Modelling Uncertainty in Architectures of Parametric Component-Based Systems

George Rahonis
(Joint work with Maria Pittou)

Aristotle University of Thessaloniki
Greece

RAQM 2021
Thessaloniki, June 22-23, 2021

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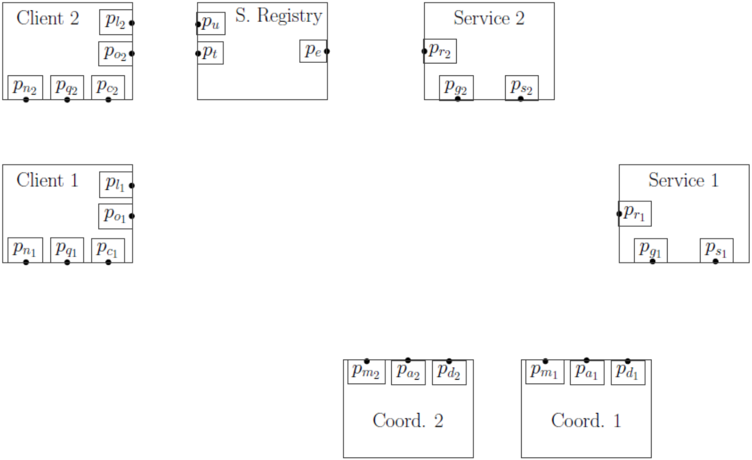
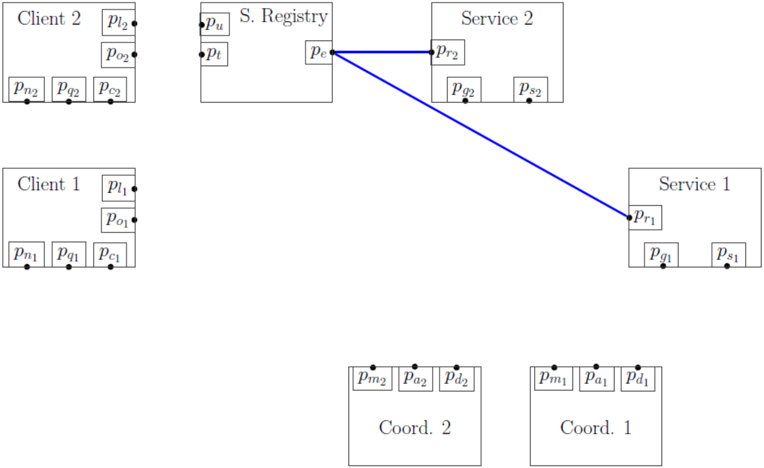
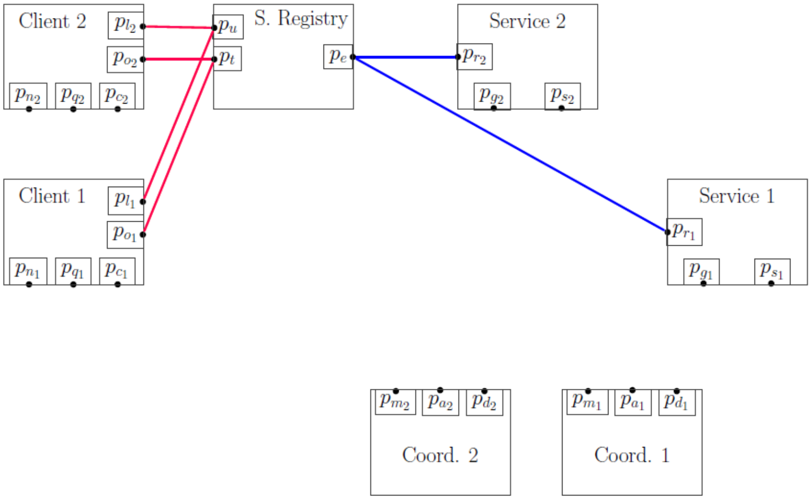
- **Parametric systems:** are constructed by a finite number of component types with an unbounded number of copies (instances) of them.


