

A Compositional Semantics for OWL-S

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Introduction

- OWL is *Web Ontology Language*, proposed to W3C for Semantic Web
- OWL-S is ‘service ontology’, defining *Semantic Web Services*
- OWL-S *process model* describes formation of services by composition
- OWL-S process model therefore defines *orchestration via workflow*

Context

- OWL-S process model aims to capture common subset of workflow features

whereas

- WS-BPEL ends up with an all-inclusive superset of features

More Context

- YAWL attempts to capture all workflow 'patterns' in Petri net dialect

whereas

- Much process calculus-like work directly models specific features

'Composability' vs. Compositionality

- 'Composability' implies:
 - Existing (semantic) results should extend to new syntactic features
(not so for direct process model)
- Principle of compositionality:
 - Semantics of (syntactic) composite should derive from semantics of components
(not so for Petri nets)

Aims

- Create a compositional model for OWL-S process model in general process algebra

but

- Composable?
- Compositional through what equivalence?

Approach

- Take existing model of coarsely (sequentially) interleaved dataflow (CONCUR03), which is one of OWL-S composite process types
- ‘Compose’ other OWL-S process types
- Apply existing notion of behavioural equivalence (temporal observation congruence)

(Generalised) OWL-S Processes

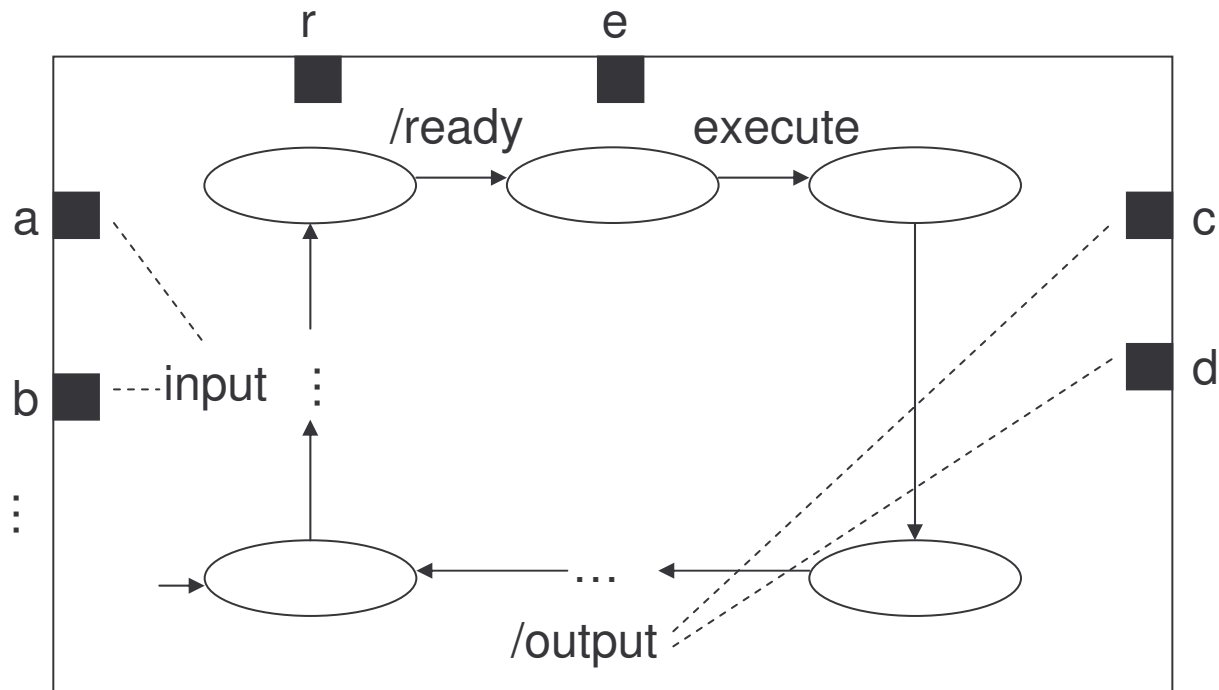
```
Process ::= AtomicProcess ... |  
          CompositeProcess CProcess ...  
CProcess ::= AnyOrder PerformanceList |  
            Sequence PerformanceList |  
            Split PerformanceList |  
            SplitJoin PerformanceList |  
            ChooseOne PerformanceList |  
            IfThenElse Performance  
                Performance |  
            RepeatWhile Performance |  
            RepeatUntil Performance  
PerformanceList Performance |  
                PerformanceList; Performance |  
                PerformanceList; Connect ...  
Performance ::= Perform Process
```


