RESEARCH SEMINAR “AI: FROM TUTORIALS TO HANDS ON”

THE QUEST TOWARDS COORDINATION FROM DISTRIBUTED TO SOCIO-TECHNICAL SYSTEMS

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COMPLEXITY OF MODERN SYSTEMS CALLS FOR PRINCIPLED APPROACHES TO GOVERN INTERACTIONS BETWEEN THEIR DISTRIBUTED COMPONENTS---NAMELY, COORDINATION.

THIS SEMINAR WILL TAKE YOU ACROSS THE LANDSCAPE OF COORDINATION MODELS, LANGUAGES, AND TECHNOLOGIES, FROM DISTRIBUTED COMPUTING TO SOCIO-TECHNICAL SYSTEMS.

Abstract

OUTLINE

- Basics of interaction & coordination
- Tuple-based coordination
- Coordination technologies
- Situated coordination
- Socio-technical systems
- Anticipatory coordination
- Blockchain and coordination

ISSUES IN DISTRIBUTED SYSTEMS

- Concurrency / Parallelism: multiple independent activities / loci of control active simultaneously
- Distribution: activities running on different and heterogeneous execution contexts
- Social interaction
  - dependencies among activities
  - collective goals involving activities coordination / cooperation
- Situated interaction
  - interaction with environmental resources (computational or physical)
  - interaction within the time-space fabric

NON-ALGORITHMIC COMPUTATION

- Component = computational abstraction with
  - own computational activity
  - I/O capabilities
- => Two (orthogonal?) dimensions
  - computation
  - **interaction**
    - Turing's choice machines and unorganised machines
    - Wegner's Interaction Machines

GOVERNING INTERACTION

- *"A coordination model is the* glue *that binds separate activities into an ensemble"* –Gelertner and Carriero, 1992
- *"A coordination model provides a* framework *in which the interaction of active and independent entities called agents can be expressed"* –Ciancarini, 1996
- A coordination model:
  - provides high-level **abstractions** and expressive **mechanisms**
  - adds **properties** to systems independently of components (e.g. self-org.)

COORDINATION MODELS

- Control-oriented: focus on communication acts (e.g. send, receive, …)
  - message-based (e.g. Reo, FIPA protocols)
  - coordination as configuration of communication topology
- Data-oriented: focus on data exchange (e.g. put, take, …)
  - space-based (e.g. Linda, Bach)
  - coordination as ruling dependencies between data and activities

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LINDA MODEL

- Tuple: ordered collection of data chunks
- Template: ordered collection of placeholders for data chunks
- Matching mechanism: binds placeholders to data chunks
- Tuple space: tuples repository
- Operations:
  - out(t) to put a tuple t in the space
  - in(T) to withdraw a tuple matching template T from the space
  - rd(T) to read a tuple matching template T from the space

LINDA PROPERTIES

- **Generative communication**: tuples live independently w.r.t. their producers, are equally accessible to every process, are bound to none
- **Associative access**: tuples accessed based on content & structure, not name, address, or location
- **Suspensive semantics**: operations (in, rd) suspended when missing matching tuples, then resumed when such tuples become available
- => Data-driven synchronisation of activities based on partial knowledge

LINDA LIMITATIONS

- Tuple space behaviour immutable:
  - problems easy to express in terms of operations fit well
  - others don't
- Introducing ad-hoc operations not scalable or general purpose solution
- "Burden of coordination" charged upon interacting processes
  - violating software engineering principle of separation of concerns

TUPLE CENTRE MODEL

- Tuple space + behaviour specification: reactions of a tuple centre in response to coordination events
  - expressed in terms of a reaction specification language
  - associates events to computations
- Reactions can:
  - access & modify tuple space
  - access event meta-data
- => Tuple centre behaviour mutable (**programmable**) to fit different needs

TUPLE CENTRE CYCLE

1. Operation requested (event), corresponding reactions (if any) triggered, then executed **atomically** and **transactionally** in a **non-deterministic order**
2. Once reactions executed, operation is served
3. Upon completion (event), corresponding reactions (if any) triggered, then executed as for §1
4. Once reactions executed, restart from §1