Client 2
p_{l_2}
p_{o_2}
p_{n_2}
p_{q_2}
p_{c_2}
p_u
S. Registry
p_t
p_e
Service 2
p_{r_2}
p_{g_2}
p_{s_2}
Client 1
p_{l_1}
p_{o_1}
p_{n_1}
p_{q_1}
p_{c_1}
Service 1
p_{r_1}
p_{g_1}
p_{s_1}
p_{m_2}
p_{a_2}
p_{d_2}
Coord. 2
p_{m_1}
p_{a_1}
p_{d_1}
Coord. 1

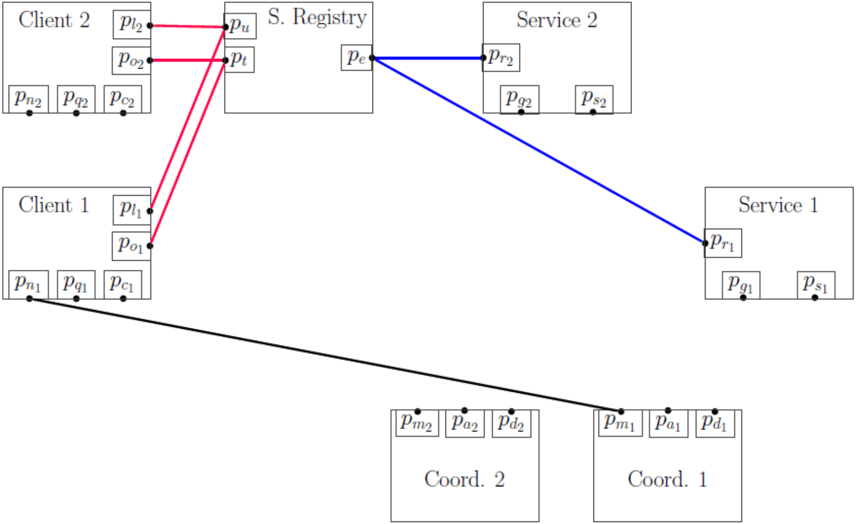
Initially services enroll in registry in any order



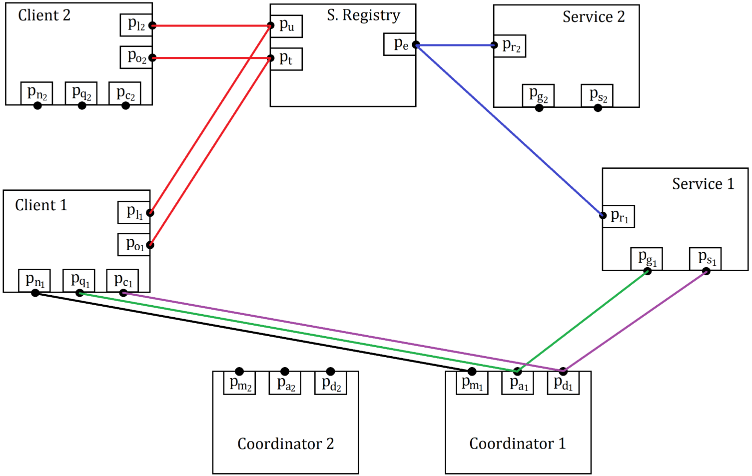
Clients search the registry and obtain a service's address



Client connects to coordinator



Client sends request to service and receives its response (via coordinator)



- Extended Propositional Interaction Logic (EPIL) describes architectures and the order of implementation of its interactions
- First-Order Interaction Logic (FOEIL) describes parametric architectures and the order of implementation of its interactions
- weighted EPIL (over commutative semirings)
- weighted FOEIL
- M. Pittou, G. Rahonis. Architecture modelling of parametric component-based systems, in: S. Bliudze and L. Bocchi, editors, COORDINATION 2020, *LNCS* 12134, pages 281–300, 2020.
- M. Pittou, G. Rahonis, Architectures in parametric component-based systems: Qualitative and quantitative modelling (submitted). https://arxiv.org/abs/1904.02222

Architecture modelling in early stages of software development where there is an ambiguity or missing information about the components' behavior and connections

implies

that uncertainties show up, affecting the correctness of the designed architecture and thus of the corresponding system.