Existing Model

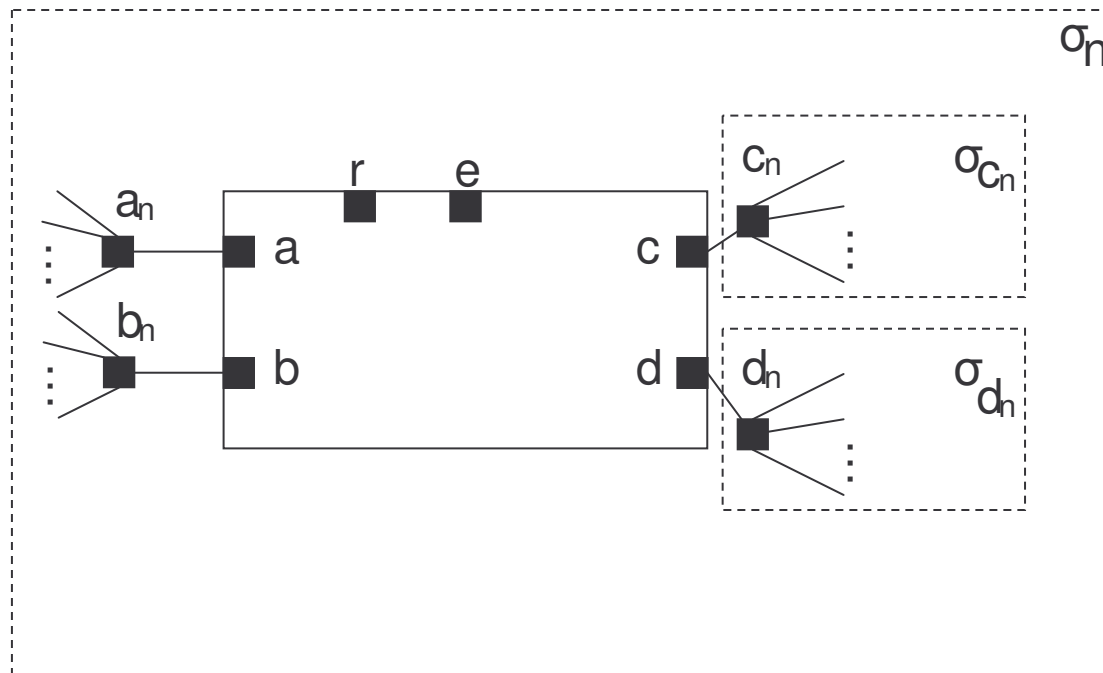
- Take automata describing *interfaces* of components
- Compose agent representing participation in *global synchronisation* to form instance
- Compose instances together, in model aware of communication-style (local) and global synchronisations
- Compare for conformance to interface (automaton) assigned to composite

'Interface Automata'

- Generally:



Instantiation



Basis (Regular CCS) ...

