Featured Team Automata

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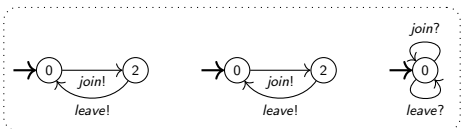
[4]CISTER, ISEP, Polytechnic Institute of Porto, Portugal

T-LADIES kick-off, 6–7 July 2022

Background

Team Automata:[1]

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



Goal: safe communication[3] – *no message loss, no indefinite waiting, ...*

[1] ter Beek, *Team Automata*. Ph.D. thesis, Leiden University, 2003

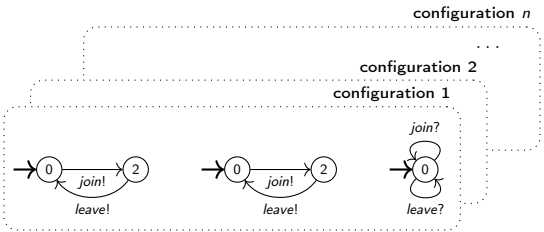
[2] ter Beek, Ellis, Kleijn & Rozenberg, *Synchronizations in team automata for groupware systems*. Comput. Sup. Coop. Work 12, 2003

[3] ter Beek, Hennicker & Kleijn, *Compositionality of Safe Communication in Systems of Team Automata*. ICTAC 2020

Motivation

Many systems today are highly configurable (in terms of features):[4]

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



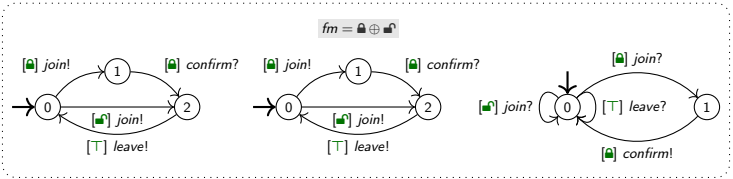
Challenge: system-by-system analysis of safe communication quickly becomes unfeasible

[4] Classen, Cordy, Schobbens, Heymans, Legay & Raskin, *Featured Transition Systems: Foundations for Verifying Variability-Intensive Systems and Their Application to LTL Model Checking*. IEEE Trans. Softw. Eng. 39, 2013

Approach

Featured Team Automata:[5]

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

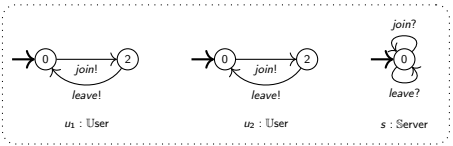


Goal: family-based analysis of safe communication

[5] ter Beek, Cledou, Hennicker & Proença, *Featured Team Automata*. FM 2021

Team Automata

ICTAC'20:



Systems

Team Automata

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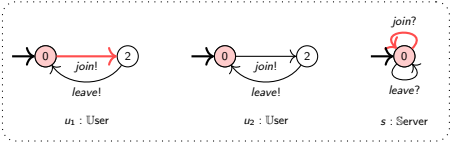

Systems

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

Team Automata

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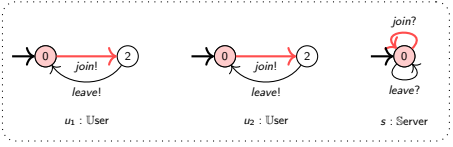

Systems

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Team Automata

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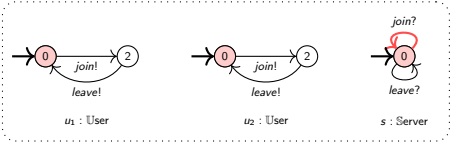

Systems

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

might not be desirable

Team Automata

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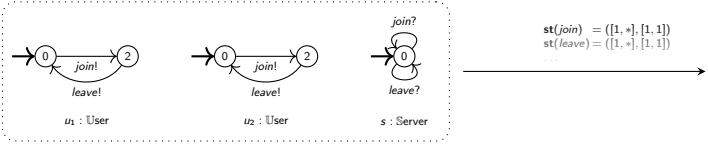

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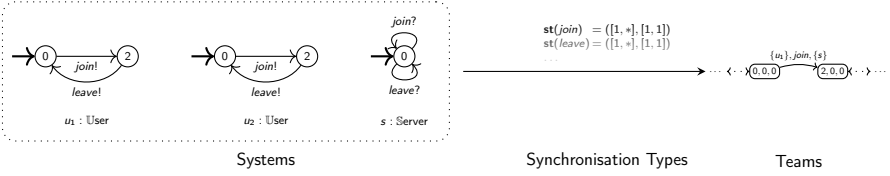

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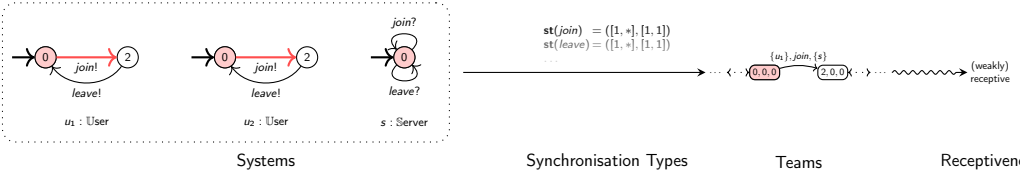