Uncertainties, may occur in parametric architectures for Web Services and IoT applications. Such applications operate in an unstable environment where several components are replaced dynamically by other ones.

We consider a fuzzy EPIL and a fuzzy FOEIL to describe the uncertainty of architectures.

$(K, \vee, \wedge, 0, 1, \overline{\cdot})$ De Morgan algebra, i.e., a bounded distributive lattice with complement mapping $\overline{\cdot} : K \longrightarrow K$

- $\overline{k \vee k'} = \overline{k} \wedge \overline{k'}$
- $\overline{k \wedge k'} = \overline{k} \vee \overline{k'}$
- $\overline{\overline{k}} = k$

for every $k, k' \in K$.

- P set of **ports**
- **Syntax** of fuzzy extended propositional logic (fEPIL) formulas over P and K

$$\varphi ::= \mathrm{true} \mid p \mid \neg\varphi \mid \varphi \oplus \varphi \mid \varphi \odot \varphi \mid \varphi \varpi \varphi \mid \varphi^{+}$$

where $p \in P$ and

- $\oplus$ fuzzy disjunction,
- $\odot$ fuzzy concatenation,
- ϖ fuzzy shuffle,
- $+$ fuzzy iteration.

Fuzzy interactions over P and K: $\quad a : P \to K$ with $\sup \mathrm{p}(a) \neq \emptyset$

$fI(P)$: set of fuzzy interactions over P

Semantics of fEPIL formulas φ over P and K : series
$\|\varphi\| : fI(P)^+ \to K, \quad w \in fI(P)^+$

- $\|\mathrm{true}\|(w) = 1,$

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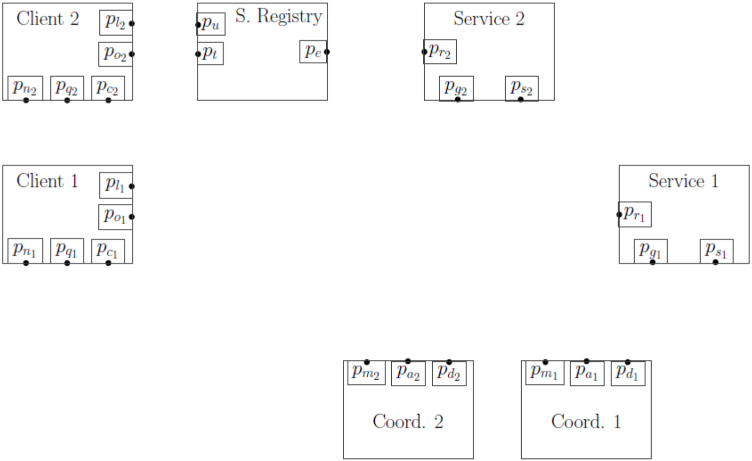
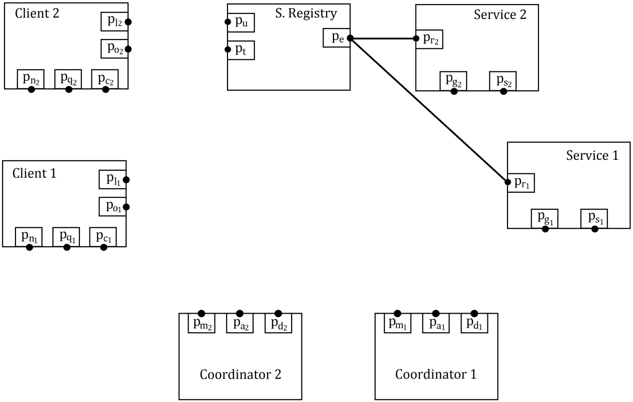
- $\|\varphi^+\|(w) = \bigvee_{n \geq 1} \|\varphi\|^n(w)$, where $\|\varphi\|^{n+1} = \|\varphi\|^n \odot \|\varphi\|$



Components are labelled transition systems with ports as labels.