$$\mathcal{E} ::= \mathbf{0} \mid \alpha.\mathcal{E} \mid \mathcal{E} + \mathcal{E} \mid \mu X.\mathcal{E} \mid X$$

$$a, \bar{a}, b, \bar{b}, \dots \in \Lambda \cup \bar{\Lambda}$$

$$\alpha, \beta, \dots \in \Lambda \cup \bar{\Lambda} \cup \{\tau\}$$

$$\text{Act} \quad \frac{}{\alpha.P \xrightarrow{\alpha} P}$$

$$\text{Sum1} \quad \frac{P \xrightarrow{\alpha} P'}{P + Q \xrightarrow{\alpha} P'}$$

$$\text{Sum2} \quad \frac{Q \xrightarrow{\alpha} Q'}{P + Q \xrightarrow{\alpha} Q'}$$

$$\text{Rec} \quad \frac{E\{\mu X.E/X\} \xrightarrow{\alpha} P}{\mu X.E \xrightarrow{\alpha} P}$$

Basis (CCS) ...

$$\mathcal{E} ::= \mathbf{0} \mid \alpha.\mathcal{E} \mid \mathcal{E} + \mathcal{E} \mid \mathcal{E}|\mathcal{E} \quad \mid \mu X.\mathcal{E} \mid X$$

$$a, \bar{a}, b, \bar{b}, \dots \in \Lambda \cup \bar{\Lambda}$$

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$$\text{Sum2} \quad \frac{Q \xrightarrow{\alpha} Q'}{P + Q \xrightarrow{\alpha} Q'}$$

$$\text{Com1} \quad \frac{P \xrightarrow{\alpha} P'}{P | Q \xrightarrow{\alpha} P' | Q}$$

$$\text{Com2} \quad \frac{Q \xrightarrow{\alpha} Q'}{P | Q \xrightarrow{\alpha} P | Q'}$$

$$\text{Com3} \quad \frac{P \xrightarrow{a} P' \quad Q \xrightarrow{\bar{a}} Q'}{P | Q \xrightarrow{\tau} P' | Q'}$$

$$\text{Rec} \quad \frac{E\{\mu X.E/X\} \xrightarrow{\alpha} P}{\mu X.E \xrightarrow{\alpha} P}$$

+ Deterministic Time ...

$$\mathcal{E} ::= \mathbf{0} \mid \alpha.\mathcal{E} \mid \mathcal{E} + \mathcal{E} \mid \mathcal{E}|\mathcal{E} \mid [\mathcal{E}]\sigma(\mathcal{E}) \mid \mu X.\mathcal{E} \mid X$$

$$a, \bar{a}, b, \bar{b}, \dots \in \Lambda \cup \bar{\Lambda}$$

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$$\gamma, \delta, \dots \in \Lambda \cup \bar{\Lambda} \cup \{\tau, \sigma\}$$

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$$\text{Com4} \quad \frac{P \xrightarrow{\sigma} P' \quad Q \xrightarrow{\sigma} Q'}{P | Q \xrightarrow{\sigma} P' | Q'}$$

$$\text{TO1} \quad \frac{-}{[P]\sigma(Q) \xrightarrow{\sigma} Q}$$

$$\text{Sum2} \quad \frac{Q \xrightarrow{\alpha} Q'}{P + Q \xrightarrow{\alpha} Q'}$$

$$\text{Com2} \quad \frac{Q \xrightarrow{\alpha} Q'}{P | Q \xrightarrow{\alpha} P | Q'}$$

$$\text{Patient} \quad \frac{-}{a.P \xrightarrow{\sigma} P}$$

$$\text{TO2} \quad \frac{P \xrightarrow{\alpha} P'}{[P]\sigma(Q) \xrightarrow{\alpha} P'}$$

$$\text{Sum3} \quad \frac{P \xrightarrow{\sigma} P' \quad Q \xrightarrow{\sigma} Q'}{P + Q \xrightarrow{\sigma} P' + Q'}$$

$$\text{Com3} \quad \frac{P \xrightarrow{\alpha} P' \quad Q \xrightarrow{\bar{\alpha}} Q'}{P | Q \xrightarrow{\tau} P' | Q'}$$

$$\text{Idle} \quad \frac{-}{\mathbf{0} \xrightarrow{\sigma} \mathbf{0}}$$

$$\text{Rec}' \quad \frac{E\{\mu X.E/X\} \xrightarrow{\gamma} P}{\mu X.E \xrightarrow{\gamma} P}$$