TUPLE CENTRE FEATURES

- Empty behaviour specification => Linda tuple space behaviour
- Behaviour specification => ad-hoc tuple space behaviour, complex as needed
- Hybrid coordination models
  - data-driven: preserves Linda's features
  - control-driven: burden of coordination on tuple centre (reactions)

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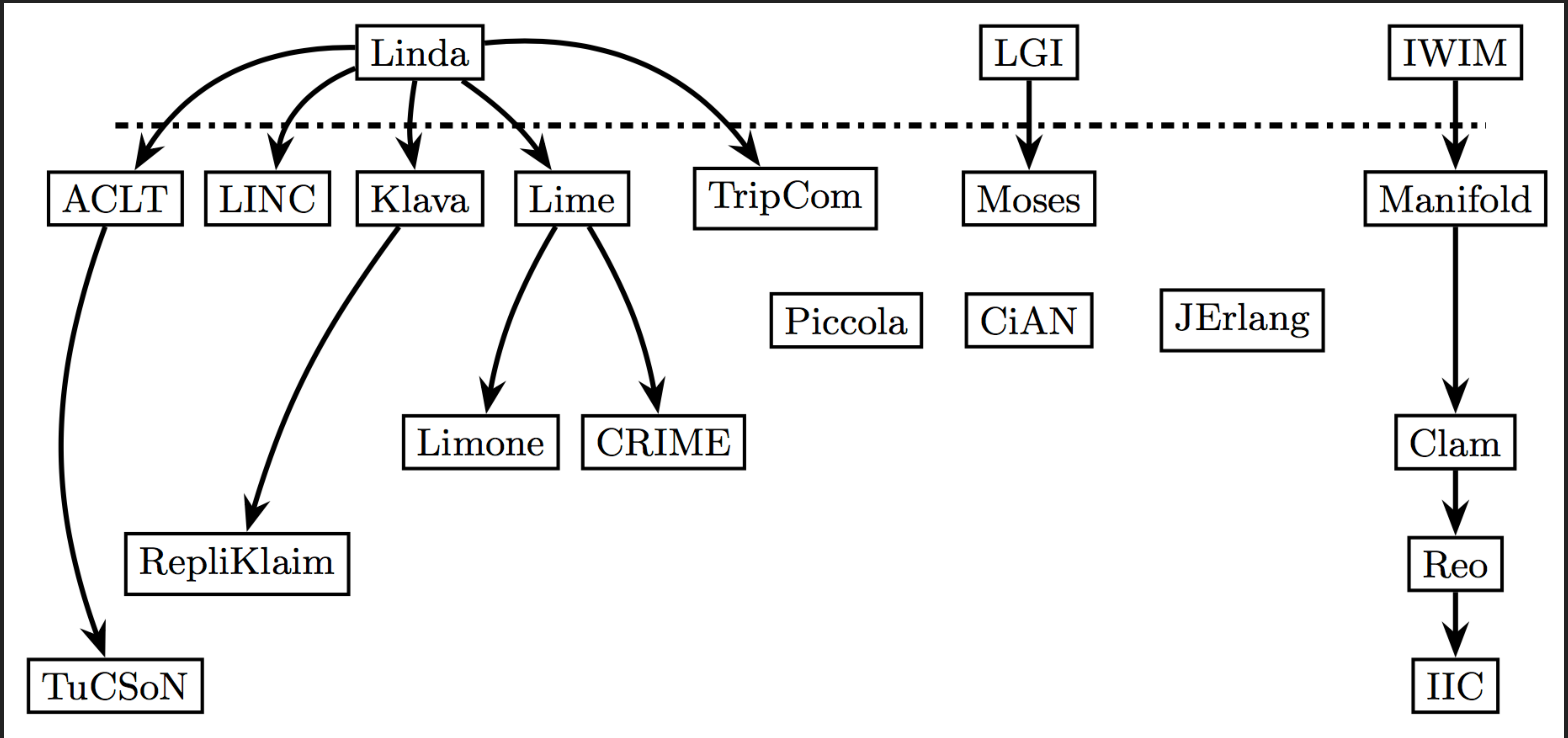
(PARTIAL) STATE OF ART