Initially services enroll in registry in any order



$$\#_f(p_e \otimes p_{r_1})\varpi\#_f(p_e \otimes p_{r_2})$$

$$p_e \otimes p_{r_1} = \neg(\neg p_e \oplus \neg p_{r_1})$$

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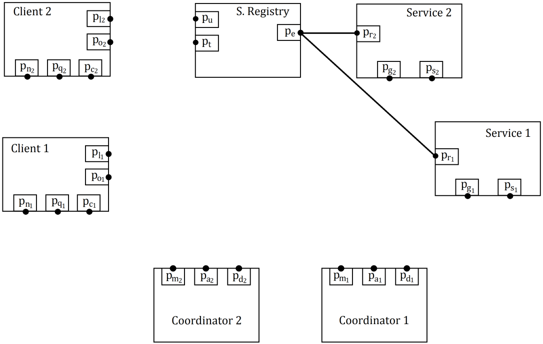

$$\#_f(p_e \otimes p_{r_1}) \varpi \#_f(p_e \otimes p_{r_2})$$

$$\#_f(p_e \otimes p_{r_1}) := (p_e \otimes p_{r_1}) \otimes \bigotimes_{p \in P \setminus \{p_e, p_{r_1}\}} \neg p$$

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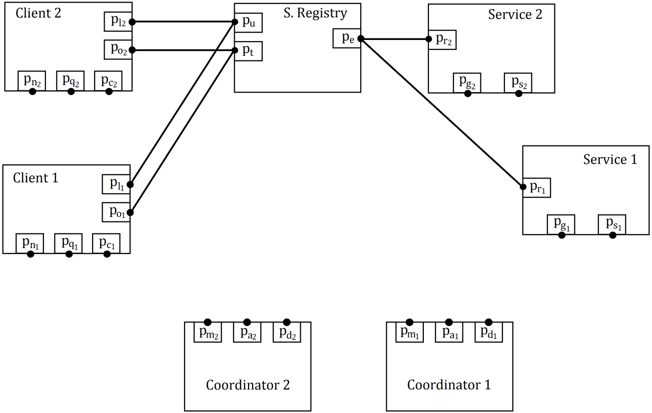
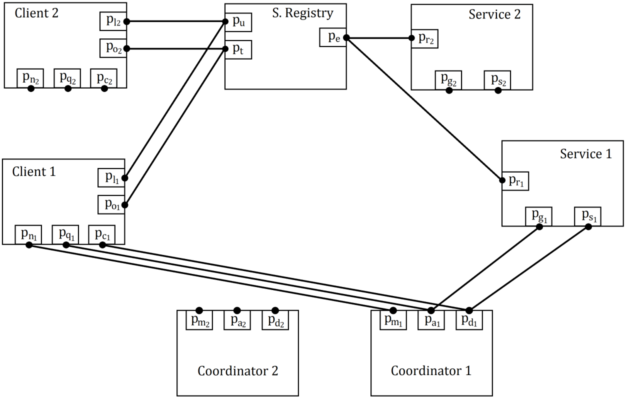
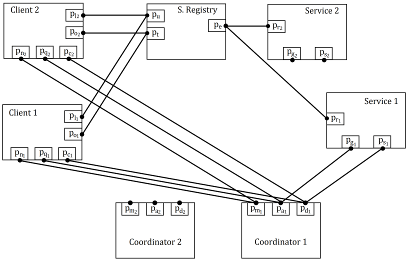


$$(\#_f(p_e \otimes p_{r_1})\varpi\#_f(p_e \otimes p_{r_2}))\odot$$
$$((\#_f(p_{l_1} \otimes p_u) \odot \#_f(p_{o_1} \otimes p_t))\varpi(\#_f(p_{l_2} \otimes p_u) \odot \#_f(p_{o_2} \otimes p_t)))$$

