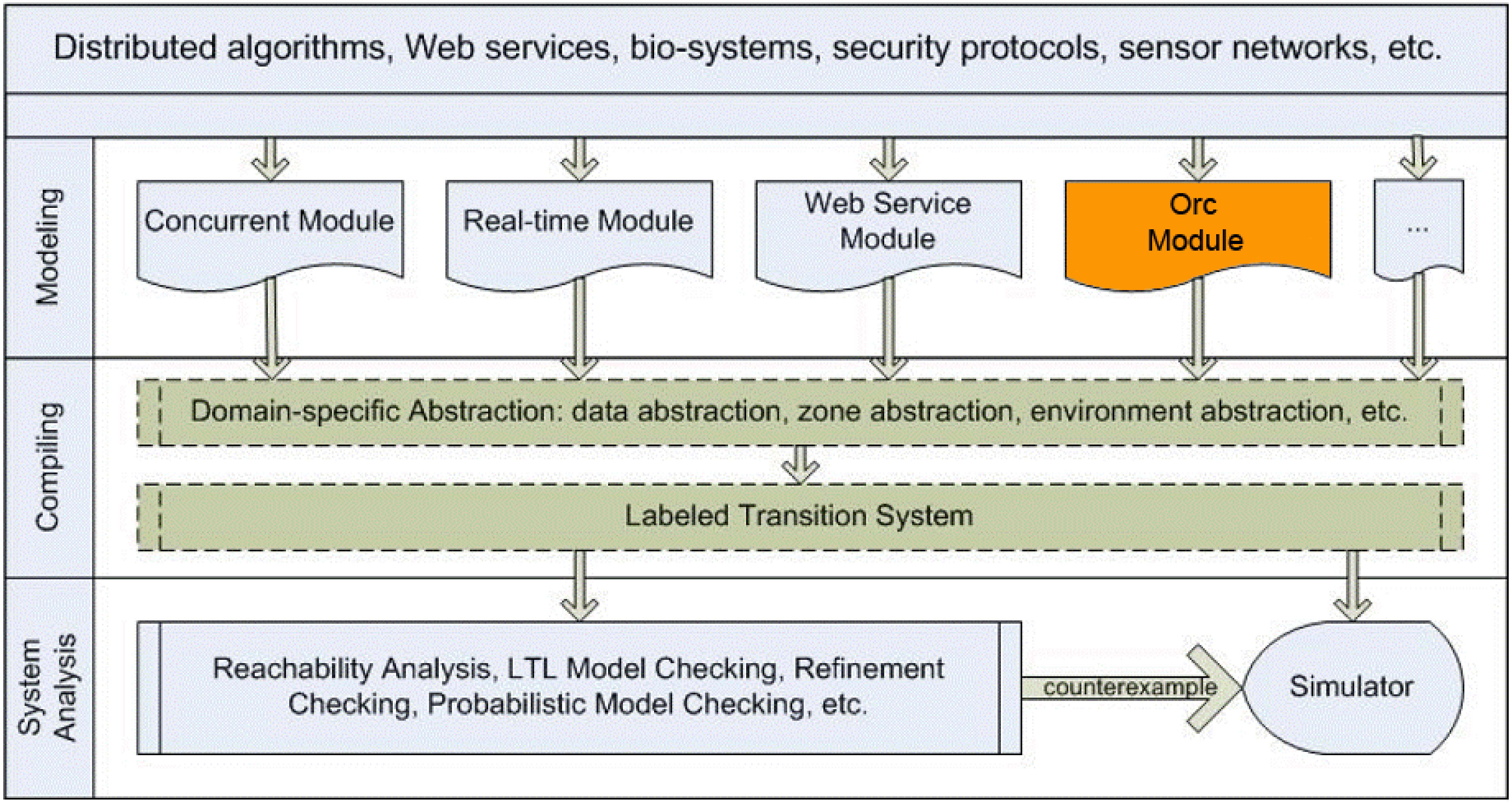
PAT Architecture



Verification using PAT

- Support all combinators
- Local Site
  - Fundamental – Arithmetic and logic operator, If site.
  - Time – Rtimer
  - Other – Ref site, SynChannel site, and so on …
- Remote Site
- Approach
  - Parse the language into the model.
  - Applying abstraction (such as Process Counter Abstraction) on the model.
  - Generate the labeled transition system with operational semantics
  - After that, the pool of verification algorithms in PAT will be available for usage.

Challenges of Verifying Orc

- State explosion problem
  - Many normal operations such as declaration of variable, or application of function are designed to run in parallel.
    - val a=1+1
      1+1+a
    - def f(a,b)=1+1+a+b
      f(1+1, 1+1)
- Solution:
  - Partial Order Reduction

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- Support verification of more libraries such as channel, semaphore, etc of Orc
- Refined the current state reduction approach
- Explore on more state reduction techniques

References

- [1] William R. Cook, Sourabh Patwardhan, and Jayadev Misra, **“Workflow Patterns in Orc”,** Proc. of the International Conference on Coordination Models and Languages (COORDINATION), 2006.
- [2] Ian Wehrman, David Kitchin, William R. Cook. Jayadev Misra, **“A Timed semantics of Orc”**, Theoretical Computer Science, August 2008.
- [3] David Kitchin, William R. Cook and Jayadev Misra, **“A Language for Task Orchestration and its Semantic Properties”**, Proc. of the International Conference on Concurrency Theory (CONCUR), 2006.
- [4] David Kitchin, “**Operational and Denotational Semantics of the Otherwise Combinator (DRAFT)**”,
Unpublished, 2009.
- [5] J. S. Dong, Y. Liu, J. Sun, and X. Zhang, “**Verification of Computation Orchestration via Timed Automata**”, Proc. of the 8th Int. Conference on Formal Engineering Methods, volume 4260 of LNCS, pages 226–245. Springer Verlag, 2006.

Thanks!