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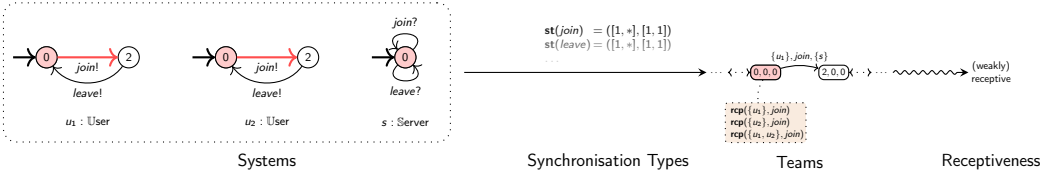

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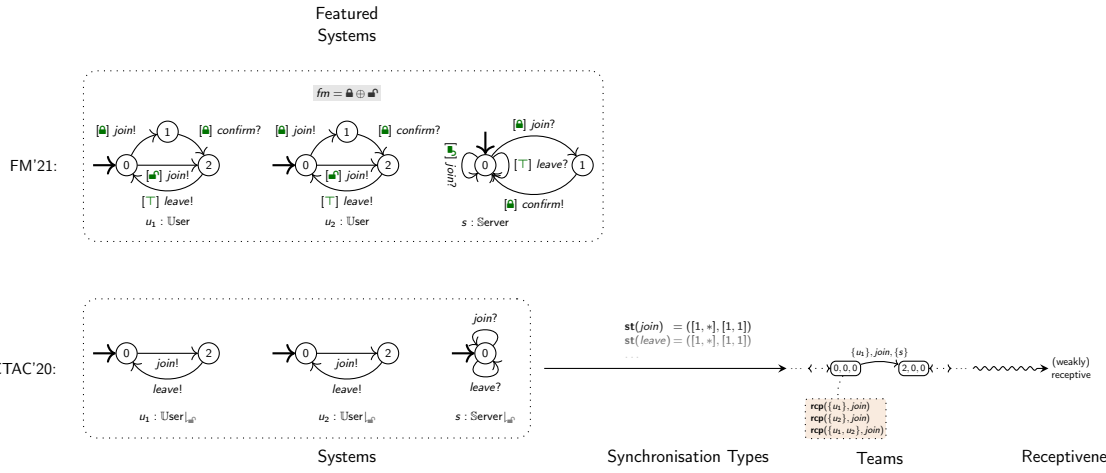

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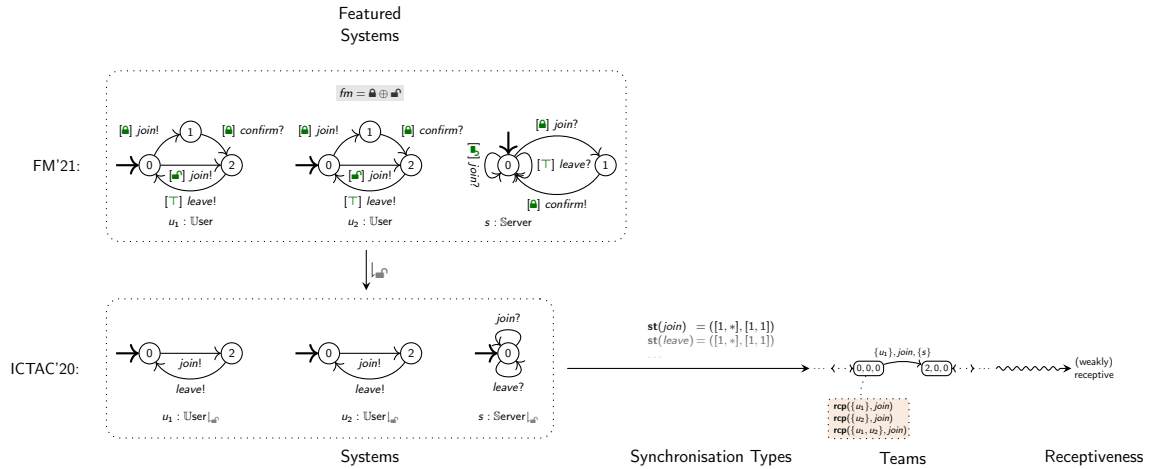