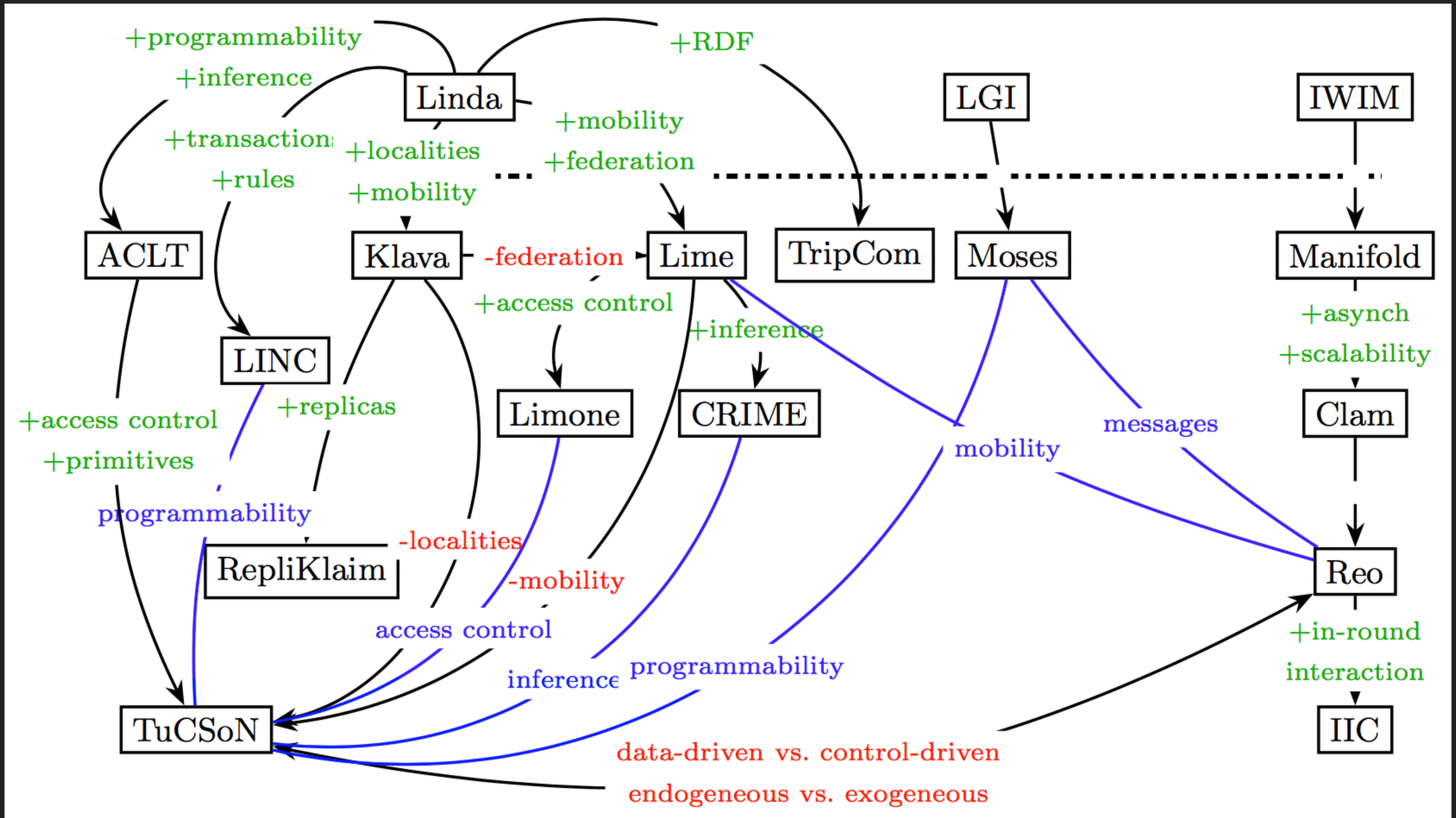
- Look back at past 20 years of COORDINATION conference series
  - most cited paper about tech?   7 / 19 ~ 37%
  - most downloaded paper about tech?   8 / 19 ~ 42%
  - tech papers?   47 / 390 ~ 12%

Ciatto G., Mariani S., Louvel M., Omicini A., Zambonelli F. (2018)
Twenty Years of Coordination Technologies: State-of-the-Art and Perspectives.
Lecture Notes in Computer Science, vol 10852 (doi: 10.1007/978-3-319-92408-3_3)

