Immediate Observation in Mediated Population Protocols

Tobias Prehn Myron Rotter

Technische Universität Berlin

Modelle und Theorie Verteilter Systeme

31 October 2019
@ Munich

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& several other things

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$$\text{system} \quad > \quad \sum \text{parts}$$

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system	$>$	$\sum$ parts
global	vs.	local

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$$\begin{array}{rcl} \text{system} & > & \sum \text{parts} \\ \text{global} & \text{vs.} & \text{local} \\ \text{top-down} & \text{vs.} & \text{bottom-up} \end{array}$$

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Javier Esparza @ Marktoberdorf 2015

Parameterized Verification of Crowds of Anonymous Processes

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Preliminaries

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$$SEM \xrightarrow{\text{[D. Angluin et al. 2004 / 2007]}} \mathbf{PP}$$

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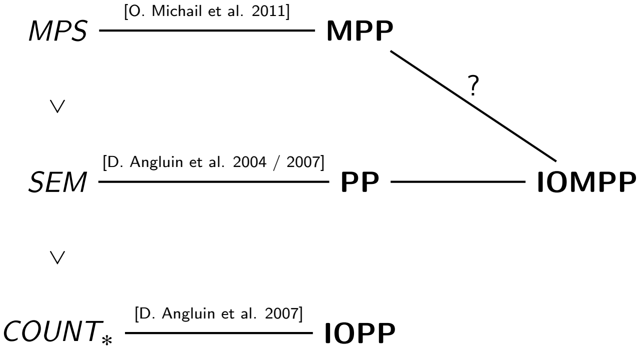

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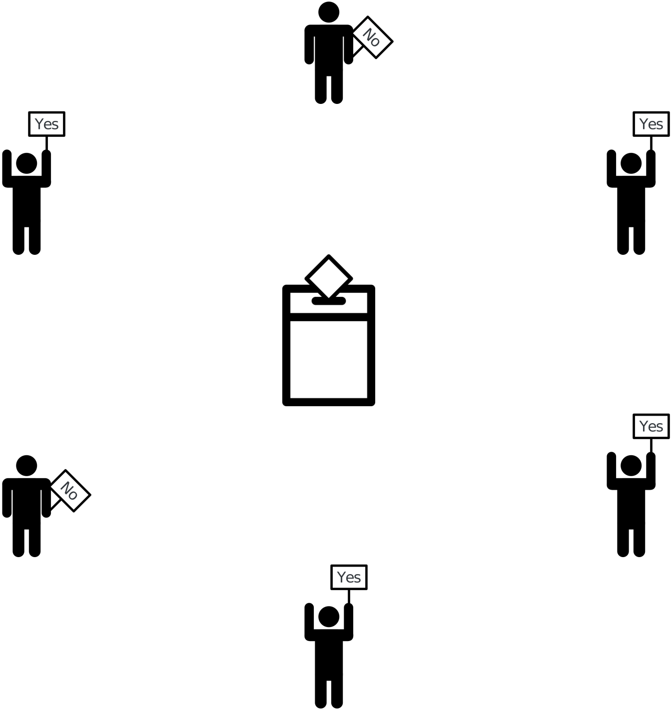
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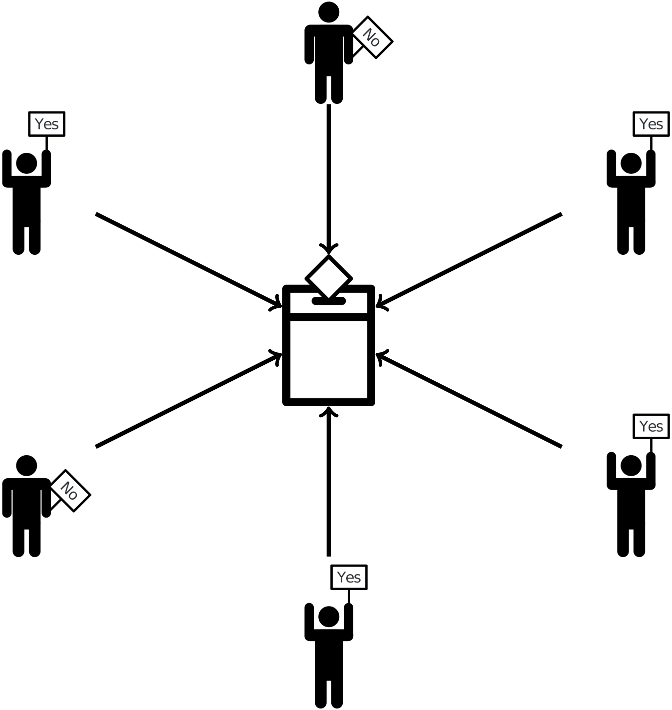
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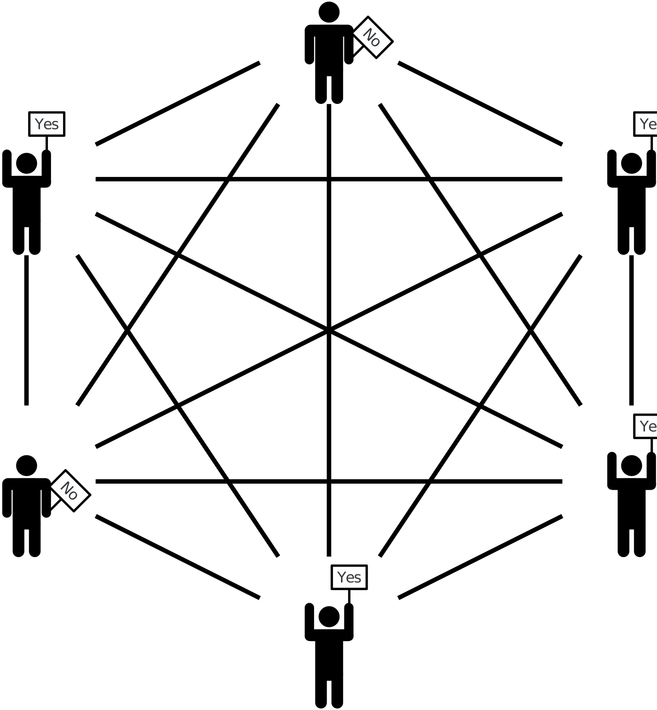
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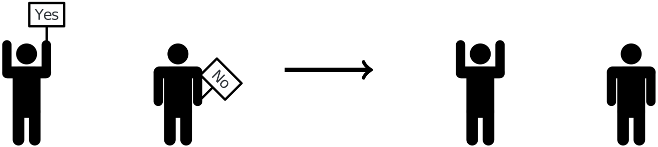
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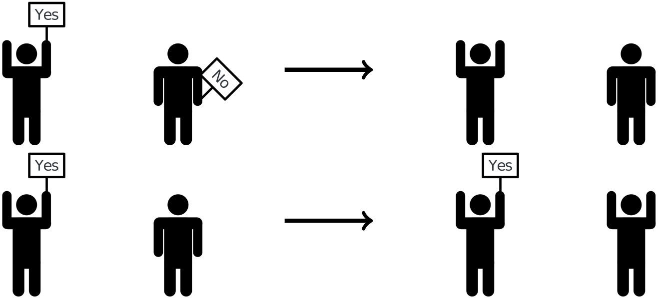
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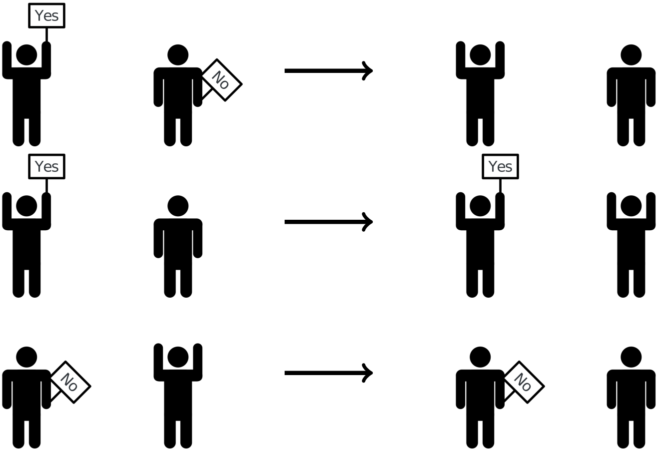
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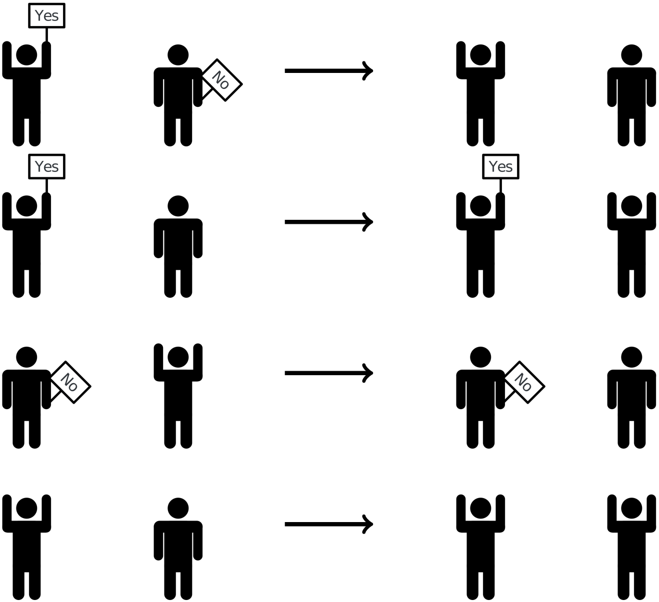