+ Maximal Progress (\approx TPL) ...

$$\mathcal{E} ::= \mathbf{0} \mid \alpha.\mathcal{E} \mid \mathcal{E} + \mathcal{E} \mid \mathcal{E}|\mathcal{E} \mid [\mathcal{E}]\sigma(\mathcal{E}) \mid \mu X.\mathcal{E} \mid X$$

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$$\text{Com4} \quad \frac{P \xrightarrow{\sigma} P' \quad Q \xrightarrow{\sigma} Q'}{P | Q \xrightarrow{\sigma} P' | Q'} \quad P|Q \xrightarrow{\tau}$$

$$\text{TO1} \quad \frac{-}{[P]\sigma(Q) \xrightarrow{\sigma} Q} \quad P \xrightarrow{\tau}$$

$$\text{Sum2} \quad \frac{Q \xrightarrow{\alpha} Q'}{P + Q \xrightarrow{\alpha} Q'}$$

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+ 'Stalling' (=PMC's $\mathbf{0}$)...

$$\mathcal{E} ::= \mathbf{0} \mid \boxed{\Delta} \mid \alpha.\mathcal{E} \mid \mathcal{E} + \mathcal{E} \mid \mathcal{E}|\mathcal{E} \mid [\mathcal{E}]\sigma(\mathcal{E}) \mid \mu X.\mathcal{E} \mid X$$

$$a, \bar{a}, b, \bar{b}, \dots \in \Lambda \cup \bar{\Lambda}$$

$$\alpha, \beta, \dots \in \Lambda \cup \bar{\Lambda} \cup \{\tau\}$$

$$\gamma, \delta, \dots \in \Lambda \cup \bar{\Lambda} \cup \{\tau, \sigma\}$$

N.B. Equivalent to adding insistent communication, since:

$$\underline{a}.P \stackrel{\text{def}}{=} a.P + \Delta$$

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$$\text{Idle} \quad \frac{-}{\mathbf{0} \xrightarrow{\sigma} \mathbf{0}}$$

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+ Multiple Clocks (a la PMC, CSA)...

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$$\rho, \sigma, \dots \in \mathcal{T}$$

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$$\text{Patient} \quad \frac{-}{a.P \xrightarrow{\sigma} P}$$

$$\text{TO2}' \quad \frac{P \xrightarrow{\gamma} P'}{[P]\sigma(Q) \xrightarrow{\gamma} P'} \quad \gamma \neq \sigma$$

$$\text{Sum3} \quad \frac{P \xrightarrow{\sigma} P' \quad Q \xrightarrow{\sigma} Q'}{P + Q \xrightarrow{\sigma} P' + Q'}$$

$$\text{Com3} \quad \frac{P \xrightarrow{\alpha} P' \quad Q \xrightarrow{\alpha} Q'}{P | Q \xrightarrow{\tau} P' | Q'}$$

$$\text{Idle} \quad \frac{-}{\mathbf{0} \xrightarrow{\sigma} \mathbf{0}}$$

$$\text{Rec}' \quad \frac{E\{\mu X.E/X\} \xrightarrow{\gamma} P}{\mu X.E \xrightarrow{\gamma} P}$$

+ Hiding (= CaSE)

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Sum1 $\frac{P \xrightarrow{\alpha} P'}{P + Q \xrightarrow{\alpha} P'}$

Com1 $\frac{P \xrightarrow{\alpha} P'}{P | Q \xrightarrow{\alpha} P' | Q}$

Com4 $\frac{P \xrightarrow{\sigma} P' \quad Q \xrightarrow{\sigma} Q'}{P | Q \xrightarrow{\sigma} P' | Q'} \quad P|Q \xrightarrow{\tau}$