A FAMILY TREE



RELATIVES


+programmability
+inference
+RDF
Linda
LGI
IWIM
+transactions
+rules
+localities
+mobility
+mobility
+federation
ACLT
Klava
-federation
Lime
TripCom
Moses
Manifold
+access control
+inference
LINC
+asynch
+scalability
+replicas
Limone
CRIME
mobility
messages
Clam
+access control
+primitives
programmability
-localities
RepliKlaim
-mobility
Reo
access control
inference
programmability
+in-round
interaction
TuCSoN
IIC
data-driven vs. control-driven
endogeneous vs. exogeneous

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SITUATEDNESS

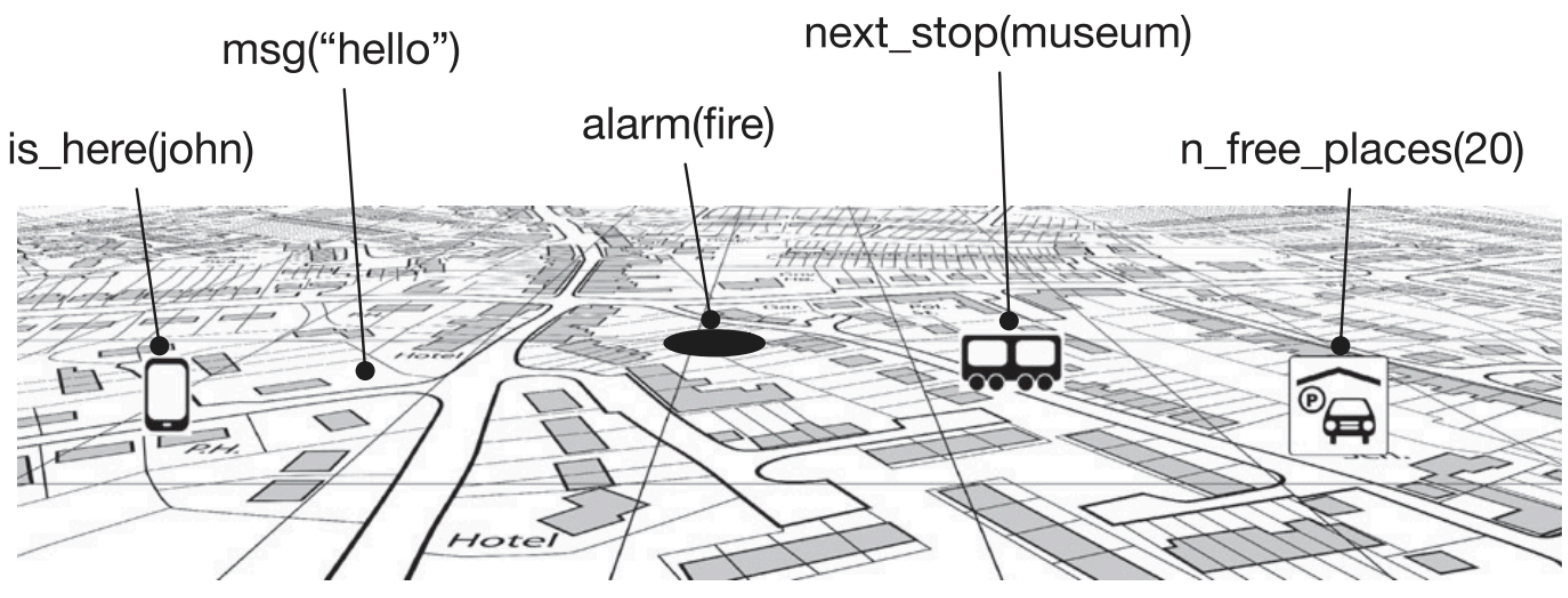
- Property of systems of perceiving and affecting **environment**
  - mobile, adaptive, pervasive systems emphasised the need
  - modern systems require at least situatdness in time and space
- A coordination issue, too?