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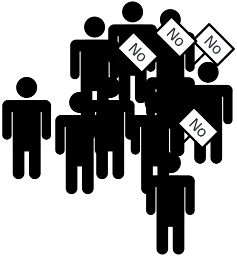

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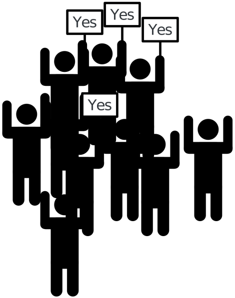

Population Protocols

Model designed to represent sensor networks consisting of
very limited mobile agents
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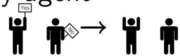
- computation by direct interaction 

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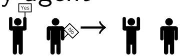
- computation by direct interaction 

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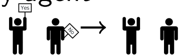
- computation by direct interaction 

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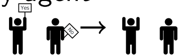
- computation by direct interaction 

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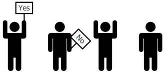

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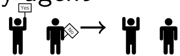

- distributed inputs and outputs
- convergence instead of termination
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- anonymous

Model — PP [D. Angluin et al. 2004]

A protocol $P = (Q, \Sigma, I, O, \delta)$ is formally specified by

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↳ computational power:
SEM (modulo, threshold, and boolean combinations)

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$COUNT_*$ (count number of initial states)

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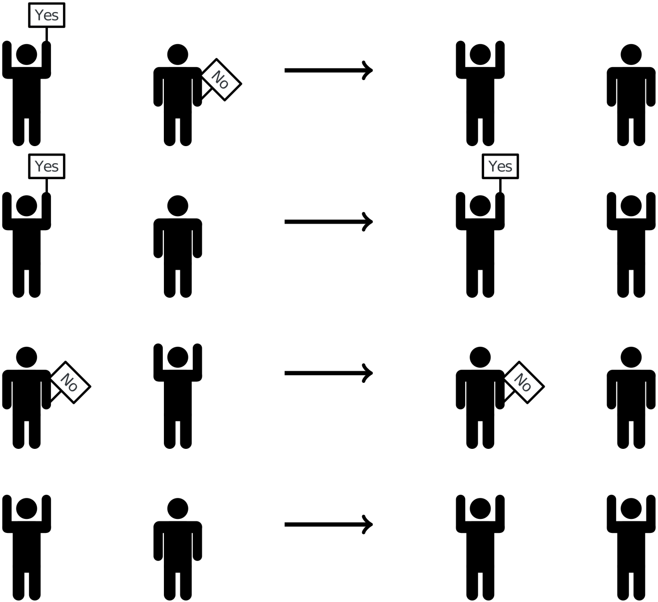