Hid1 $\frac{P \xrightarrow{\gamma} P'}{P/\sigma \xrightarrow{\gamma} P'/\sigma} \quad \gamma \neq \sigma$

TO1 $\frac{-}{[P]\sigma(Q) \xrightarrow{\sigma} Q} \quad P \xrightarrow{\tau}$

Sum2 $\frac{Q \xrightarrow{\alpha} Q'}{P + Q \xrightarrow{\alpha} Q'}$

Com2 $\frac{Q \xrightarrow{\alpha} Q'}{P | Q \xrightarrow{\alpha} P | Q'}$

Patient $\frac{-}{a.P \xrightarrow{\sigma} P}$

Hid2 $\frac{P \xrightarrow{\sigma} P'}{P/\sigma \xrightarrow{\tau} P'/\sigma}$

TO2' $\frac{P \xrightarrow{\gamma} P'}{[P]\sigma(Q) \xrightarrow{\gamma} P'} \quad \gamma \neq \sigma$

Sum3 $\frac{P \xrightarrow{\sigma} P' \quad Q \xrightarrow{\sigma} Q'}{P + Q \xrightarrow{\sigma} P' + Q'}$

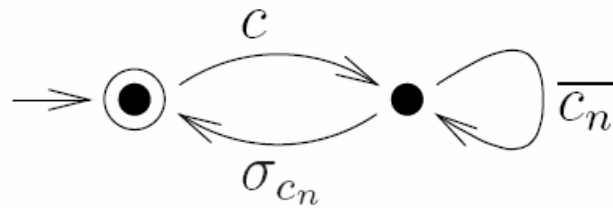
Com3 $\frac{P \xrightarrow{\alpha} P' \quad Q \xrightarrow{\alpha} Q'}{P | Q \xrightarrow{\tau} P' | Q'}$

Idle $\frac{-}{\mathbf{0} \xrightarrow{\sigma} \mathbf{0}}$

Rec'' $\frac{E \xrightarrow{\gamma} E'}{\mu X.E \xrightarrow{\gamma} E'\{\mu X.E/X\}}$