SPATIAL TUPLES

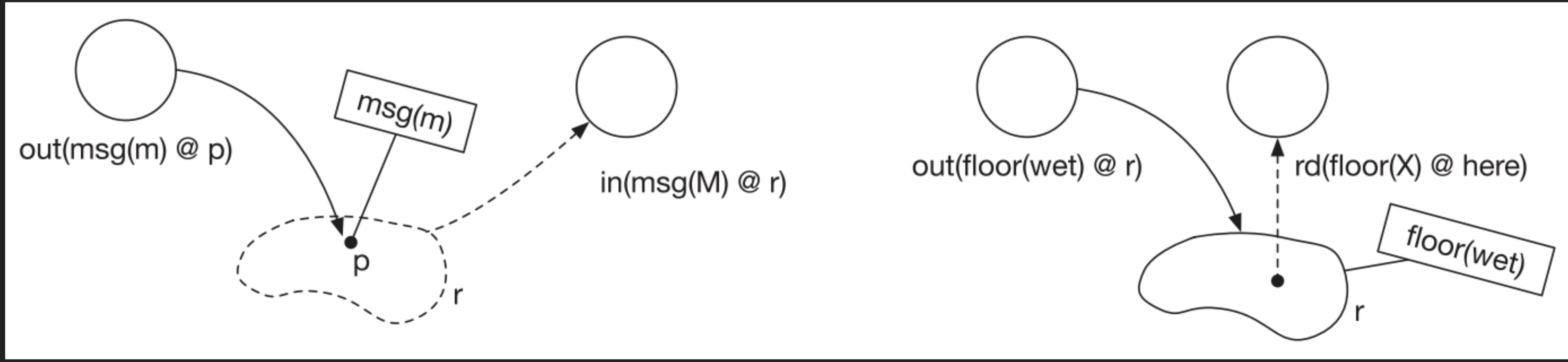
- A Spatial Tuple is a tuple associated to a spatial information, of any sort
  - physical (e.g. GPS coordinates)
  - virtual (e.g. IP address)
  - logical (e.g. Computer science building, 2nd floor)
- A spatial tuple decorates space, augmenting reality with information
- A space-description language specifies the spatial information decorating the tuples and the matching mechanism

Ricci, A, Viroli, M, Omicini, A, Mariani, S, Croatti, A, Pianini, D. (2018)
Spatial Tuples: Augmenting Reality with Tuples.
Expert Systems, vol 35, issue 5 (doi: 10.1111/exsy.12273)