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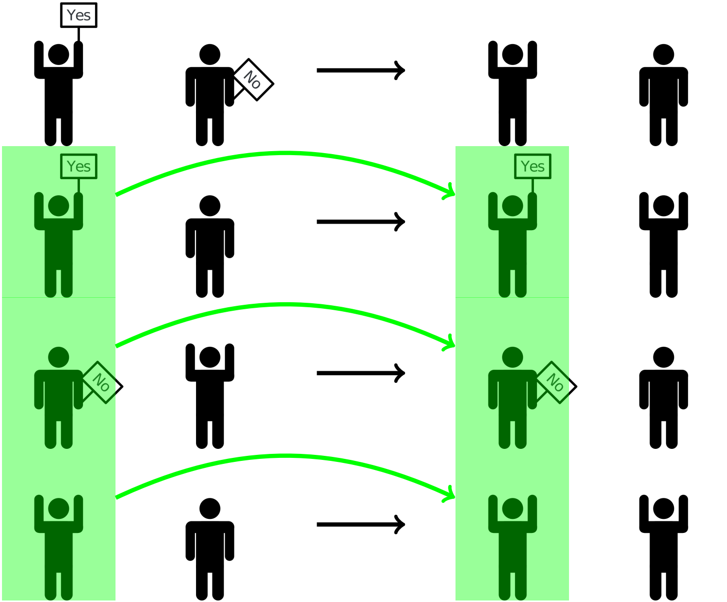

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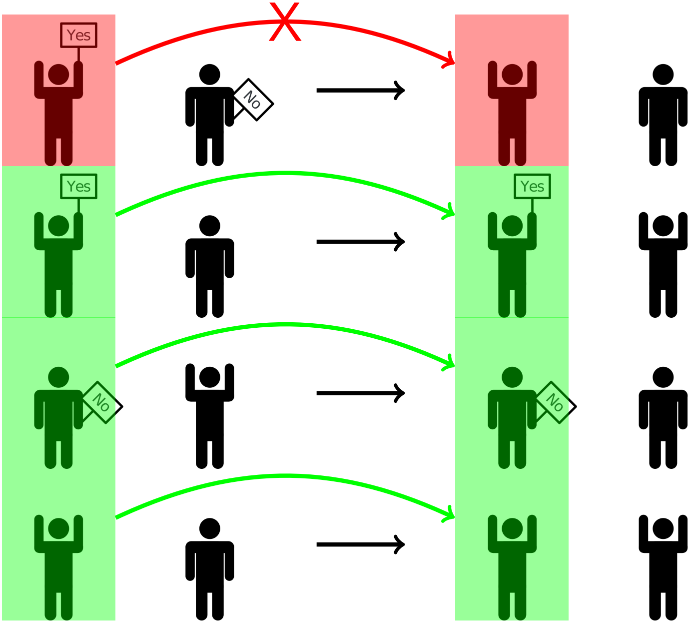

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MPS (symmetric predicates in NSPACE(n^2))

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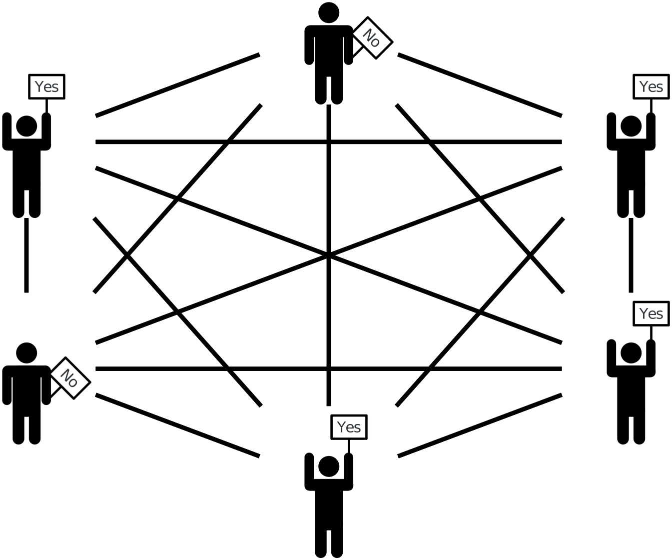

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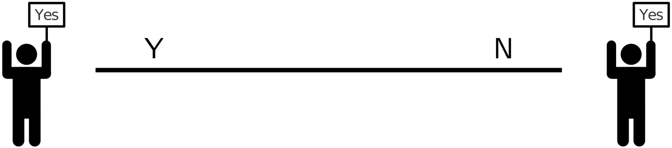

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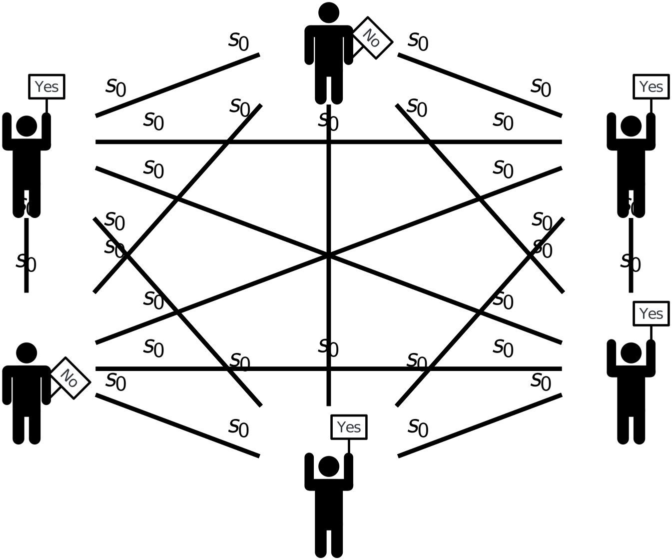

Model — IOMPP

An immediate observation mediated population protocol P is a 7-tuple $P = (Q, \Sigma, \qquad I, O, \delta)$

- Q, a finite set of agent states
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  $\delta(p, s, q, r) = (p, s, q', r')$

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↳ criteria for encodings to be good

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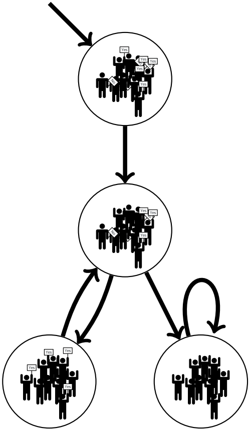
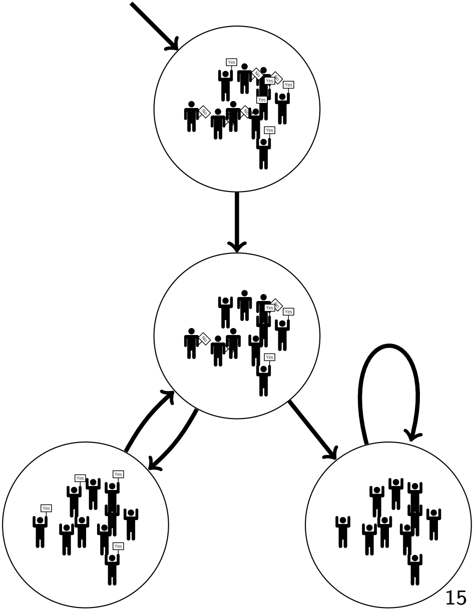
D. Gorla 2010 — *Towards a unified approach to encodability and separation results for process calculi*
↳ criteria for encodings to be good

Original configurations can be translated to configurations of the “good” simulation such that the following criteria hold.