Client sends request to service and receives its response



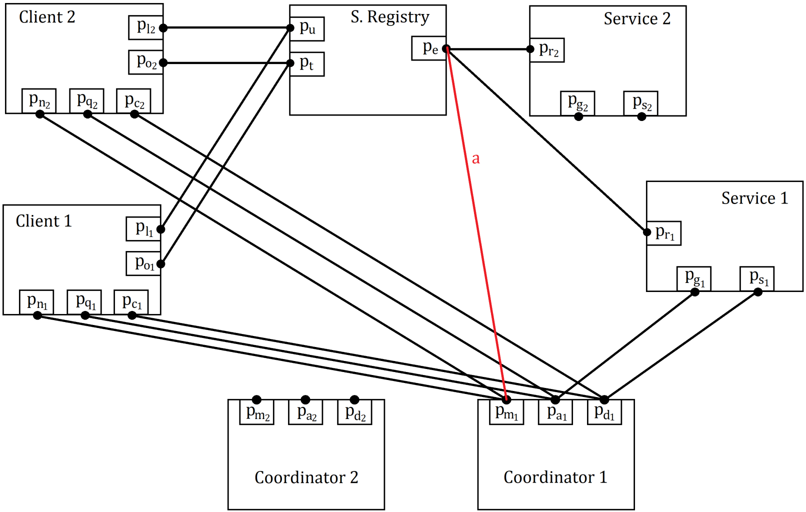
$$
\begin{aligned}
&(\#_f(p_e \otimes p_{r_1})\varpi\#_f(p_e \otimes p_{r_2}))\odot \\
&\quad((\#_f(p_{l_1} \otimes p_u) \odot \#_f(p_{o_1} \otimes p_t))\varpi(\#_f(p_{l_2} \otimes p_u) \odot \#_f(p_{o_2} \otimes p_t)))\odot \\
&\qquad(\#_f(p_{n_1} \otimes p_{m_1}) \odot \#_f(p_{q_1} \otimes p_{a_1} \otimes p_{g_1}) \odot \#_f(p_{c_1} \otimes p_{d_1} \otimes p_{s_1}))
\end{aligned}
$$



$$\varphi = (\#_f(p_e \otimes p_{r_1}) \varpi \#_f(p_e \otimes p_{r_2})) \odot$$
$$((\#_f(p_{l_1} \otimes p_u) \odot \#_f(p_{o_1} \odot p_t)) \varpi (\#_f(p_{l_2} \otimes p_u) \odot \#_f(p_{o_2} \otimes p_t))) \odot$$
$$\begin{pmatrix} (\varphi_{11} \oplus \varphi_{21} \oplus (\varphi_{11} \odot \varphi_{21}) \oplus (\varphi_{21} \odot \varphi_{11}))^+ \oplus \\ (\varphi_{12} \oplus \varphi_{22} \oplus (\varphi_{12} \odot \varphi_{22}) \oplus (\varphi_{22} \odot \varphi_{12}))^+ \oplus \\ ((\varphi_{11} \oplus \varphi_{21} \oplus (\varphi_{11} \odot \varphi_{21}) \oplus (\varphi_{21} \odot \varphi_{11}))^+ \varpi \\ (\varphi_{12} \oplus \varphi_{22} \oplus (\varphi_{12} \odot \varphi_{22}) \oplus (\varphi_{22} \odot \varphi_{12}))^+)^+ \end{pmatrix}^+$$

$$\varphi_{ij} = \#_f(p_{n_i} \otimes p_{m_j}) \odot \#_f(p_{q_i} \otimes p_{a_j} \otimes p_{g_j}) \odot \#_f(p_{c_i} \otimes p_{d_j} \otimes p_{s_j})$$

But it may happen that a wrong interaction occurs!