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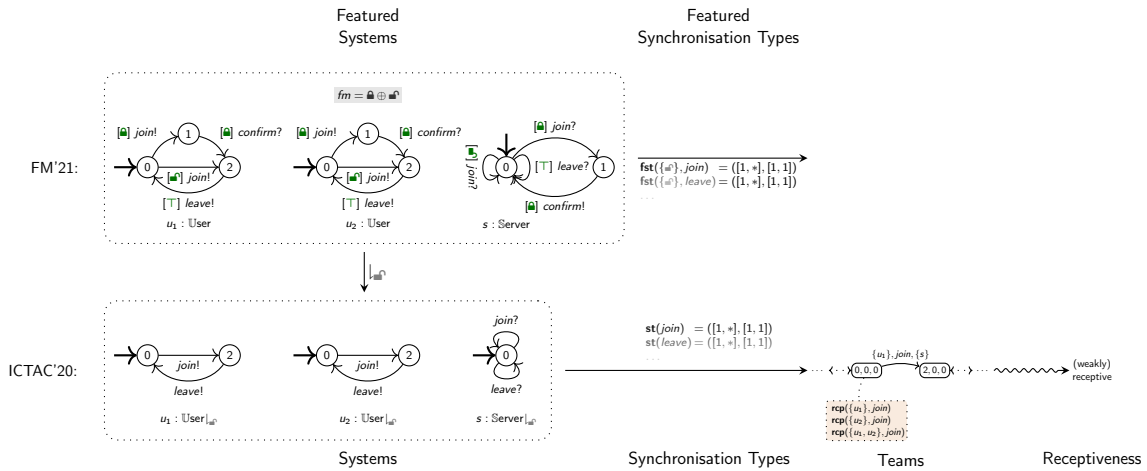

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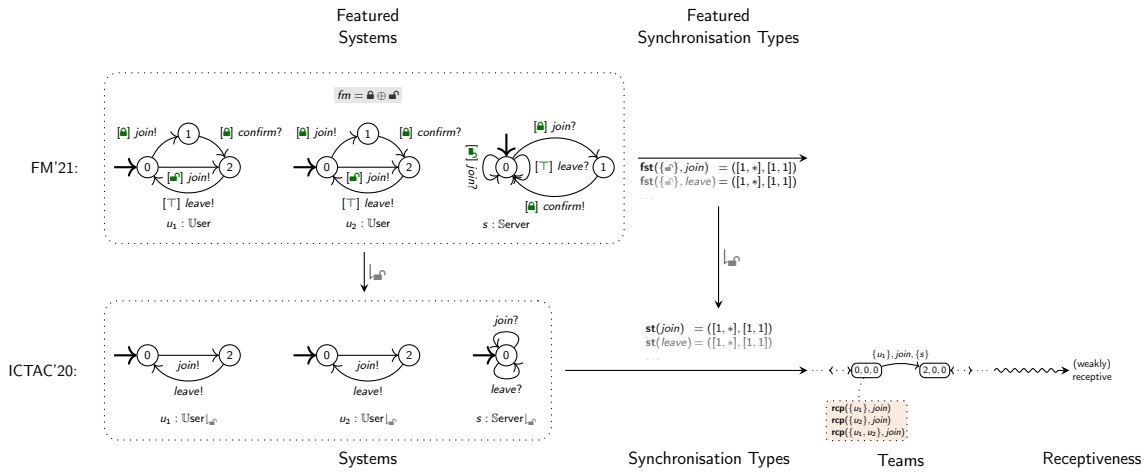

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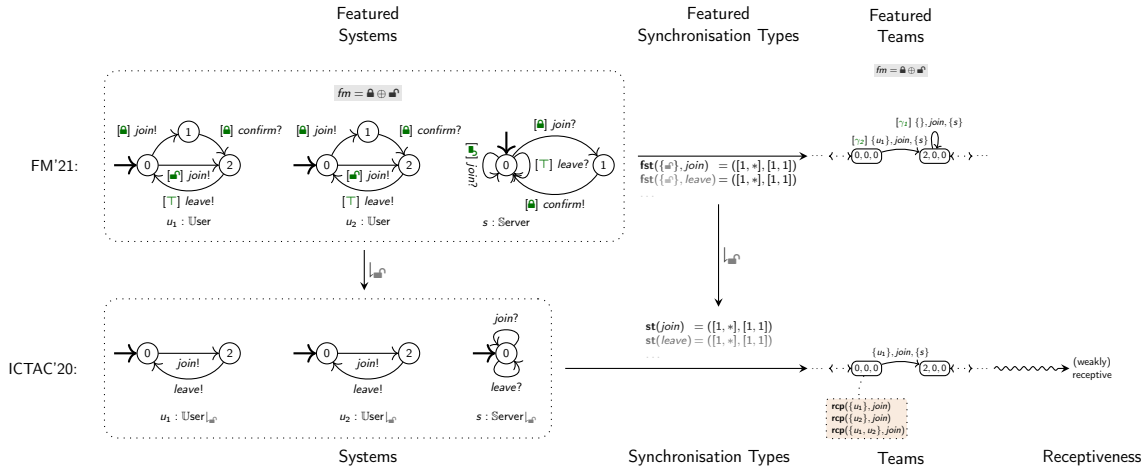