Translation Criteria





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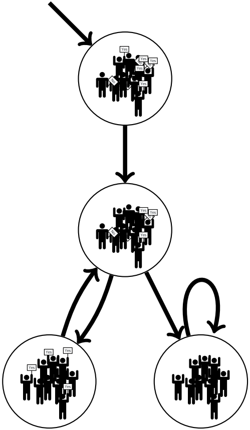

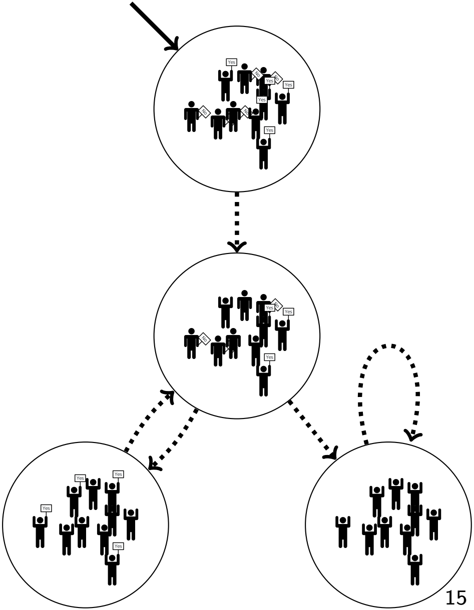

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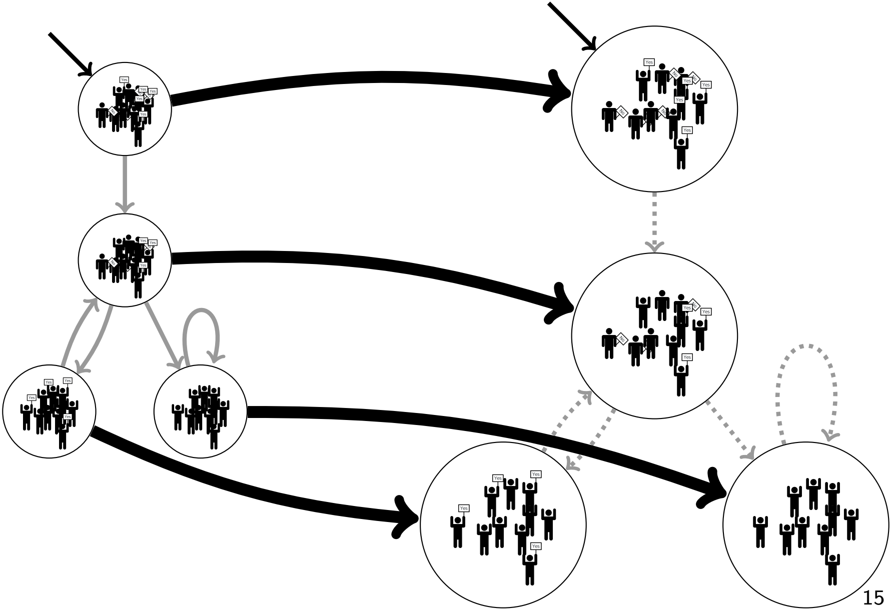
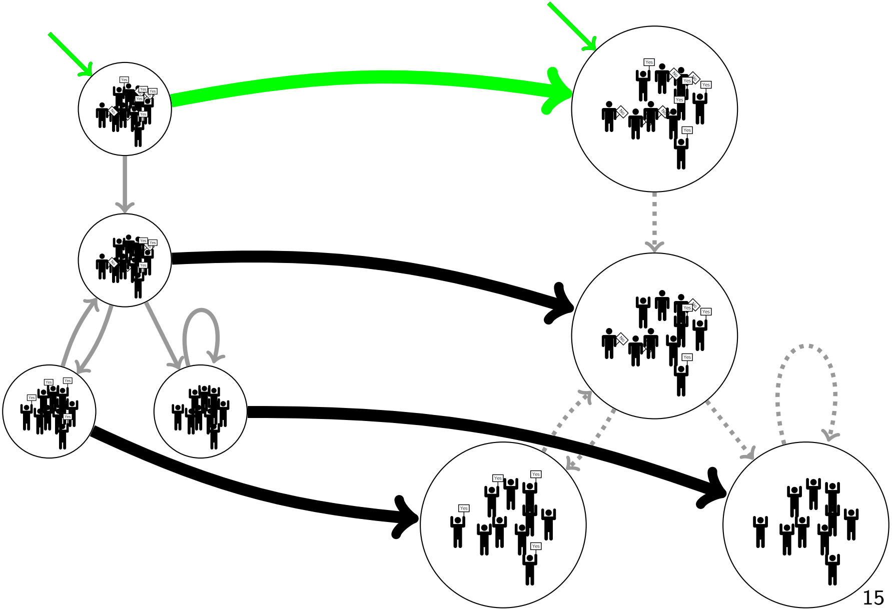


