Featured Team Automata

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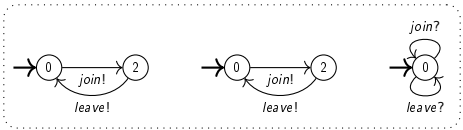
Background

Team Automata: [1]

- Systems of communicating components: synchronise over shared actions
- Synchronisation types per action: *peer-2-peer, broadcast, ...*



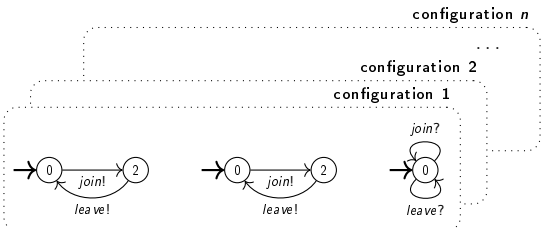
Goal: Safe communication – *no message loss, no indefinite waiting, ...*

[1] ter Beek et al., Compositionality of Safe Communication in Systems of Team Automata. ICTAC 2020

Motivation

Many systems today are highly configurable:

- Large sets of similar systems that share a lot of behaviour but differ in other

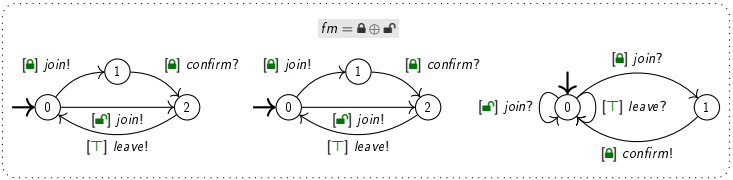


Challenge: System by system analysis of safe communication quickly becomes unfeasible

Approach

Featured Team Automata:

- Families (sets) of Team Automata model as a Software Product Line
- Single model parametrised by features [2] (e.g.: 🔒, 🔓), and a feature model (🔒 ⊕ 🔓)

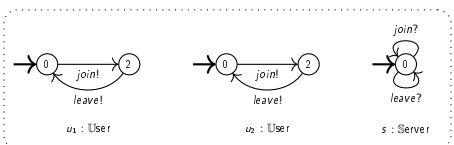


Goal: Family-based analysis of safe communication

[2] Classen et al., Featured Transition Systems: Foundations for Verifying Variability-Intensive Systems and Their Application to LTL Model Checking. IEEE Trans. Softw. Eng. 39 (2013)

Team Automata

Previous work:



Systems

Team Automata

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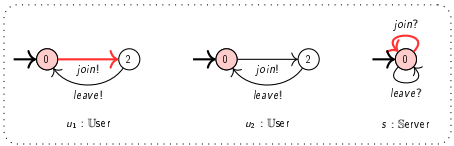

Systems

$$(0,0,0) \xrightarrow{(\{u_1\},join,\{s\})} (2,0,0)$$

Team Automata

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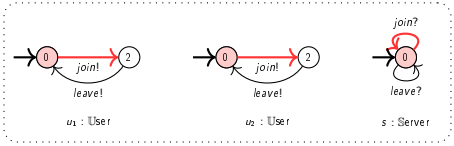

Systems

$$(0,0,0) \xrightarrow{(\{u_1,u_2\},join,\{s\})} (2,2,0)$$

Team Automata

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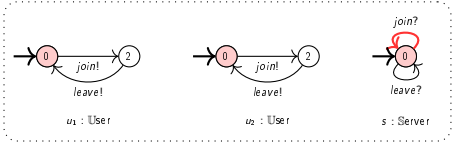

Systems

$(0,0,0) \xrightarrow{(\{\},join,\{s\})} (0,0,0)$

might not be desirable

Team Automata

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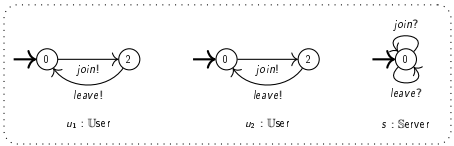
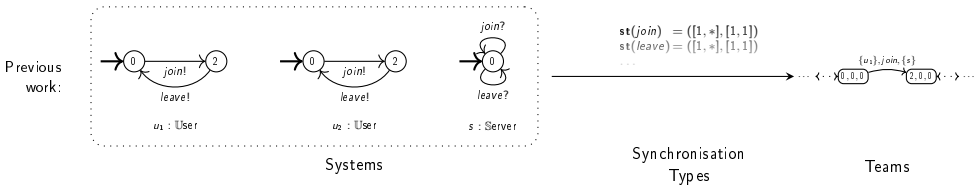


Systems

$\mathbf{st}(join) = ([1,*],[1,1])$
$\mathbf{st}(leave) = ([1,*],[1,1])$
...

Synchronisation Types

Team Automata



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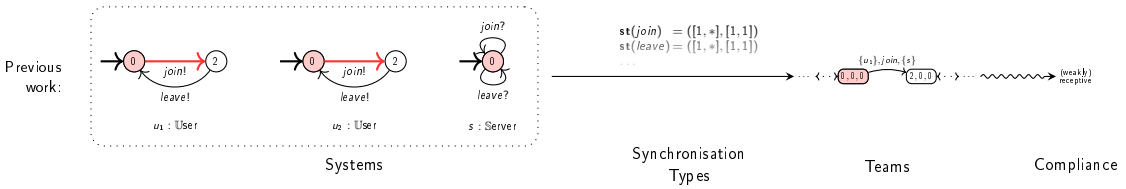

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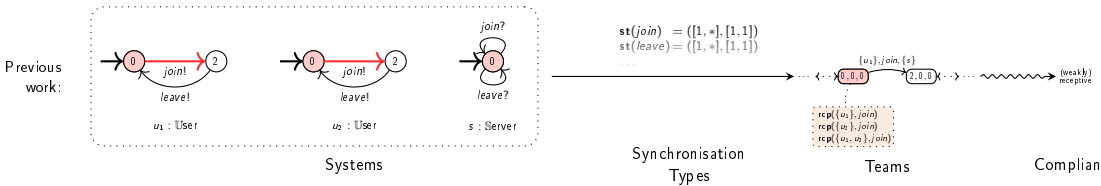