OPERATIONS

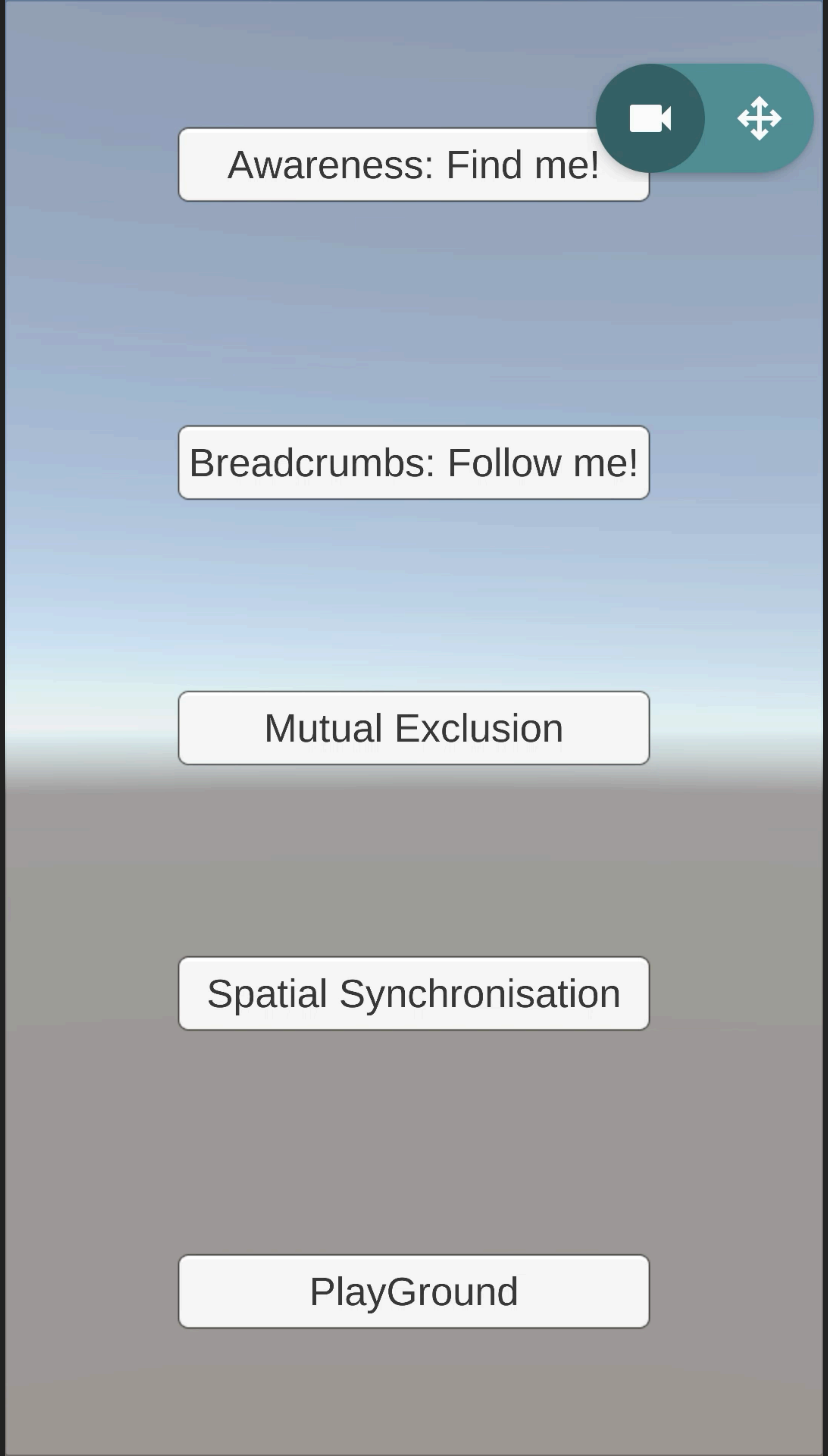


Set intersection used to define matching: region `r` matches region template `rt` if their intersection is not empty



INDIRECT SITUATEDNESS

- A tuple can be associated to a **situated component** located in space
  - if `id` identifies a situated component, `out(t @ id)` puts `t` "on" `id`
  - such an association holds while `id` moves
- If agent performing operation is itself associated to a situated component:
  - `out(t @ me)`
  - `rd(tt @ here)`



SPATIAL MUTUAL EXCLUSION

CASE STUDY: RESCUE

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DEFINITION

- *"Systems involving complex* **dependencies** *between* **humans, machines,** *and the* **environment** *within which they operate"* –Trist 1981
- *"Socio-technical systems arise when cognitive and social* **interaction** *is* **mediated** *by information technology rather than by the natural world (alone)"* –Whitworth 2006
- *"A STS is a system of principals (stakeholders such as people and organisations) whose* **interaction** *is supported by* **technical components** *for both computation and communication"* –Chopra and Singh 2016

ROLE OF COORDINATION

- People interact with other people through technology, as the definition of STS itself implies
- => Coordination enables collective action necessary to tame STS complexity
- Many research efforts
  - social machines
  - human-agent collectives
  - e-Institutions & normative MAS
  - etc…