Translation Criteria - Input Correspondence



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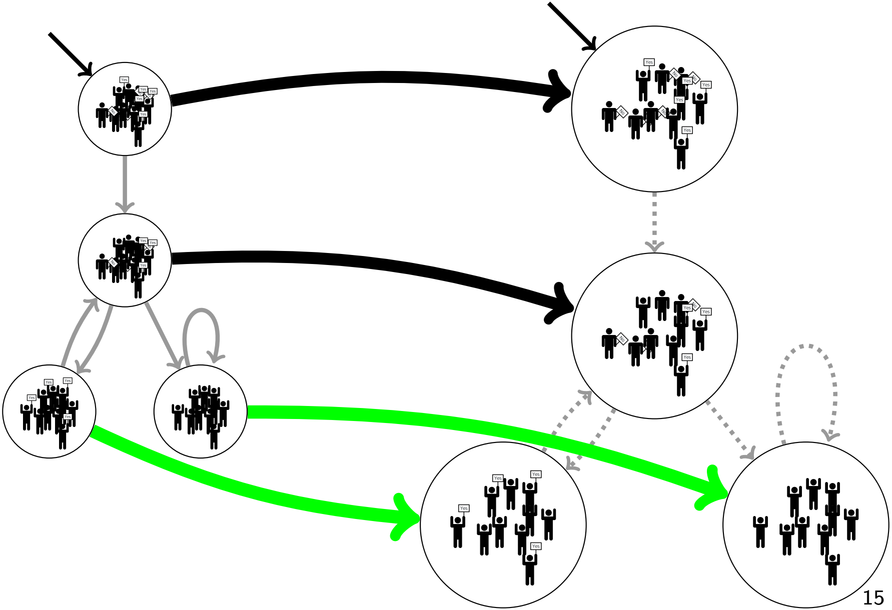
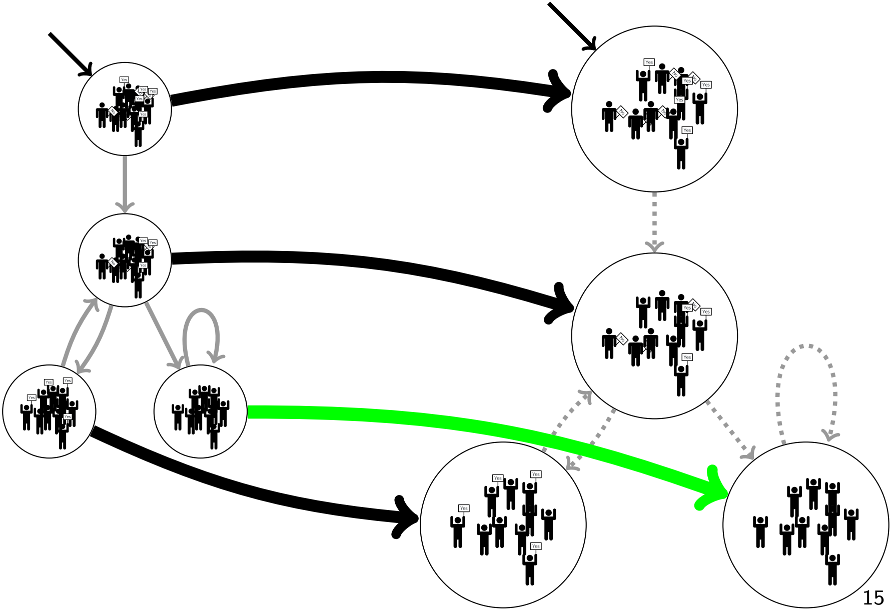
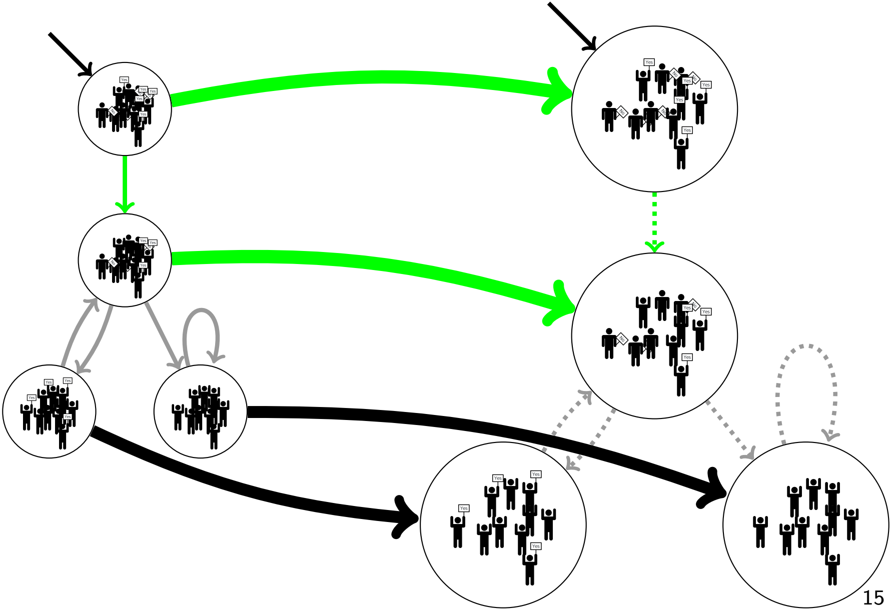


Translation Criteria - Output Stability Preservation



Translation Criteria - Operational Correspondence [Gorla]



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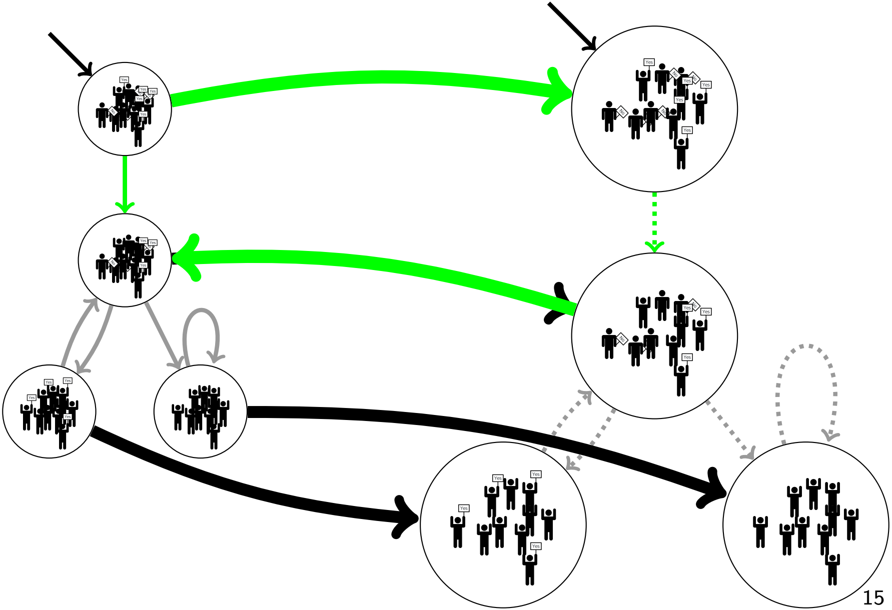