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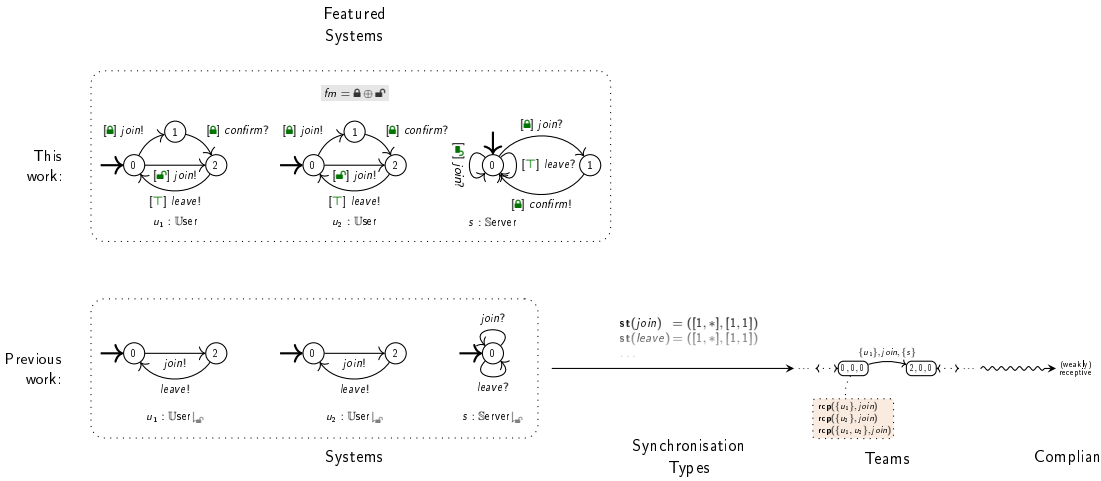

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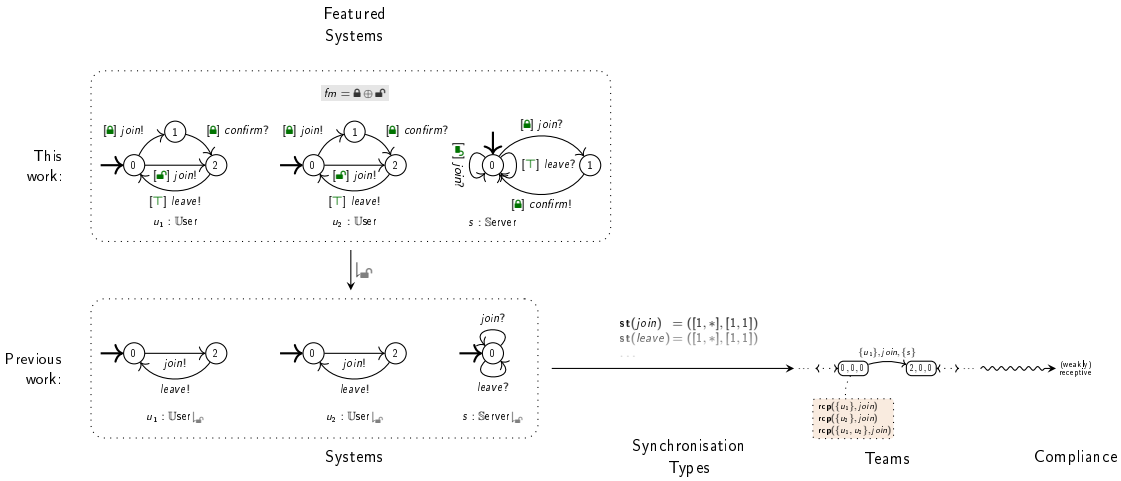

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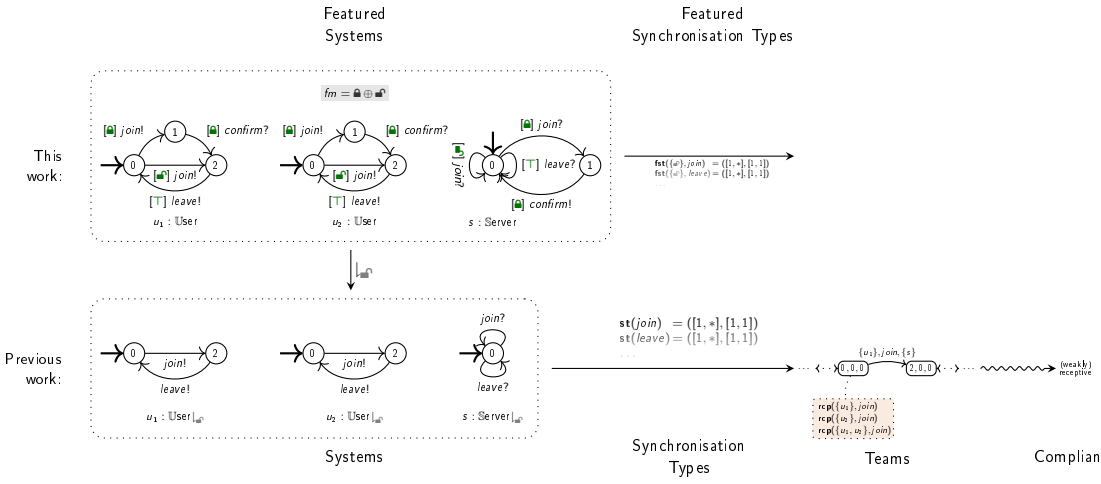

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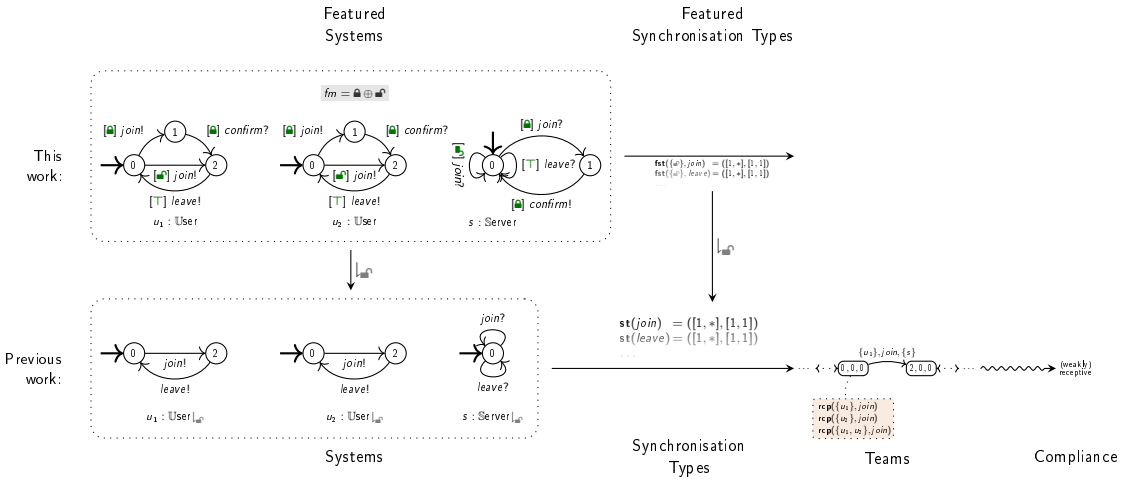