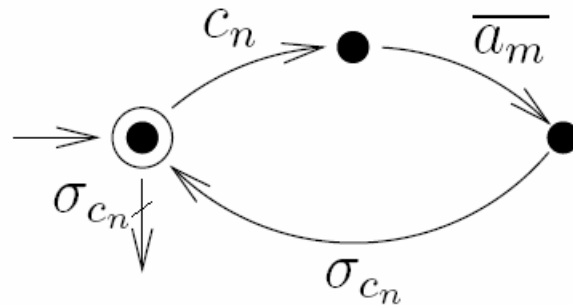
Compositional Broadcast

- Broadcast



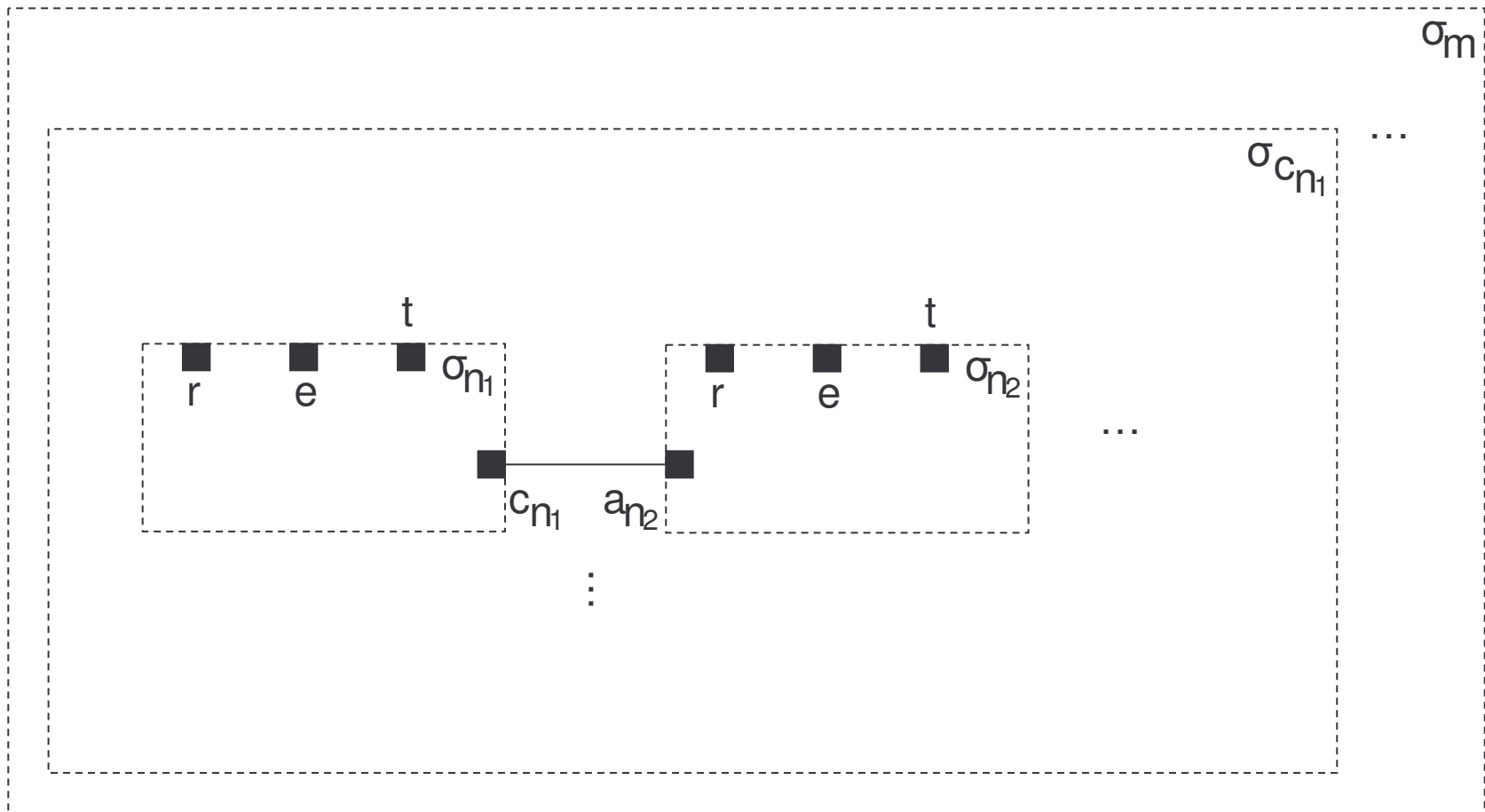
$$\mu X. \underline{c}_{\sigma_{c_n}} \cdot \mu Y. [\overline{c_n} \cdot Y] \sigma_{c_n} (X)$$

- Connection



$$\mu X. c_n. \overline{a_m}. \underline{\sigma_{c_n}} \cdot X$$

Composition



Conclusion

- Modulo small extension, calculus allows ‘composition’ of OWL-S process types
- Theoretical results:
 - Temporal observation congruence holds
 - Full abstraction holds
 - To do:
 - extension of algebraic theory
- Practical results
 - Implementation in Haskell
 - To do:
 - extend partition refinement
 - implementation in LISP

Further Work

- Fix cashew-s as a rich language for choreography (WSMO insists service interface provide both orch & chor)
- Establish expressiveness of cashew-nuts to give semantics to orchestration and choreography
- Investigate temporal observation congruence as a conformance test between orch & chor
- Now part of DIP (European Integrated) Project, therefore providing input to WSMO