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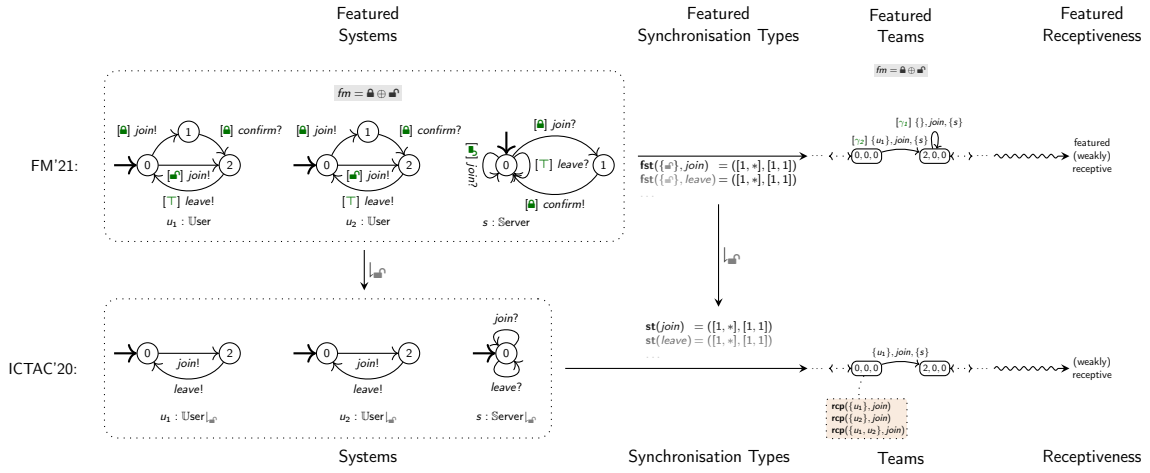

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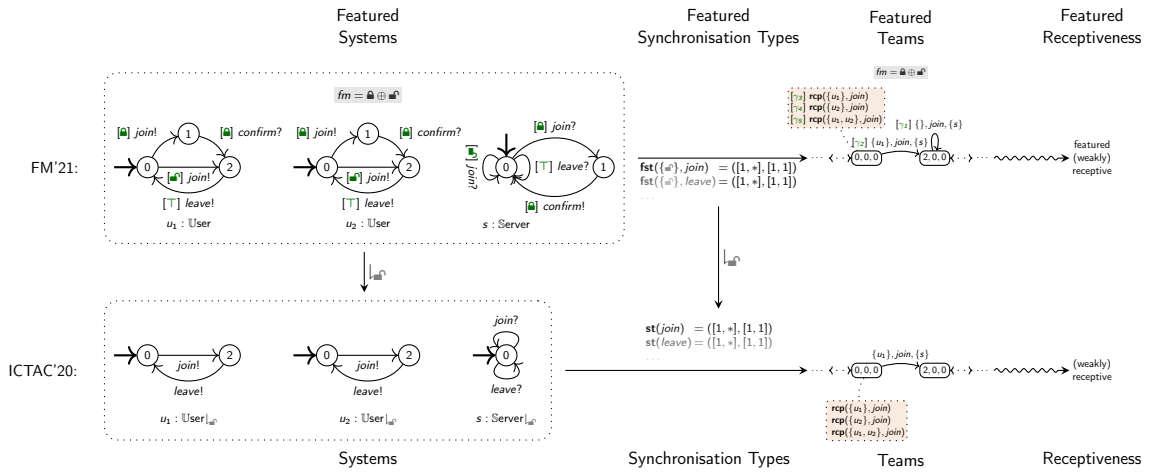

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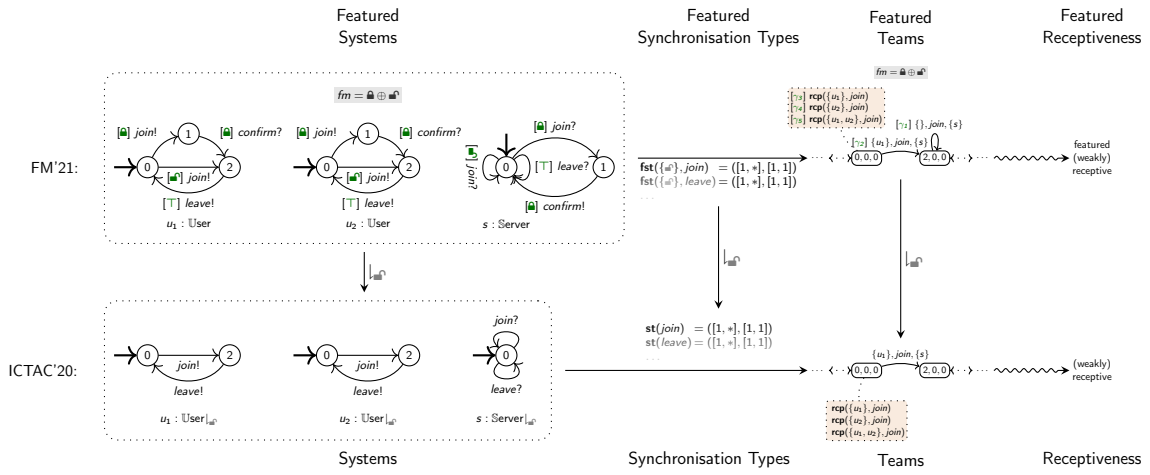