ENGINEERING PERSPECTIVE

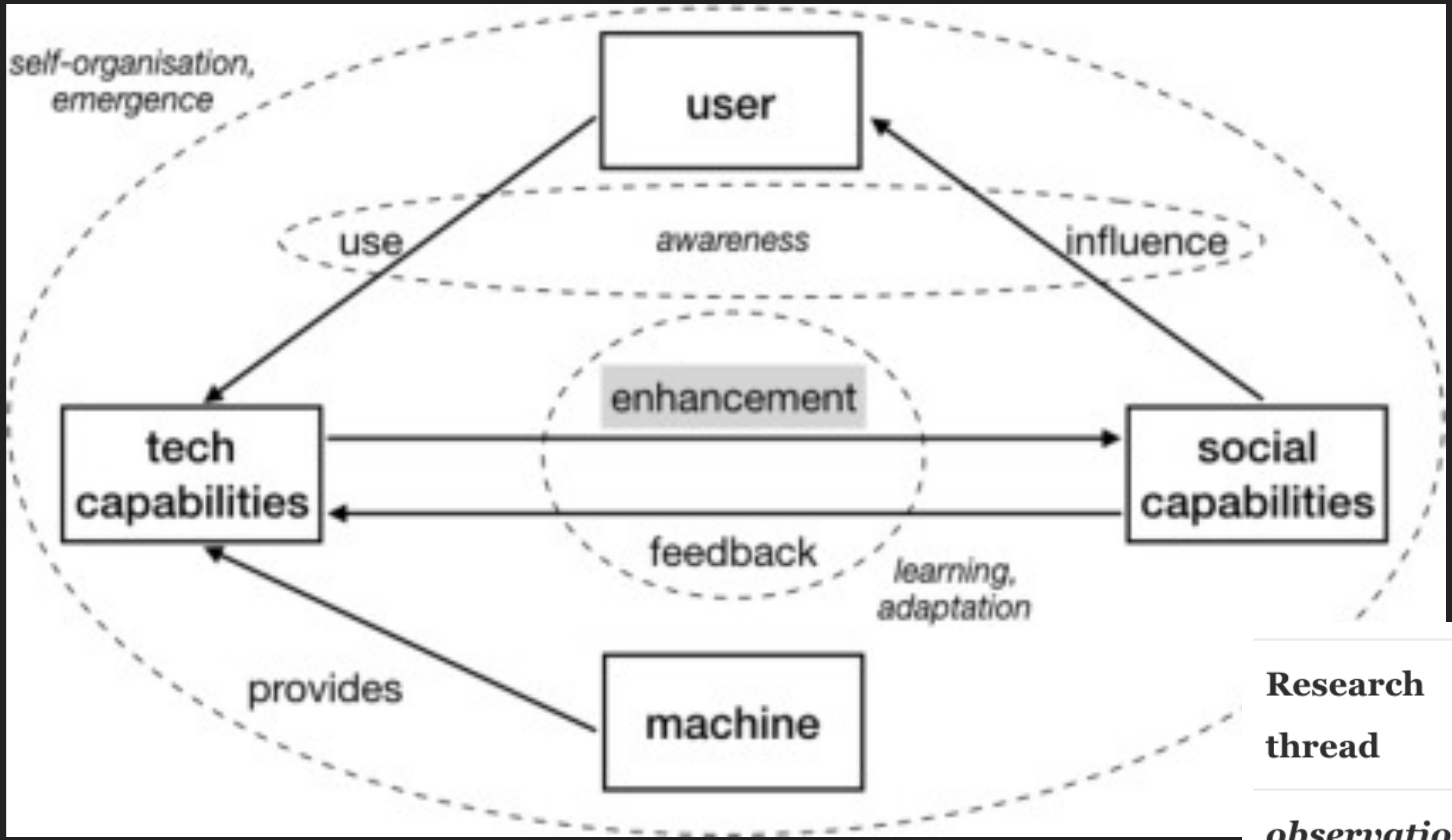
Social desiderata	Requirement	Technical mechanism
coordination, efficiency	*(peripheral) awareness*	observability of actions, their side effects, their outcomes
flexibility	*adaptation*, *self-organisation*	observability, situatedness, pro-activeness
low cognitive overhead	low *abstraction gap*	goal-orientation, situation recognition, argumentation, institutional setting
trust	*accountability*	observability, transparency, argumentation, commitments, norms

Mariani, S. (2019)
Coordination in Socio-technical Systems: Where are we now? Where do we go next?.
Science of Computer Programming, vol 184 (doi: 10.1016/j.scico.2019.102317)

CHALLENGES

- **Awareness**: observability of others' activities, information flow, dependencies amongst activities
- **Adaptation**: people adapt to the systems they use, while also striving to adapt those systems to best meet their needs
- **Emergence**: system properties stem from interactions and are difficult to design and control
- **Abstraction**: people think in terms of goals, situations, arguments, … vs. devices understanding commands, data, conditions, …
- **Accountability**: prominent role played by social expectations and commitments in interactions between humans