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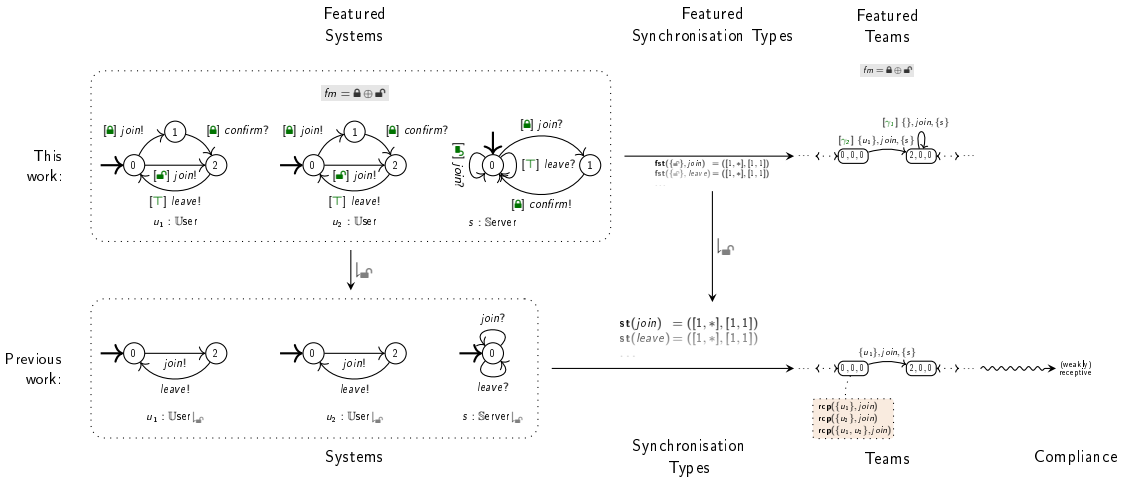

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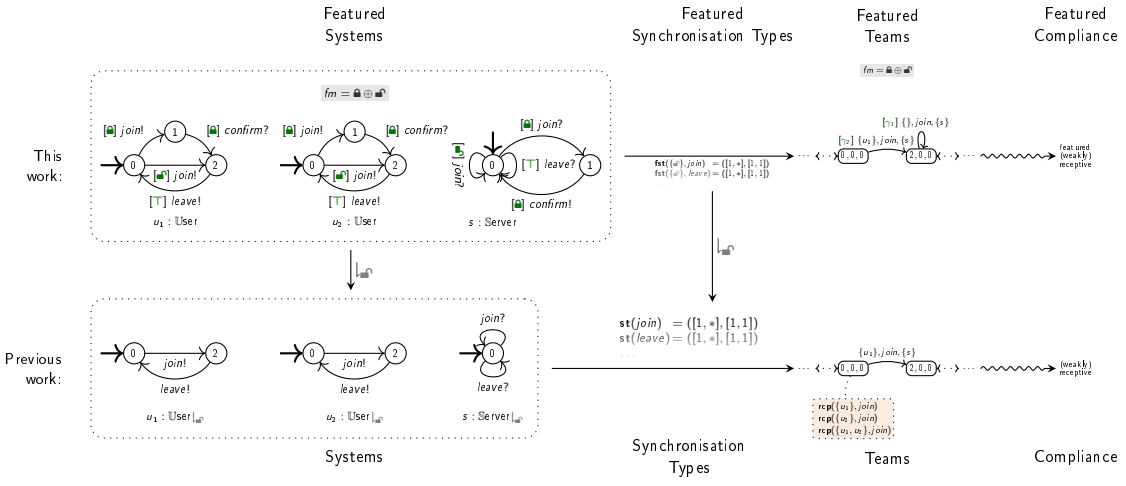

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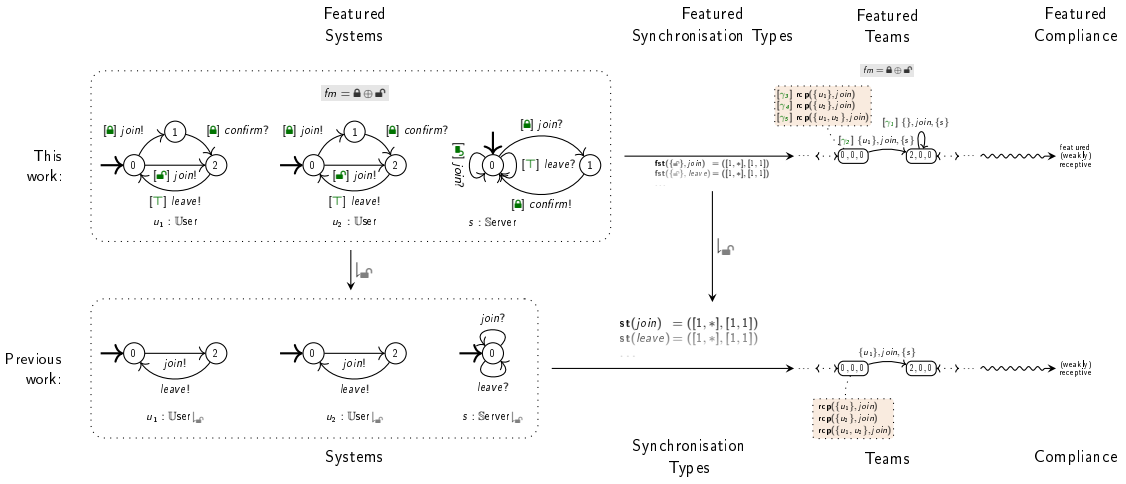