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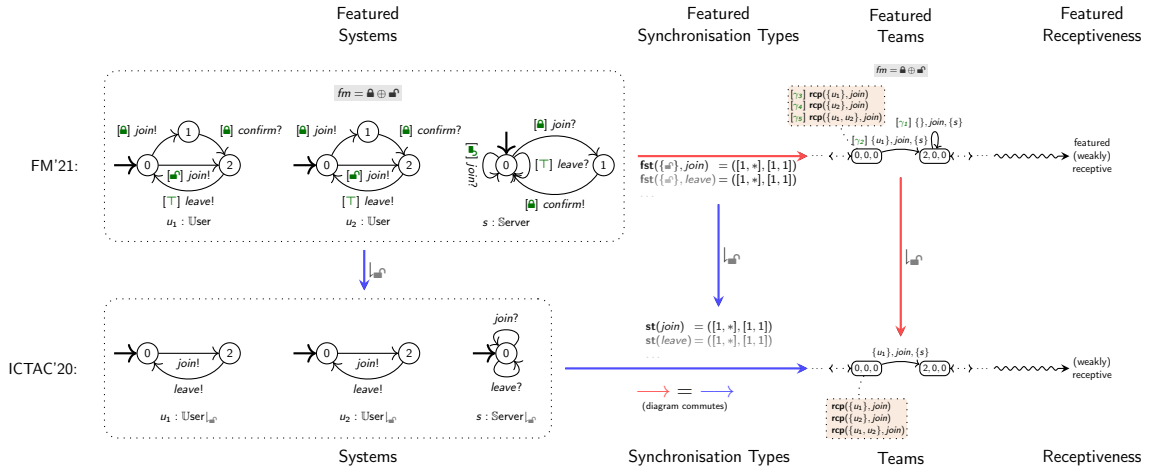

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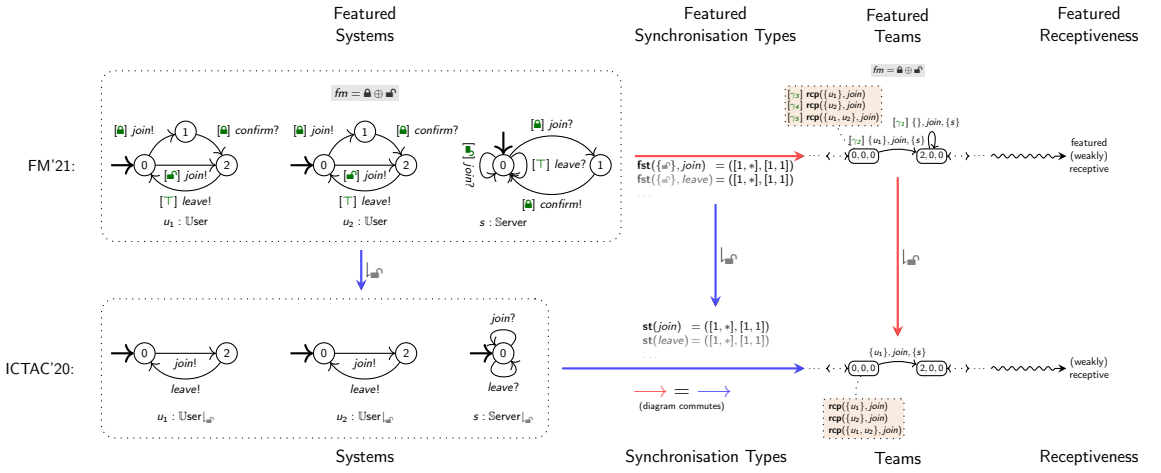

Online prototype: `http://arcatools.org/feta`

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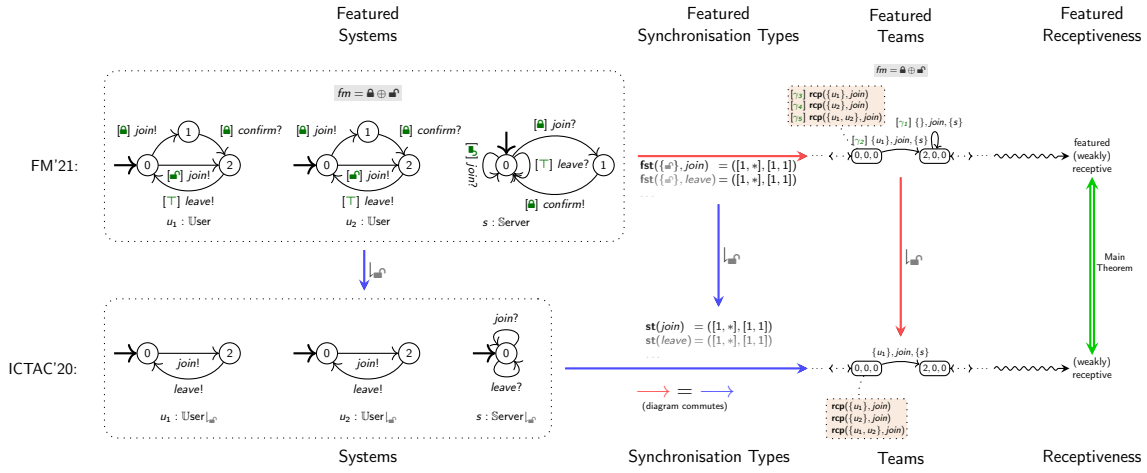