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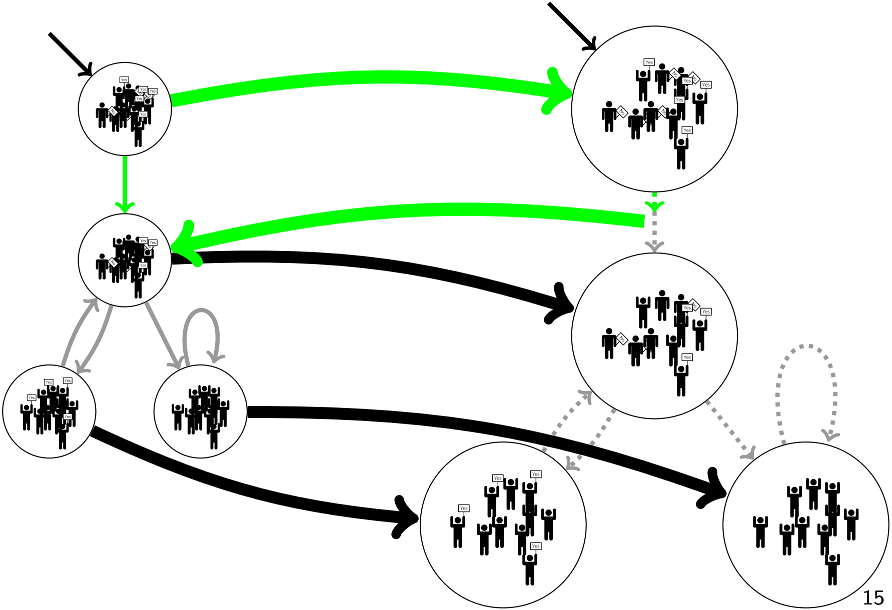

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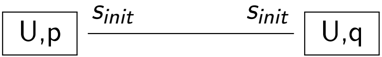

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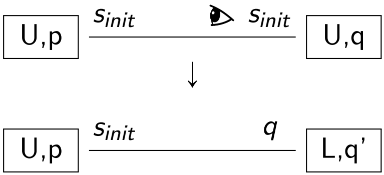

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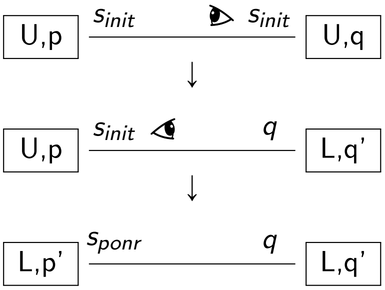

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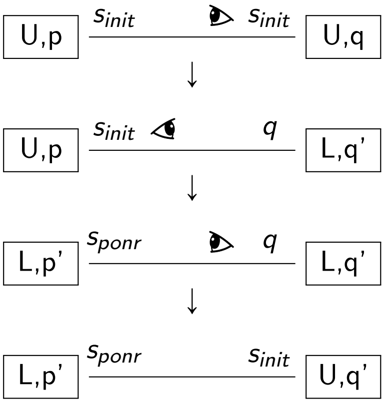

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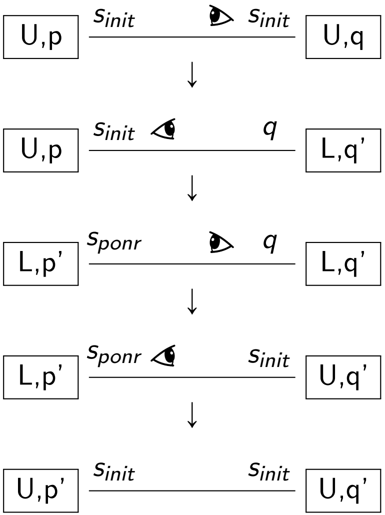

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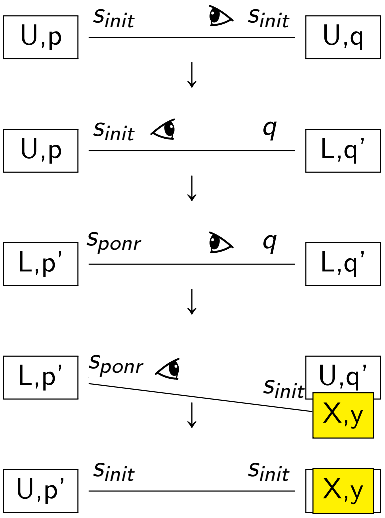

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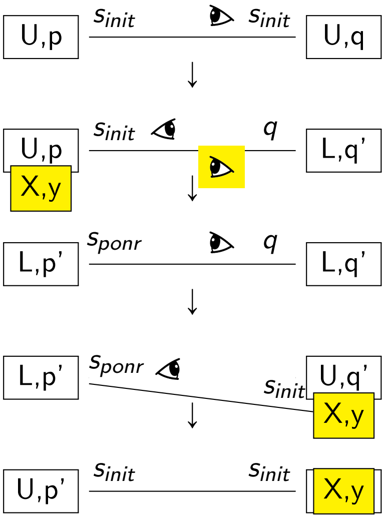

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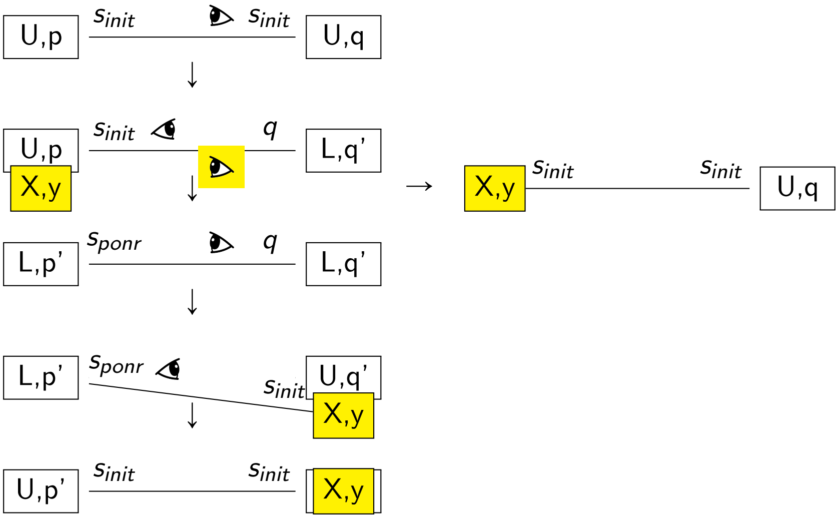

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- existence of key configurations / transitions
- (failure resistance)

Future Work I — IOMPP

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Future Work I — IOMPP

- criteria for a "good" simulation
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  $\Rightarrow$ IO does not weaken MPP

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Future Work I — IOMPP

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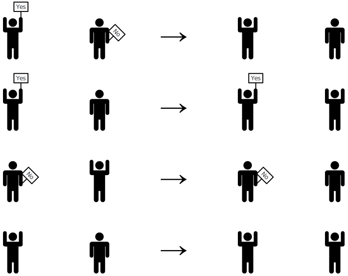
Future Work II — Well-Specified Transitions

Can we (sometimes) decide that a PP is well-specified by looking at the transitions?

or: Can we define designing guidlines for transitions that will, if followed, guarantee a well-specified PP?