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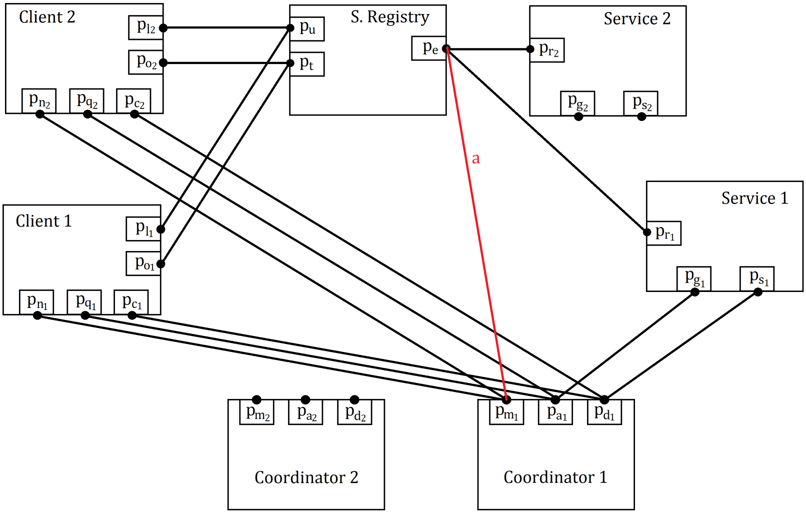
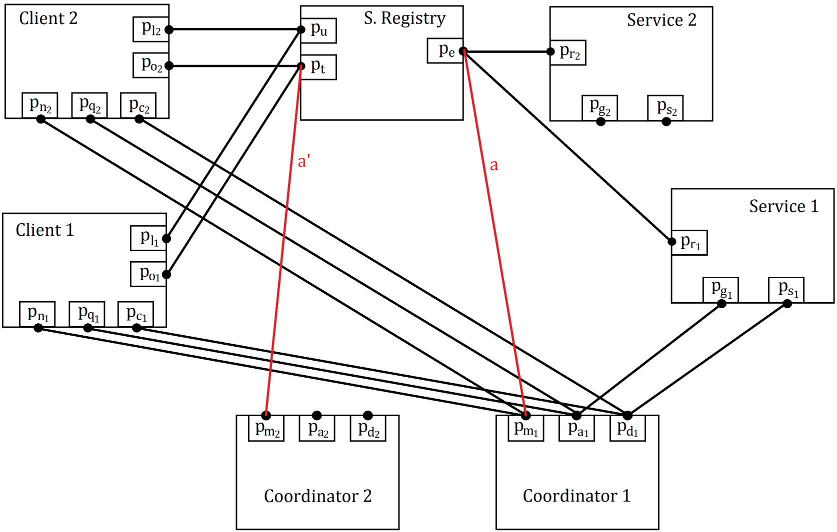


Or more than one!



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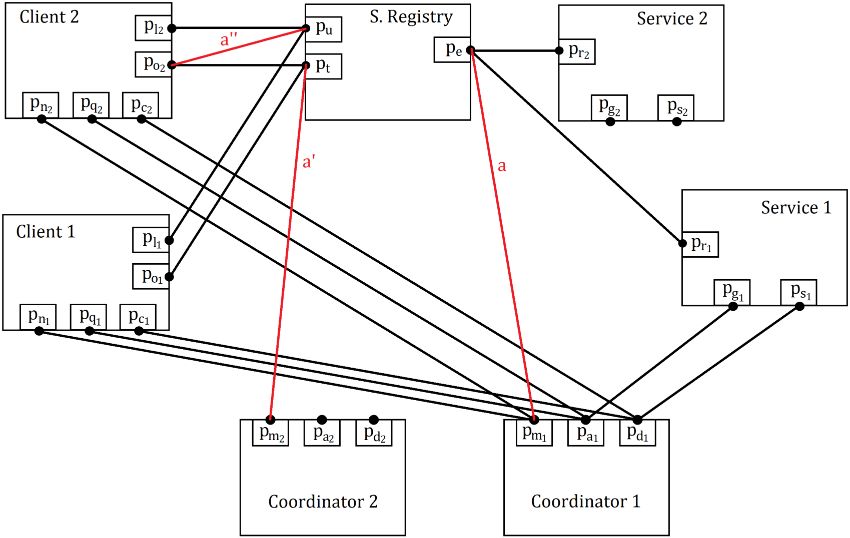