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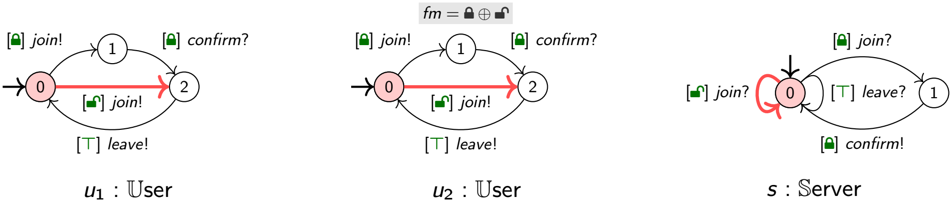
Featured Team Automata Transitions



Transitions are constrained with feature expressions by:

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

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

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

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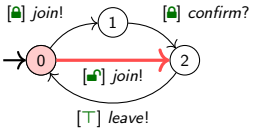
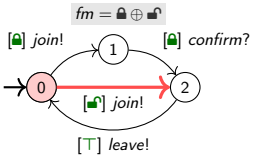
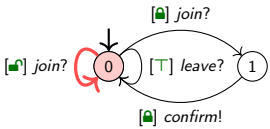


$u_1 : \mathbb{U}\text{ser}$



$u_2 : \mathbb{U}\text{ser}$



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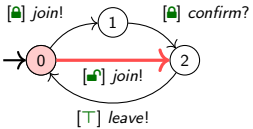

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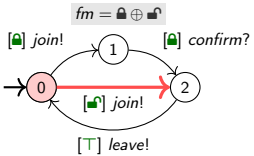

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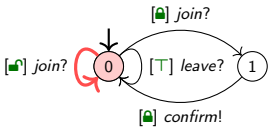

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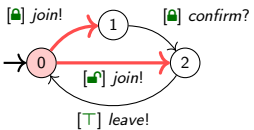
Featured Receptiveness Requirements



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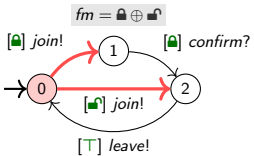

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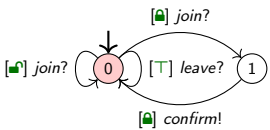

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[ ] $\mathbf{rcp}(\{u_1\}, join)$ $\wedge$ [ ] $\mathbf{rcp}(\{u_2\}, join)$ $\wedge$ [ ] $\mathbf{rcp}(\{u_1, u_2\}, join)$

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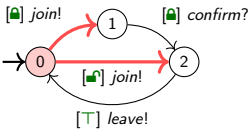

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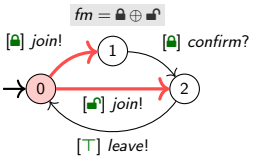

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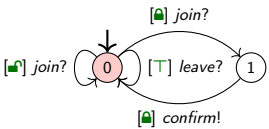

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Featured receptiveness requirements are constrained with feature expression by:

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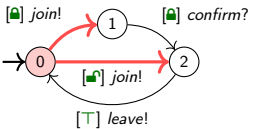

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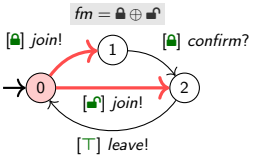

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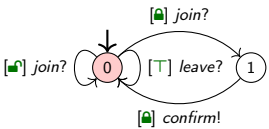

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- local feature expressions: characterise products with enabled local transitions

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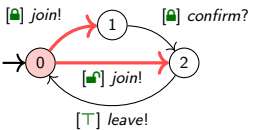

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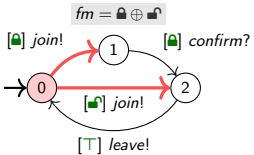

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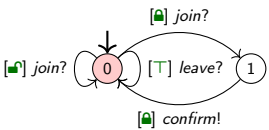

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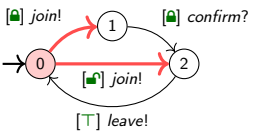

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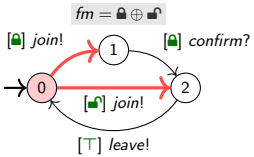

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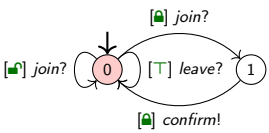

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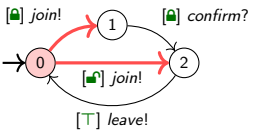
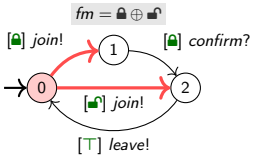
Featured receptiveness requirements are constrained with feature expression by:

- local feature expressions: characterise products with enabled local transitions
- **fst**: characterise products with the correct number of senders

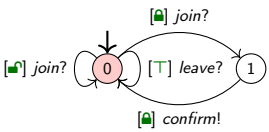
Featured Receptiveness Requirements



$u_1 : \mathbb{U}\text{ser}$



$u_2 : \mathbb{U}\text{ser}$



$s : \mathbb{S}\text{erver}$

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

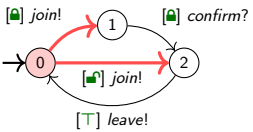
At state $(0,0,0)$:

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

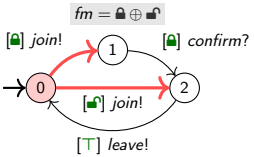
Featured receptiveness requirements are constrained with feature expression by:

- local feature expressions: characterise products with enabled local transitions
- **fst**: characterise products with the correct number of senders

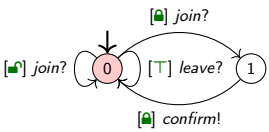
Featured Receptiveness Requirements



$u_1 : \mathbb{U}\text{ser}$



$u_2 : \mathbb{U}\text{ser}$



$s : \mathbb{S}\text{erver}$

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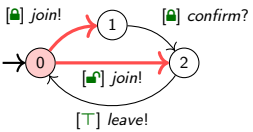
$[🔒 \vee 🔓 \wedge fm]\ \mathbf{rcp}(\{u_1\}, join)\ \wedge\ [\quad]\ \mathbf{rcp}(\{u_2\}, join)\ \wedge\ [\qquad\qquad]\ \mathbf{rcp}(\{u_1, u_2\}, join)$

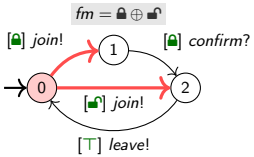
Featured receptiveness requirements are constrained with feature expression by:

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

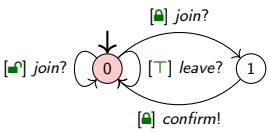
Featured Receptiveness Requirements



$u_1 : \mathbb{U}\text{ser}$



$u_2 : \mathbb{U}\text{ser}$



$s : \mathbb{S}\text{erver}$

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

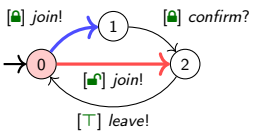
At state $(0,0,0)$:

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

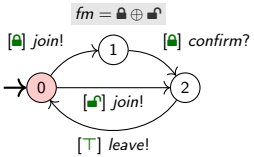
Featured receptiveness requirements are constrained with feature expression by:

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

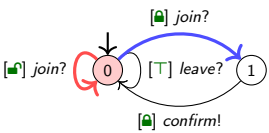
Compliance with requirements



$u_1 : \mathbb{U}\text{ser}$



$u_2 : \mathbb{U}\text{ser}$



$s : \mathbb{S}\text{erver}$

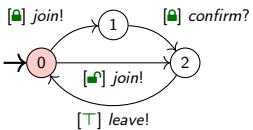
At state $(0,0,0)$:

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

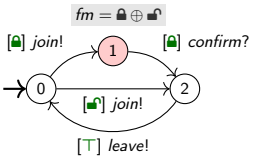
$$\{🔒\} : \ (0,0,0) \xrightarrow{[🔒 \wedge fm]\ (\{u_1\}, join, \{s\})} \mathbf{fst}[\mathcal{S}](1,0,1)$$

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

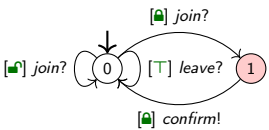
Compliance with requirements



$u_1 : \mathbb{U}\text{ser}$



$u_2 : \mathbb{U}\text{ser}$

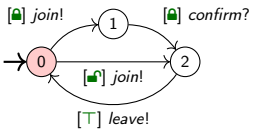


$s : \mathbb{S}\text{erver}$

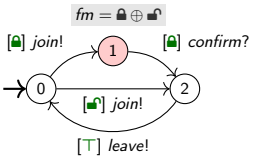
At state $(0, 1, 1)$:

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

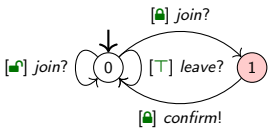
Compliance with requirements



$u_1 : \mathbb{U}\text{ser}$



$u_2 : \mathbb{U}\text{ser}$

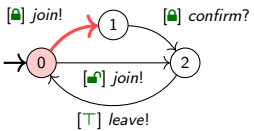


$s : \mathbb{S}\text{erver}$

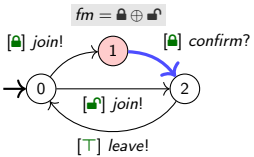
At state $(0, 1, 1)$:

$$\text{✗}[🔒 \wedge \neg 🔓]\ \mathbf{rcp}(\{u_1\}, join)\ \wedge\ \ldots$$

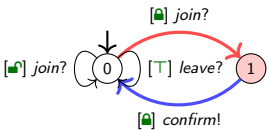
Weak compliance with requirements



$u_1 : \mathbb{U}\text{ser}$



$u_2 : \mathbb{U}\text{ser}$



$s : \mathbb{S}\text{erver}$

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

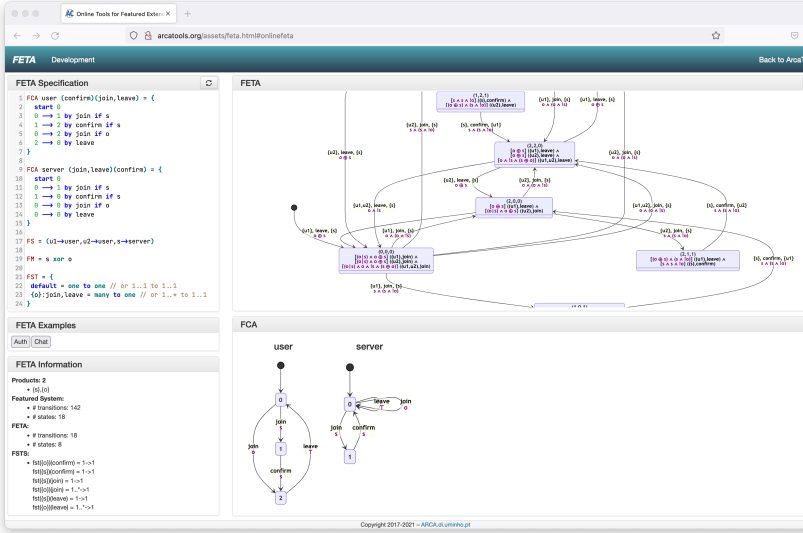
$$[🔒 \wedge \neg 🔓]\ \mathbf{rcp}(\{u_1\}, join)\ \wedge\ \ldots$$

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

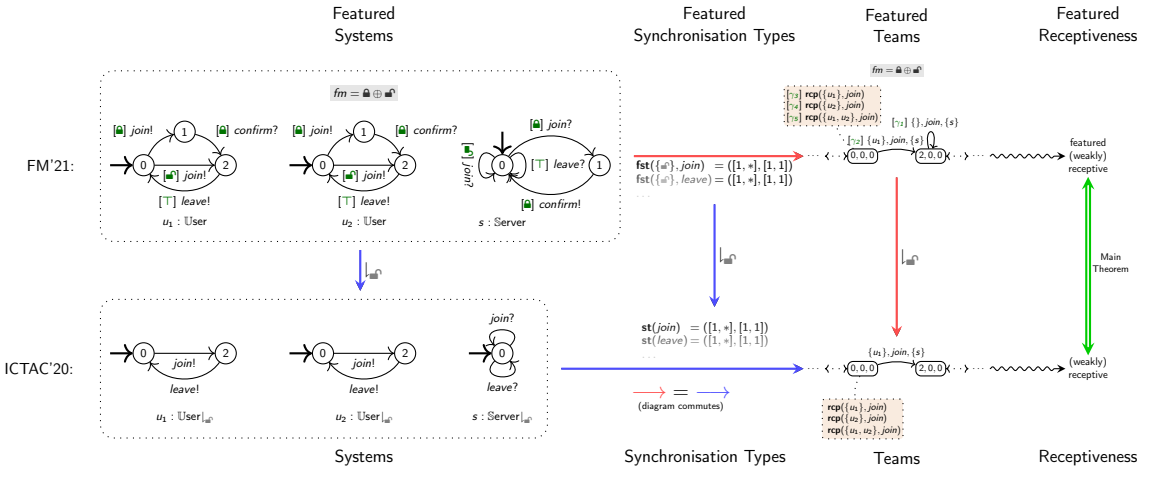
Online prototype

- Specify
- Generate*
- Visualise
- Statistics

*SAT solver to solve *fm*

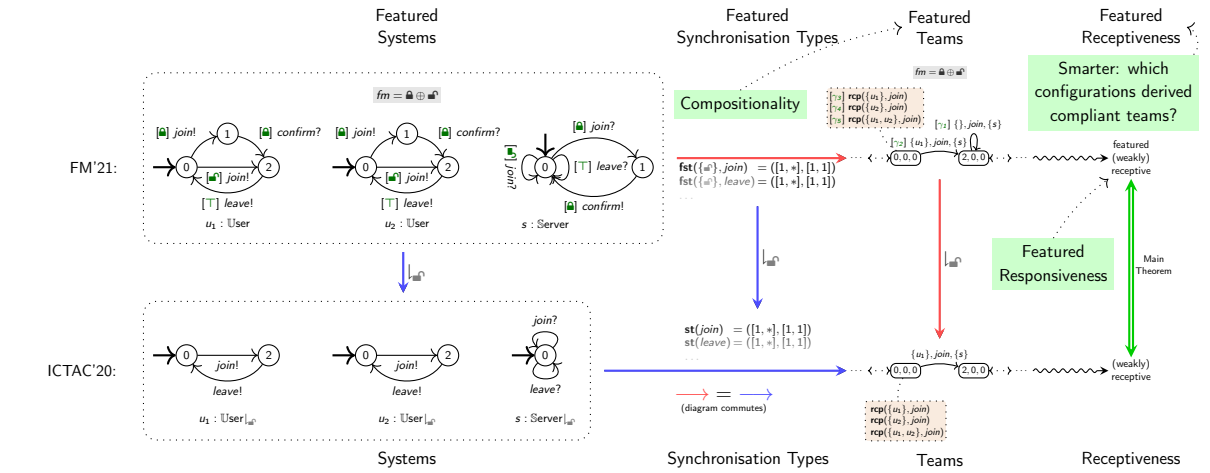


Wrapping up



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

Future and ongoing work



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

Extentions (e.g. FM'23: generate requirements as PDL formulae and check compliance with mCRL2

Thank you for your attention!
Questions?

Formal Methods and Tools Lab