Future Work II — Well-Specified Transitions



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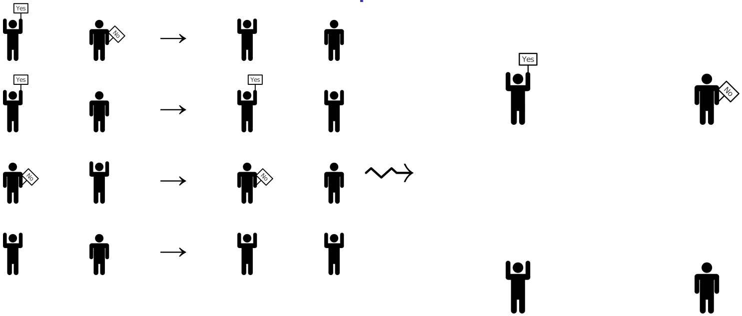

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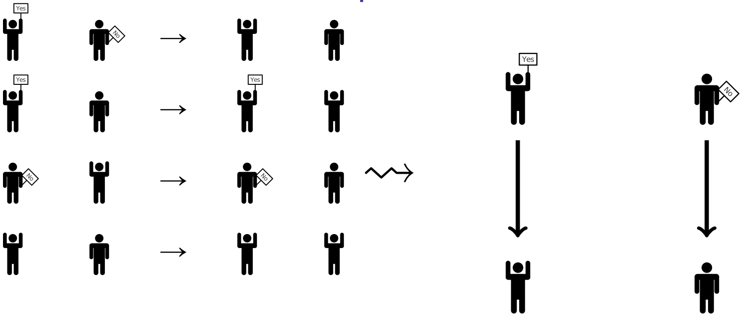

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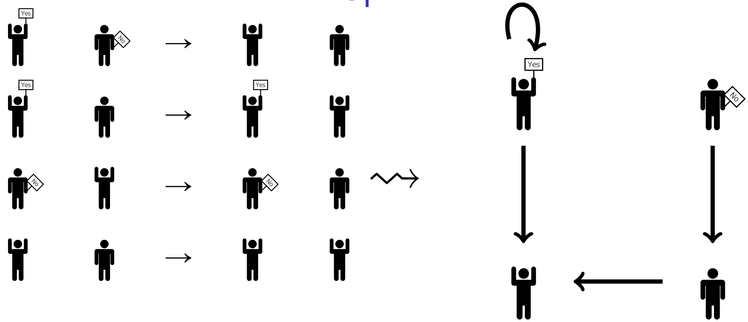

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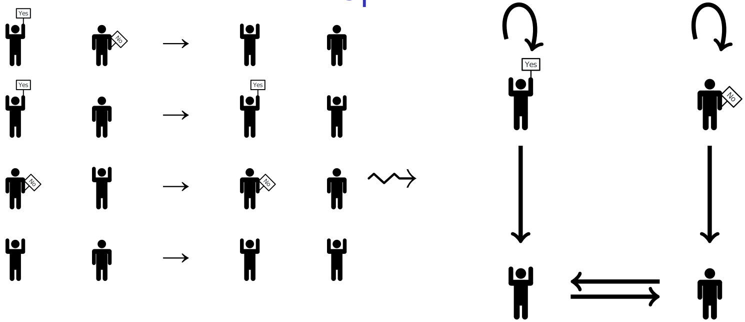

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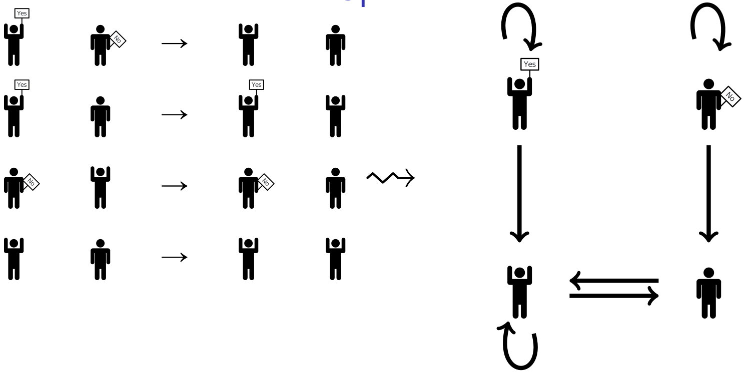

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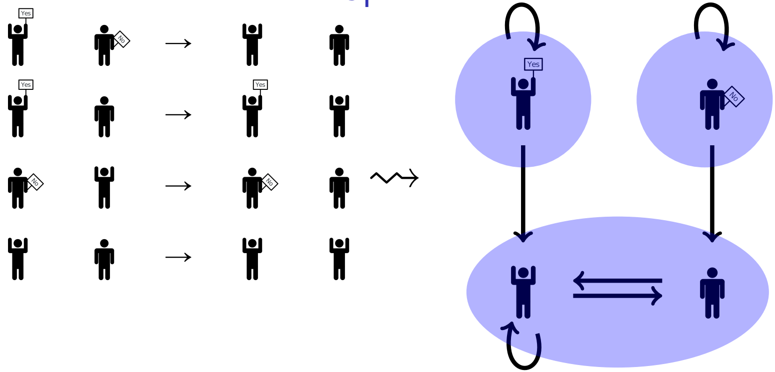

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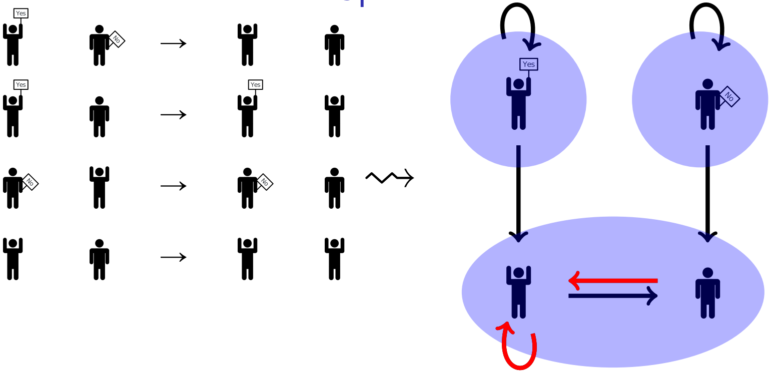