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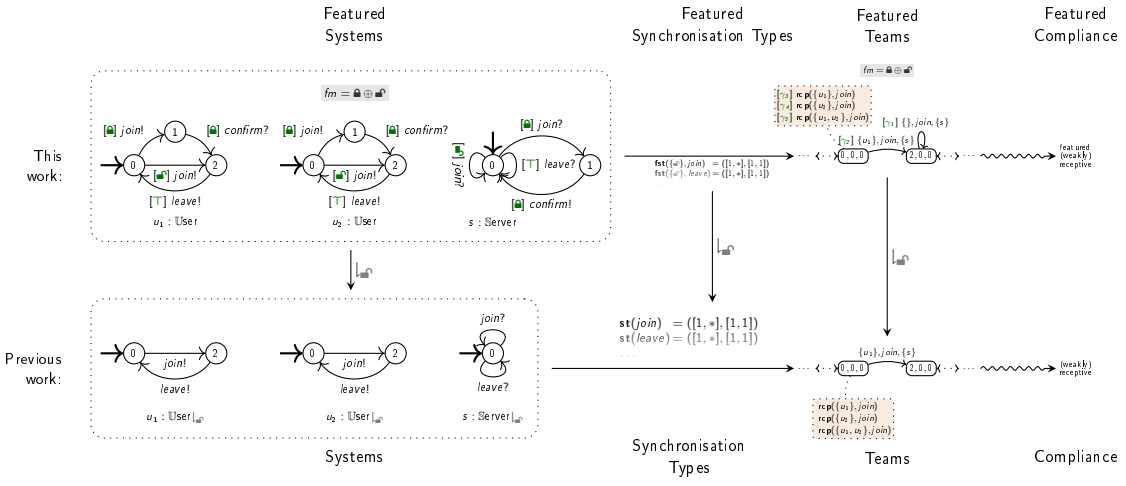

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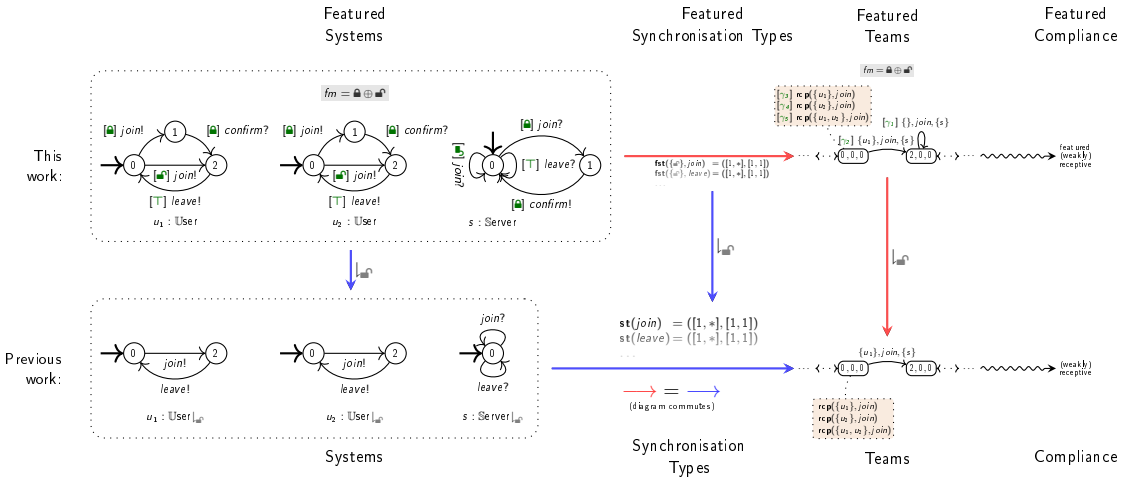

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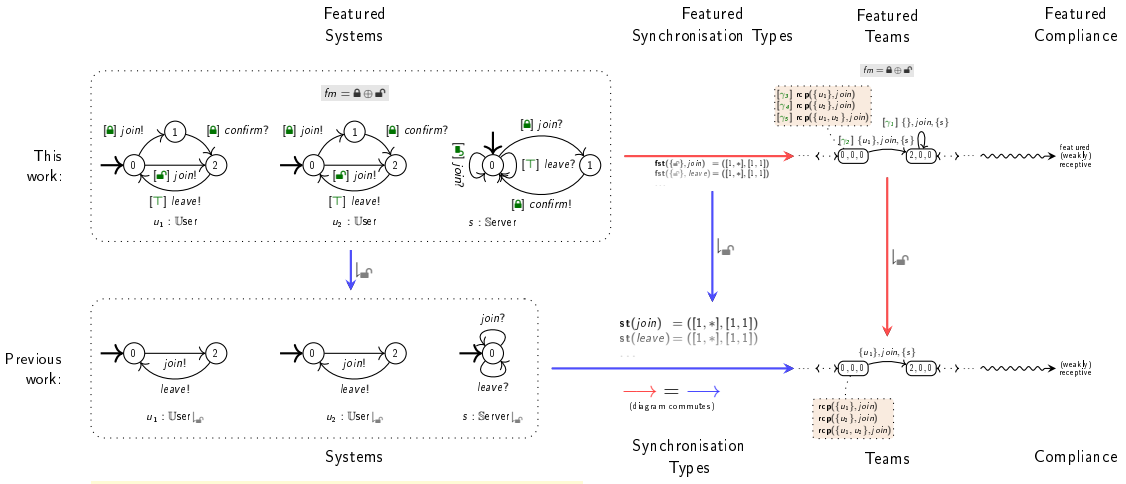

Online prototype: `http://arcatools.org/feta`

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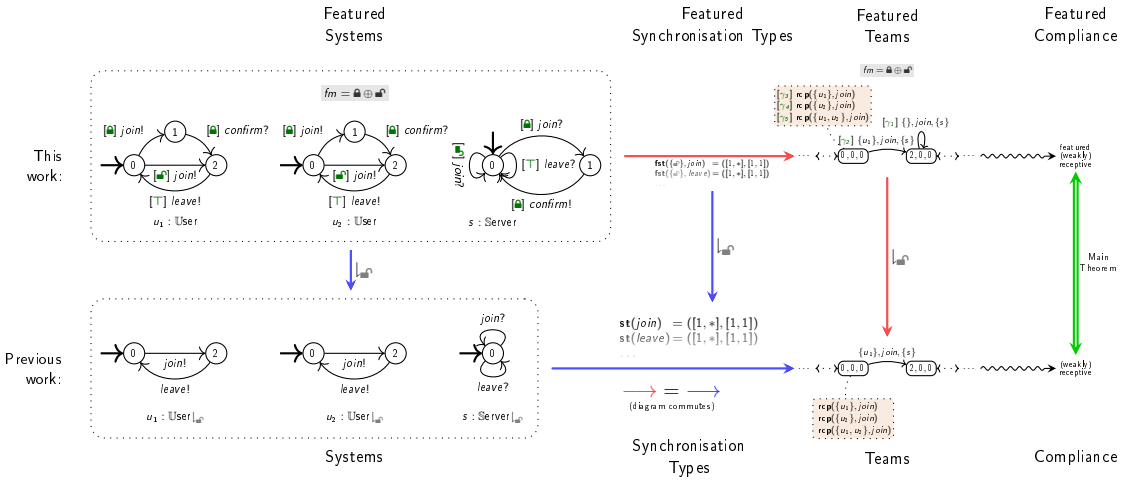