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- $P_{p\mathcal{B}(\mathcal{X})} = \{p(x^{(i)}) \mid i \in [n], p \in P(i), x^{(i)} \in \mathcal{X}^{(i)}\}$

- **Syntax** of fuzzy first-order extended interaction logic (fFOEIL) over $p\mathcal{B}$ and K

$$\psi ::= \varphi \mid x^{(i)} = y^{(i)} \mid \neg\psi \mid \psi \oplus \psi \mid \psi \odot \psi \mid \psi \varpi \psi \mid \psi^{+} \mid \sum x^{(i)}.\psi \mid \prod x^{(i)}.\psi \mid \sum\nolimits^{\odot} x^{(i)}.\psi \mid \prod\nolimits^{\odot} x^{(i)}.\psi \mid \sum\nolimits^{\varpi} x^{(i)}.\psi \mid \prod\nolimits^{\varpi} x^{(i)}.\psi$$

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  - if ψ contains $\sum^{\odot} x^{(i)}.\psi'$ or $\sum^{\varpi} x^{(i)}.\psi'$, then application of negation in ψ' is permitted only on port formulas.

- $r : [n] \to \mathbb{N}, \;\; i \in [n] \;\; r(i)$ number of instances of $B(i)$,

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- $\mathcal{V} \subset \mathcal{X}$ finite,

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- $fI_{p\mathcal{B}(r)}$ fuzzy interactions of $p\mathcal{B}(r)$. At most one port of every instance participates with non-zero weight in any interaction.

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$$\|\varphi\|(r,\sigma,w) = \|\sigma(\varphi)\|(w)$$
$$\left\|x^{(i)} = y^{(i)}\right\|(r,\sigma,w) = \begin{cases} 1 & \text{if } \sigma(x^{(i)}) = \sigma(y^{(i)}) \\ 0 & \text{otherwise} \end{cases}$$
$$\|\neg\psi\|(r,\sigma,w) = \overline{\|\psi\|(r,\sigma,w)}$$
$$\|\psi_1 \oplus \psi_2\|(r,\sigma,w) = \|\psi_1\|(r,\sigma,w) \vee \|\psi_2\|(r,\sigma,w)$$
$$\|\psi_1 \odot \psi_2\|(r,\sigma,w) = \bigvee_{w=w_1 w_2} (\|\psi_1\|(r,\sigma,w_1) \wedge \|\psi_2\|(r,\sigma,w_2))$$
$$\|\psi_1 \varpi \psi_2\|(r,\sigma,w) = \bigvee_{w \in w_1 \between w_2} (\|\psi_1\|(r,\sigma,w_1) \wedge \|\psi_2\|(r,\sigma,w_2))$$
$$\|\psi^{+}\|(r,\sigma,w) = \bigvee_{\nu \geq 1} (\|\psi\|^{\nu}(r,\sigma,w)$$

Semantics of fFOEIL over $p\mathcal{B}$ and K

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$$\left\| \sum x^{(i)}.\psi \right\| (r, \sigma, w) = \bigvee_{j \in [r(i)]} \|\psi\| \left(r, \sigma[x^{(i)} \rightarrow j], w\right)$$

$$\left\| \prod x^{(i)}.\psi \right\| (r, \sigma, w) = \bigwedge_{j \in [r(i)]} \|\psi\| \left(r, \sigma[x^{(i)} \rightarrow j], w\right)$$