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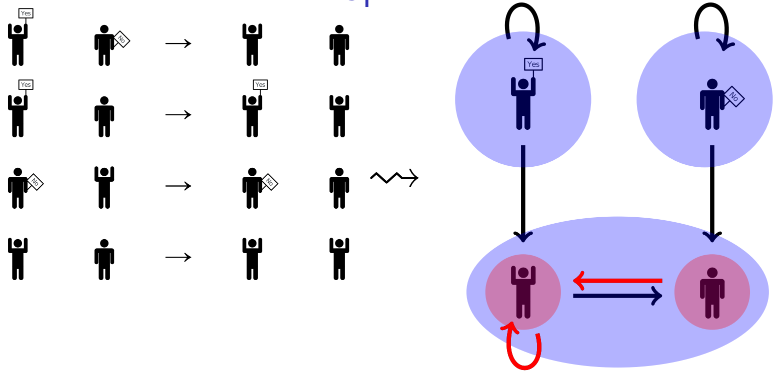

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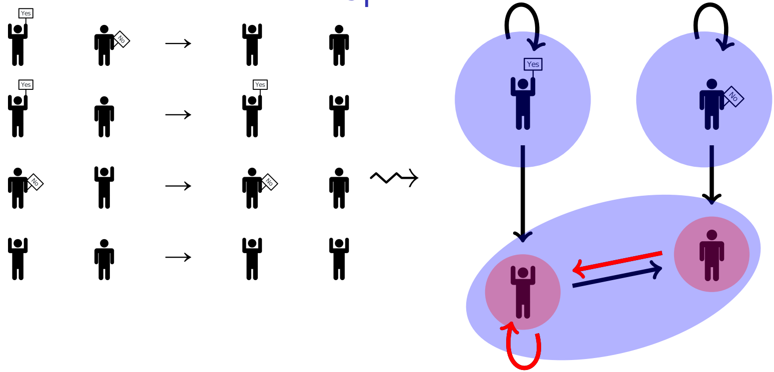

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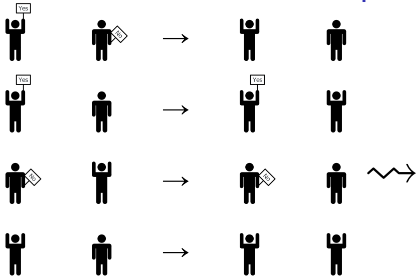
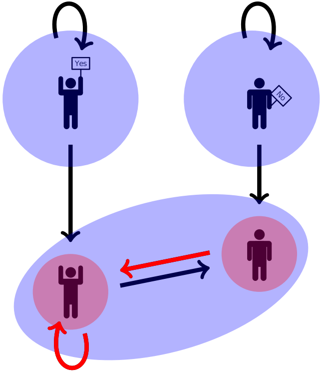




Transitions may be:

Identity:

$(p, q) \rightarrow_{\delta_P} (p, q)$ where $O(p) = O(q)$

Layer-Weakening:

$(p, q) \rightarrow_{\delta_P} (p', q')$ where $q' \ll q$ and $p' \ll= p$

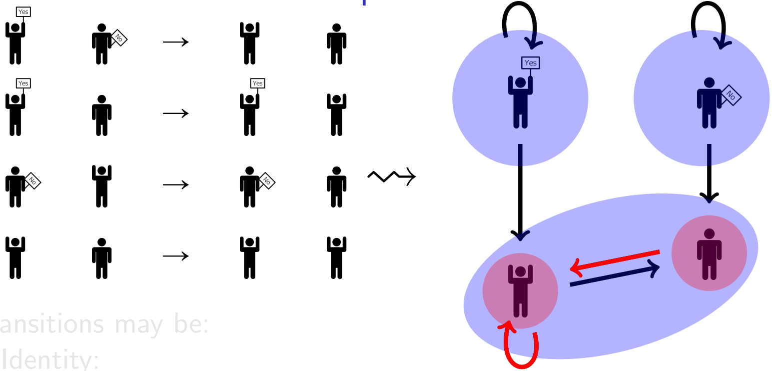
Sub-Layer-Weakening:

$(p, q) \rightarrow_{\delta_P} (p', q')$ where $p == q$ and $q' < q$ and $p' <= p$

Higher-Layer-Id-Convincing:

$(p, q) \rightarrow_{\delta_P} (p, q')$ where $q \ll p$ and $O(p) = O(q')$

Future Work II — Well-Specified Transitions



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$\Rightarrow$ “Termination” / Convergence ?
$\not\Rightarrow$ predetermined output

Future Work II — Well-Specified Transitions

From Blondin, Esparza, Kučera - CONCUR 2018:

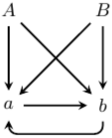
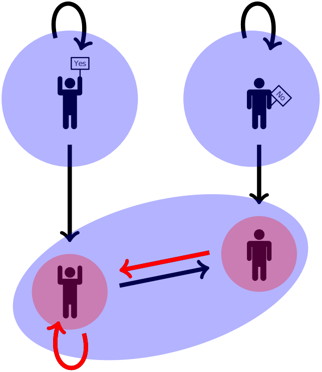


Figure 2 Transformation graphs of Example 8.



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Future Work III — Crash Failure Resistance

Crash and transient failures via split-simulate-majority vote

Delporte-Gallet et al. (2006) - *When birds die: Making population protocols fault-tolerant.*

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simple threshold k (with c crashes):

$(\#A \geqslant k)$

x	y	$\to$	x+y	0
k	y	$\to$	k	k

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$$\begin{array}{cccccc} x & y & \rightarrow & x+y & 0 \\ k & y & \rightarrow & k & k \end{array} \quad \text{vs.} \quad \begin{array}{cccccc} x & x & \rightarrow & x & x+1 \\ k & y & \rightarrow & k & k \end{array}$$

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$\#A \geqslant k + c$

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x	y	→	x+y	0			x	x	→	x	x+1
k	y	→	k	k	vs.		k	y	→	k	k

$\#A \geqslant k + c \cdot 2 \cdot (k-1)$ $\#A \geqslant k + c$

Future Work

IOMPP

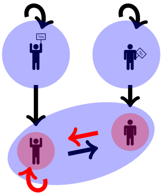
- simulation for MPP in IOMPP

  $\Rightarrow$ IO does not weaken MPP

Translation Criteria

- criteria for a "good" simulation
- study preserved attributes
- study PP with no predicate

Well-Specified Transitions



Transitions may be:

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Crash Failure Resistance

- find resistant protocols
- other failures
- other failure handling strategies