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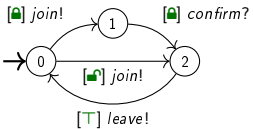
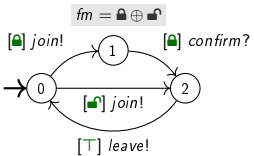
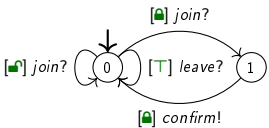
Featured Team Automata Transitions



(a) $u_1 : \mathbb{U}\text{ser}$



(b) $u_2 : \mathbb{U}\text{ser}$



(c) $s : \mathbb{S}\text{erver}$

Transitions are constraint with feature expressions by:

- local feature expressions: characterise the products with all participants present
- **fst**: characterise the products that satisfy the corresponding synchronisation type

$$\textbf{fst}(\{🔒\}, join) = ([1,1],[1,1]) \qquad \textbf{fst}(\{🔓\}, join) = ([1,*],[1,1])$$

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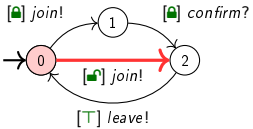

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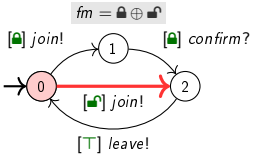

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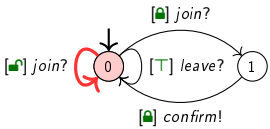

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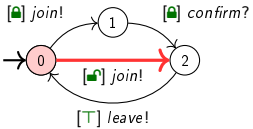

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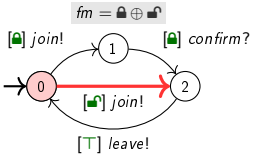

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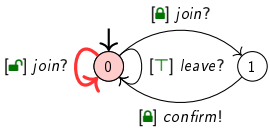

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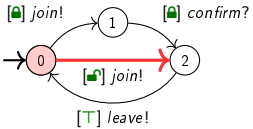

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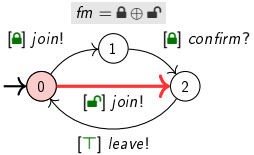

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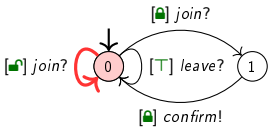

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$$(0,0,0) \xrightarrow{[🔓\wedge🔓\wedge🔓\wedge🔓\wedge\neg🔒](\{u_1,u_2\},join,\{s\})}_{\textbf{fst}[\mathcal{S}]} (2,2,0)$$

Featured Receptiveness Requirements

Here: Receptiveness – no message loss

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Featured Receptiveness Requirement:

Whenever (a group of) components want to send a message (in a product), there should be (a group of) components (in the same product) ready to receive the message in conformance with the synchronisation type

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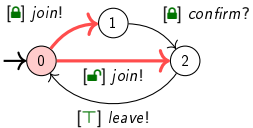
A Featured Team Automata is (weakly) receptive, if it is (weakly) compliant with all its featured requirements

Featured Receptiveness Requirements



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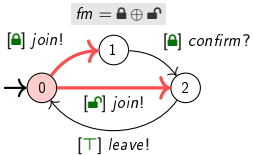

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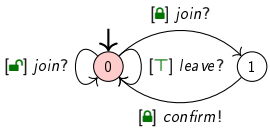

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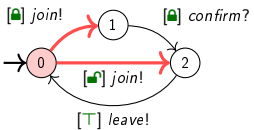
$$\mathbf{fst}(\{🔒\}, join) = ([1,1],[1,1]) \qquad \mathbf{fst}(\{🔓\}, join) = ([1,*],[1,1])$$

At state $(0,0,0)$:

[ ] $\mathbf{rcp}(\{u_1\}, join)$ $\wedge$ $\mathbf{rcp}(\{u_2\}, join)$ $\wedge$ [ ] $\mathbf{rcp}(\{u_1, u_2\}, join)$

Featured Receptiveness Requirements



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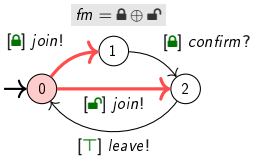

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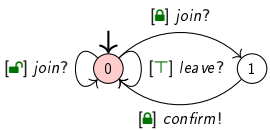

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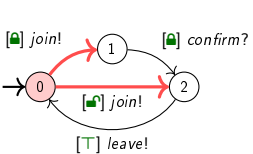
Featured receptiveness requirements are constraint with feature expression by:

Featured Receptiveness Requirements



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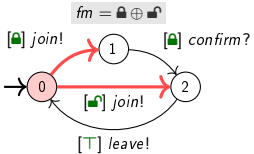

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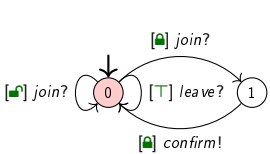

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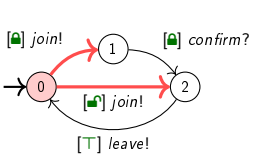
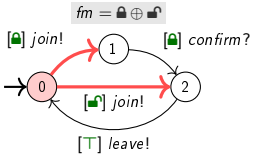
Featured receptiveness requirements are constraint with feature expression by:

- local feature expressions: characterise products where the participants are present

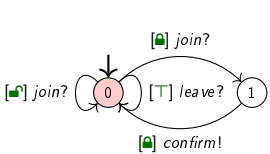
Featured Receptiveness Requirements



(a) $u_1 : \mathbb{U}\text{ser}$



(b) $u_2 : \mathbb{U}\text{ser}$



(c) $s : \mathbb{S}\text{erver}$

$$\mathbf{fst}(\{🔒\}, join) = ([1,1],[1,1]) \qquad \mathbf{fst}(\{🔓\}, join) = ([1,*],[1,1])$$

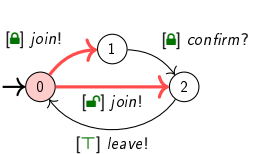
At state $(0,0,0)$:

$[🔒 \vee 🔓 \quad]\ \mathbf{rcp}(\{u_1\}, join)\ \wedge \quad \mathbf{rcp}(\{u_2\}, join)\ \wedge\ [\quad]\ \mathbf{rcp}(\{u_1, u_2\}, join)$

Featured receptiveness requirements are constraint with feature expression by:

- local feature expressions: characterise products where the participants are present

Featured Receptiveness Requirements



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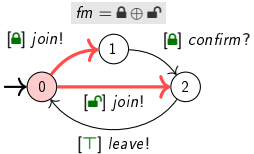
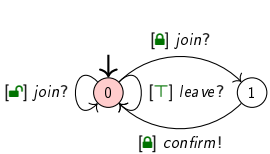


(b) $u_2 : \mathbb{U}\text{ser}$



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$$\textbf{fst}(\{🔒\}, join) = ([1,1],[1,1]) \qquad \textbf{fst}(\{🔓\}, join) = ([1,*],[1,1])$$

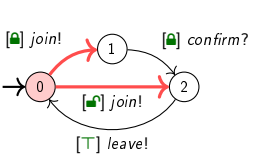
At state $(0,0,0)$:

[🔒 ∨ 🔓] $\textbf{rcp}(\{u_1\}, join) \wedge$ $\textbf{rcp}(\{u_2\}, join) \wedge$ [ ] $\textbf{rcp}(\{u_1, u_2\}, join)$

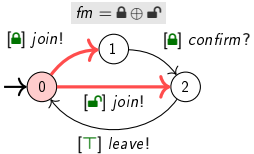
Featured receptiveness requirements are constraint with feature expression by:

- local feature expressions: characterise products where the participants are present
- **fst**: characterise products with the correct number of senders

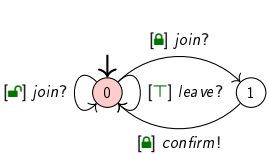
Featured Receptiveness Requirements



(a) $u_1 : \mathbb{U}\text{ser}$



(b) $u_2 : \mathbb{U}\text{ser}$



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$$\mathbf{fst}(\{🔒\}, join) = ([1,1],[1,1]) \qquad \mathbf{fst}(\{🔓\}, join) = ([1,*],[1,1])$$

At state $(0,0,0)$:

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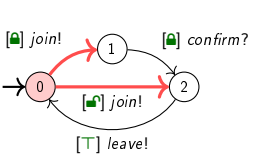
Featured Receptiveness Requirements



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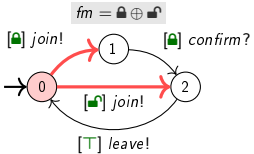
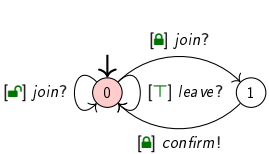


(b) $u_2 : \mathbb{U}\text{ser}$



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$$\mathbf{fst}(\{🔒\}, join) = ([1,1],[1,1]) \qquad \mathbf{fst}(\{🔓\}, join) = ([1,*],[1,1])$$

At state $(0,0,0)$:

$[🔒 \vee 🔓 \wedge fm]\ \mathbf{rcp}(\{u_1\}, join)\ \wedge \qquad \mathbf{rcp}(\{u_2\}, join)\ \wedge\ [\qquad\qquad]\ \mathbf{rcp}(\{u_1, u_2\}, join)$

Featured receptiveness requirements are constraint with feature expression by:

- local feature expressions: characterise products where the participants are present
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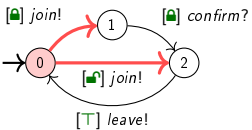
- reachable states: characterise products where the state is reachable

Featured Receptiveness Requirements



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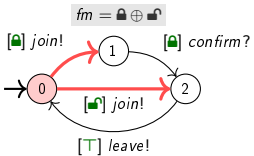
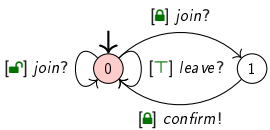


(b) $u_2 : \mathbb{U}\text{ser}$



(c) $s : \mathbb{S}\text{erver}$

$$\mathbf{fst}(\{🔒\}, join) = ([1,1],[1,1]) \qquad \mathbf{fst}(\{🔓\}, join) = ([1,*],[1,1])$$

At state $(0,0,0)$:

$[🔒 \vee 🔓 \wedge fm]\ \mathbf{rcp}(\{u_1\}, join)\ \wedge\ [fm]\ \mathbf{rcp}(\{u_2\}, join)\ \wedge\ [\qquad\qquad]\ \mathbf{rcp}(\{u_1, u_2\}, join)$

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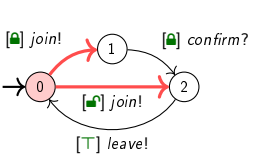
Featured Receptiveness Requirements



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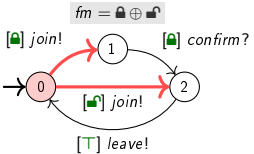
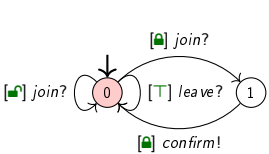


(b) $u_2 : \mathbb{U}\text{ser}$



(c) $s : \mathbb{S}\text{erver}$

$$\textbf{fst}(\{🔒\}, join) = ([1,1],[1,1]) \qquad \textbf{fst}(\{🔓\}, join) = ([1,*],[1,1])$$

At state $(0,0,0)$:

$$[🔒 \vee 🔓 \wedge fm]\ \textbf{rcp}(\{u_1\}, join)\ \wedge\ [fm]\ \textbf{rcp}(\{u_2\}, join)\ \wedge\ [🔒 \vee 🔓 \qquad]\ \textbf{rcp}(\{u_1, u_2\}, join)$$

Featured receptiveness requirements are constraint with feature expression by:

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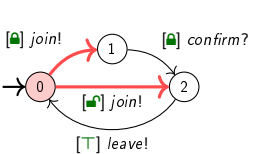
Featured Receptiveness Requirements



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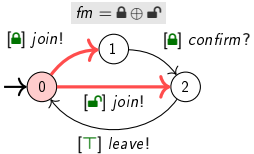
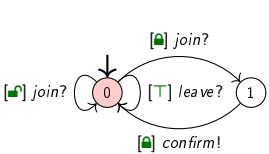


(b) $u_2 : \mathbb{U}\text{ser}$



(c) $s : \mathbb{S}\text{erver}$

$$\textbf{fst}(\{🔒\}, join) = ([1,1],[1,1]) \qquad \textbf{fst}(\{🔓\}, join) = ([1,*],[1,1])$$