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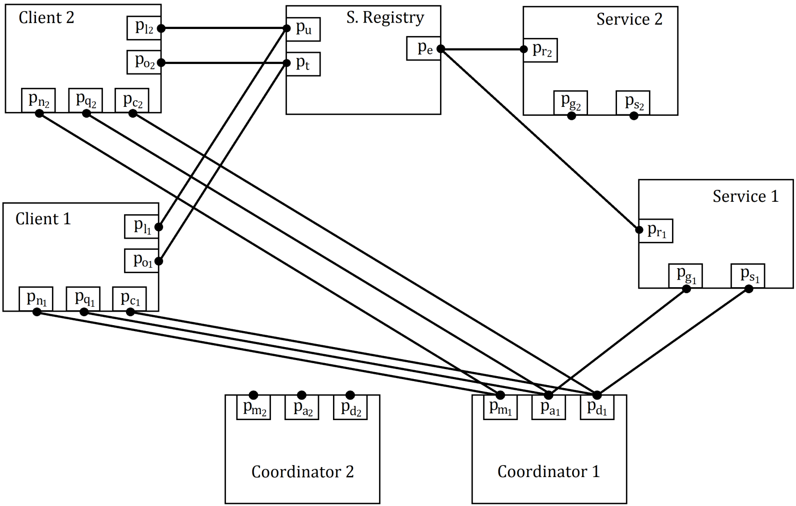
Client 2
p_{l_2}
p_{o_2}
p_{n_2}
p_{q_2}
p_{c_2}
S. Registry
p_u
p_t
p_e
Service 2
p_{r_2}
p_{g_2}
p_{s_2}
Client 1
p_{l_1}
p_{o_1}
p_{n_1}
p_{q_1}
p_{c_1}
Service 1
p_{r_1}
p_{g_1}
p_{s_1}
p_{m_2}
p_{a_2}
p_{d_2}
Coordinator 2
p_{m_1}
p_{a_1}
p_{d_1}
Coordinator 1

$\mathcal{X}^{(1)}$:registry, $\mathcal{X}^{(2)}$:services, $\mathcal{X}^{(3)}$:clients, $\mathcal{X}^{(4)}$:coordinators

$$\psi = \left(\sum x^{(1)} . \left(\begin{array}{c} (\prod^{\varpi} x^{(2)} . \#_f(p_e(x^{(1)} \otimes p_r(x^{(2)})))\odot \\ (\prod^{\varpi} x^{(3)} . (\#_f(p_l(x^{(3)}) \otimes p_u(x^{(1)})))\odot \\ \#_f(p_o(x^{(3)}) \otimes p_t(x^{(1)}))) \end{array} \right) \right) \odot$$

$$\left(\sum^{\varpi} y^{(2)} \sum x^{(4)} \sum^{\odot} y^{(3)} . \xi \otimes \left(\begin{array}{c} \prod y^{(4)} \prod z^{(3)} \prod z^{(2)} . (\theta \oplus \\ (\prod t^{(3)} \prod t^{(2)} (z^{(2)} \neq t^{(2)}) . \theta')) \end{array} \right) \right)^{+}$$

where

$$\xi = \#_f(p_n(y^{(3)}) \otimes p_m(x^{(4)}) \odot \#_f(p_q(y^{(3)}) \otimes p_a(x^{(4)}) \otimes p_g(y^{(2)}))\odot$$
$$\#_f(p_c(y^{(3)}) \otimes p_d(x^{(4)}) \otimes p_s(y^{(2)}))$$

$$\theta = \neg(\#_f(p_q(z^{(3)}) \otimes p_a(y^{(4)}) \otimes p_g(z^{(2)}))\varpi true)$$

$$\theta' = (\#_f(p_q(z^{(3)}) \otimes p_a(y^{(4)}) \otimes p_g(z^{(2)}))\varpi true)\otimes$$
$$\neg(\#_f(p_q(t^{(3)}) \otimes p_a(y^{(4)}) \otimes p_g(t^{(2)}))\varpi true)$$

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  - Then, the equivalence problem for fFOEIL sentences over $p\mathcal{B}$ and K w.r.t. r and A_r is decidable in doubly exponential time.

Work in progress

- Thresholds so that a fuzzy architecture can be considered as trustworthy.
- Second order extended interaction logic (for architectures like Ring, Linear, Grid).
- Weighted second order extended interaction logic.
- Fuzzy second order extended interaction logic.

Thank you

Ευχαριστώ