At state $(0,0,0)$:

$$[🔒 \vee 🔓 \wedge fm]\ \textbf{rcp}(\{u_1\}, join)\ \wedge\ [fm]\ \textbf{rcp}(\{u_2\}, join)\ \wedge\ [🔒 \vee 🔓 \wedge 🔓 \wedge \neg 🔒 \quad]\ \textbf{rcp}(\{u_1, u_2\}, join)$$

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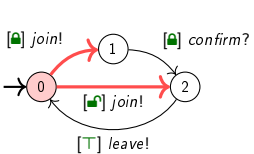
Featured Receptiveness Requirements



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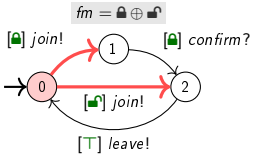
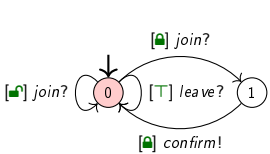


(b) $u_2 : \mathbb{U}\text{ser}$



(c) $s : \mathbb{S}\text{erver}$

$$\textbf{fst}(\{🔒\}, join) = ([1,1],[1,1]) \qquad \textbf{fst}(\{🔓\}, join) = ([1,*],[1,1])$$

At state $(0,0,0)$:

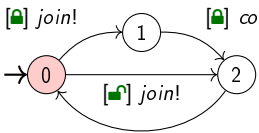
$$[🔒 \vee 🔓 \wedge fm]\ \textbf{rcp}(\{u_1\}, join)\ \wedge\ [fm]\ \textbf{rcp}(\{u_2\}, join)\ \wedge\ [🔒 \vee 🔓 \wedge 🔓 \wedge \neg 🔒 \wedge fm]\ \textbf{rcp}(\{u_1, u_2\}, join)$$

Featured receptiveness requirements are constraint with feature expression by:

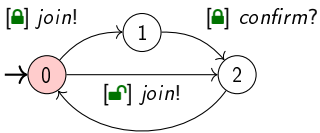
- local feature expressions: characterise products where the participants are present
- **fst**: characterise products with the correct number of senders
- reachable states: characterise products where the state is reachable

Compliance with requirements

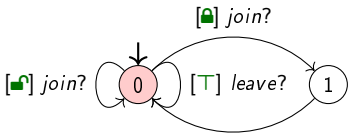
$fm = 🔒 \oplus 🔓$



(a) $u_1 : \mathbb{U}\text{ser}$



(b) $u_2 : \mathbb{U}\text{ser}$



(c) $\mathbb{S}\text{erver}$

At state $(0,0,0)$:

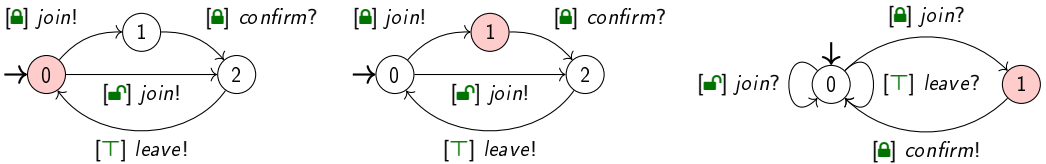
$$\underline{[fm]\ \mathbf{rcp}(\{u_1\}, join)} \ \wedge\ [fm]\ \mathbf{rcp}(\{u_2\}, join) \ \wedge\ [🔓 \wedge \neg 🔒]\ \mathbf{rcp}(\{u_1, u_2\}, join)$$

$$\{🔒\} : (0,0,0) \xrightarrow{[🔒 \wedge fm]\ (\{u_1\}, join, \{s\})}_{\mathbf{fst}[\mathcal{S}]} (1,0,1)$$

$$\{🔓\} : (0,0,0) \xrightarrow{[🔓 \wedge fm]\ (\{u_1\}, join, \{s\})}_{\mathbf{fst}[\mathcal{S}]} (2,0,0)$$

Compliance with requirements

$fm = 🔒 \oplus 🔓$



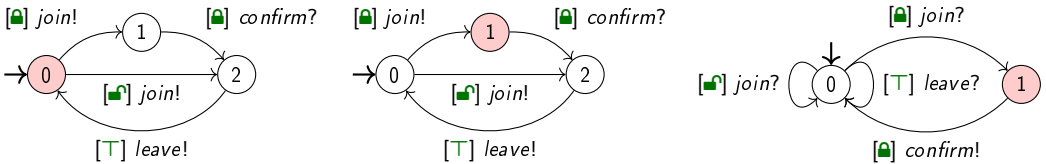
(a) $u_1 : \mathbb{U}\text{ser}$ (b) $u_2 : \mathbb{U}\text{ser}$ (c) $\mathbb{S}\text{erver}$

At state $(0, 1, 1)$:

$$\underline{[🔒 \wedge \neg 🔓]\ \mathbf{rcp}(\{u_1\}, join)} \ \wedge \ [🔒 \wedge \neg 🔓]\ \mathbf{rcp}(\{s\}, confirm)$$

Compliance with requirements

$fm = 🔒 \oplus 🔓$



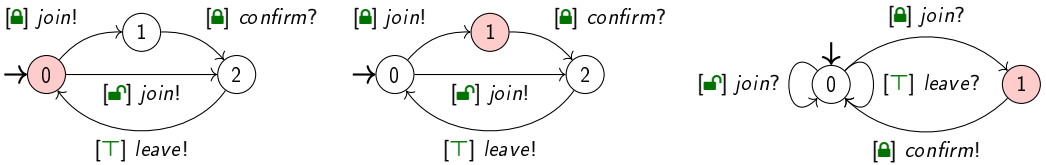
(a) $u_1 : \mathbb{U}\text{ser}$ (b) $u_2 : \mathbb{U}\text{ser}$ (c) $\mathbb{S}\text{erver}$

At state $(0, 1, 1)$:

$$✗\underline{[🔒 \wedge \neg 🔓]\ \mathbf{rcp}(\{u_1\}, join)} \ \wedge\ [🔒 \wedge \neg 🔓]\ \mathbf{rcp}(\{s\}, confirm)$$

Weak compliance with requirements

$fm = 🔒 \oplus 🔓$



(a) $u_1 : \mathbb{U}\text{ser}$ (b) $u_2 : \mathbb{U}\text{ser}$ (c) $\mathbb{S}\text{erver}$

At state $(0, 1, 1)$:

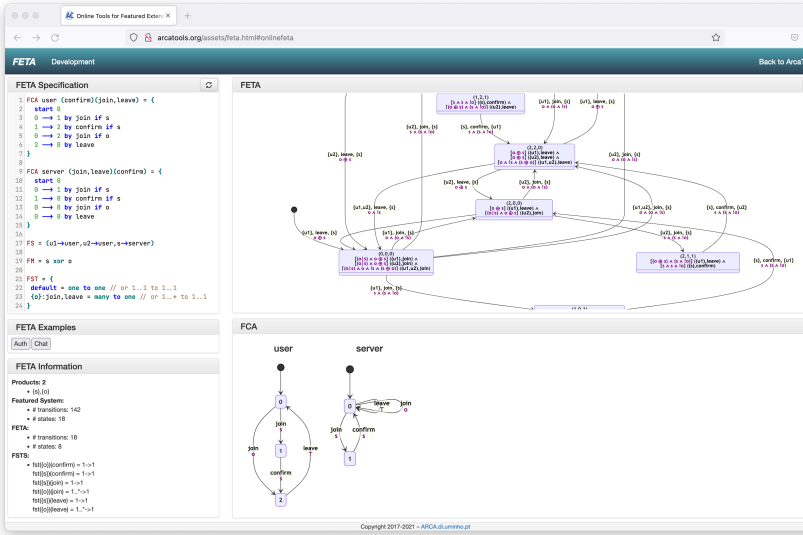
$$\underline{[🔒 \wedge \neg 🔓]\ \mathbf{rcp}(\{u_1\}, join)} \ \wedge\ [🔒 \wedge \neg 🔓]\ \mathbf{rcp}(\{s\}, confirm)$$

$$\{🔒\} :\ (0,1,1) \xrightarrow{[🔒 \wedge \underline{fm}](\{s\}, confirm, \{u_2\})}_{\mathbf{fst}[\mathcal{S}]} (0,2,0) \xrightarrow{[🔒 \wedge \underline{fm}](\{u_1\}, join, \{s\})}_{\mathbf{fst}[\mathcal{S}]} (1,2,1)$$

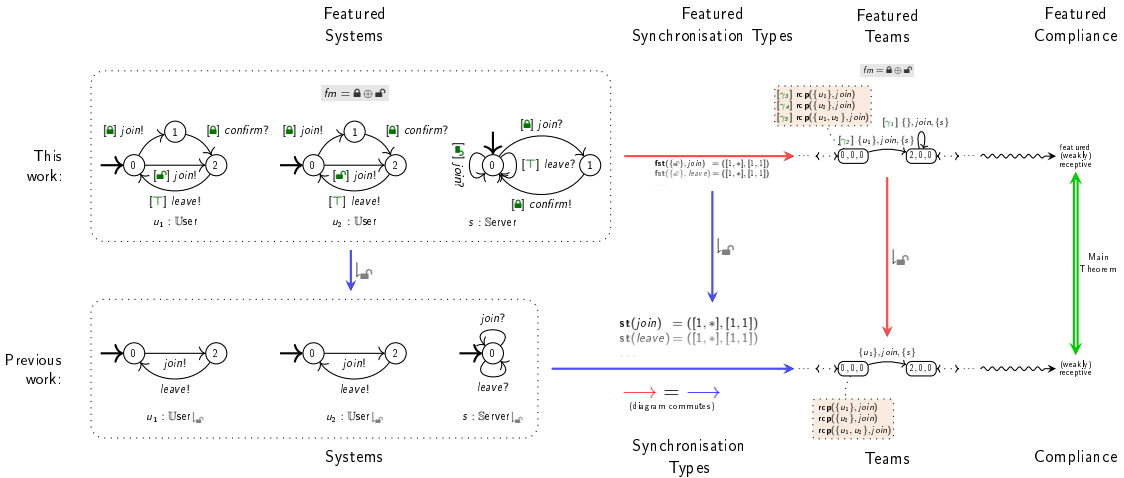
Online prototype

- Specify
- Generate*
- Visualise
- Statistics

*SAT solver to solve *fm*

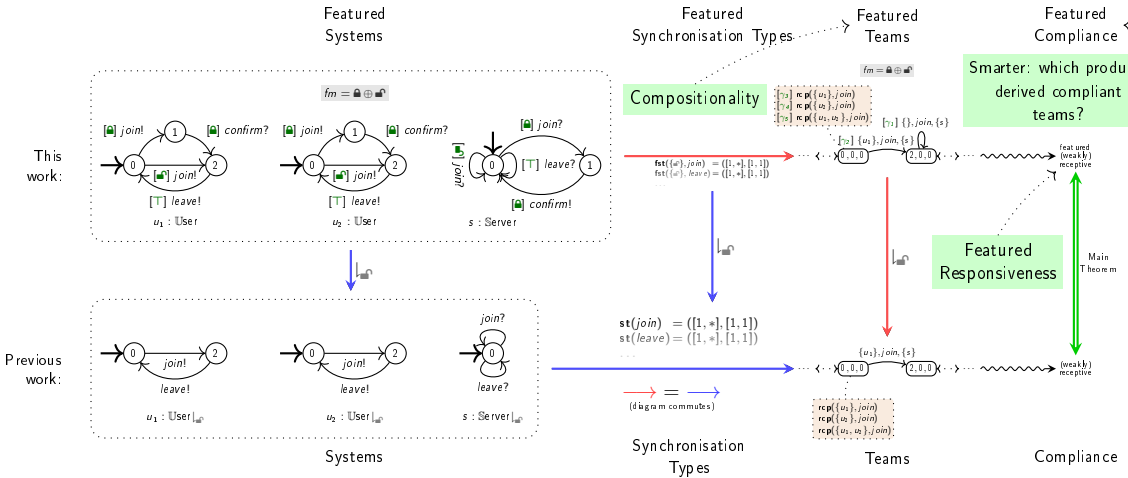


Wrapping up



Online prototype: `http://arcatools.org/feta`

Future work


Featured Systems
Featured Synchronisation Types
Featured Teams
Featured Compliance
This work:
Previous work:
Compositionality
Smarter: which products derived compliant teams?
Featured Responsiveness
Main Theorem
join!
leave!
confirm?
confirm!
[T] leave!
u1 : User
u2 : User
s : Server
(diagram commutes)
Systems
Synchronisation Types
Teams
Compliance
Online prototype: http://arcatools.org/feta
Extentions: e.g. check compliance

Thank you for your attention!
Questions?