APPROACHES: TECH-TO-SOCIAL



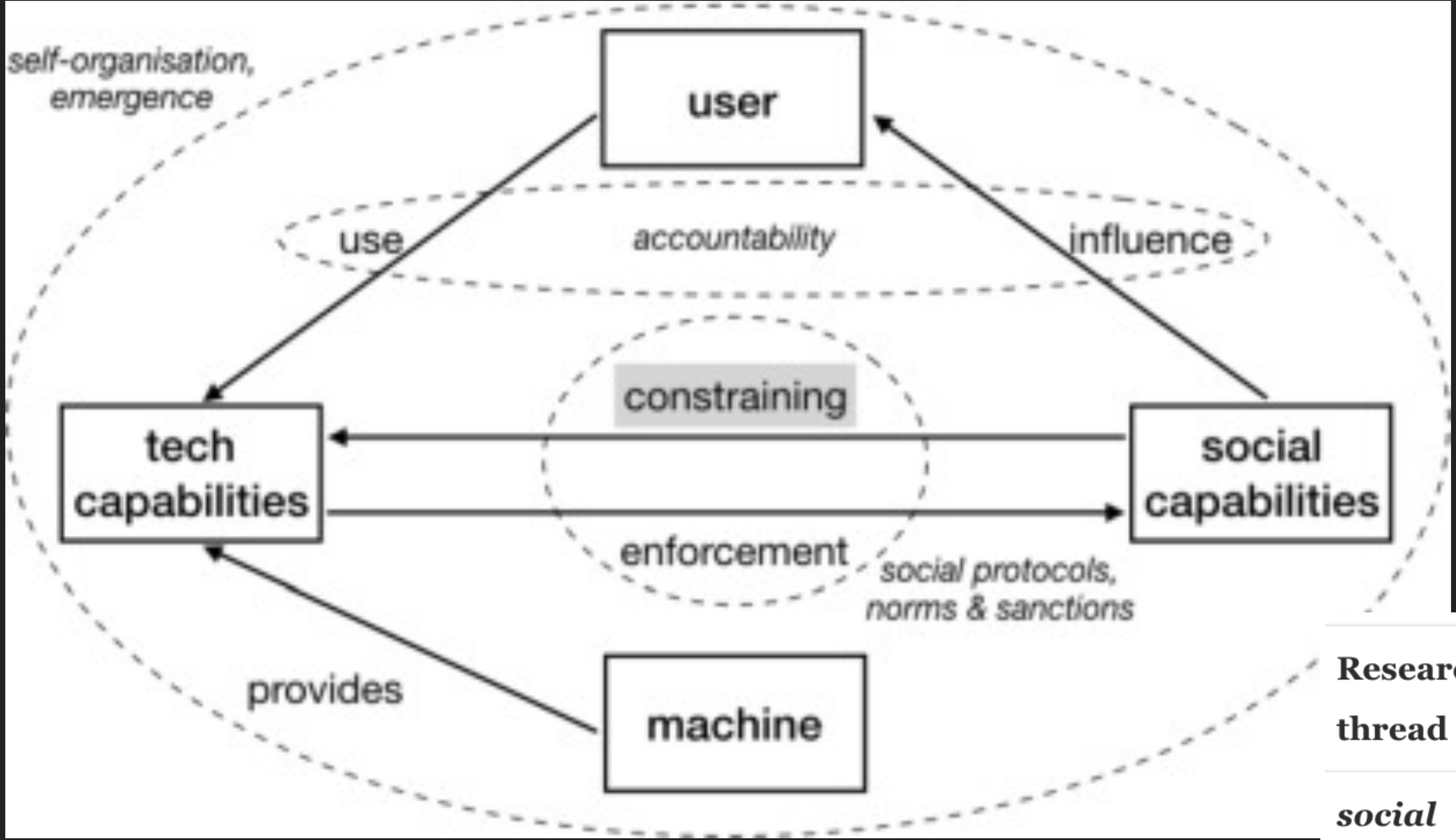
Exploit the technical components of the STS to **enhance interaction capabilities** of humans while exploiting their activities to **improve coordination** process

Observation-based coordination:

- stigmergy
- behavioural implicit comm.

Research thread	Strengths	Weaknesses
observation-based coordination	well-studied, operational formalisations, awareness enabler, high abstraction level	privacy trade-offs, scalability issues, rationality assumption
self-organising coordination	computationally simple, scales well, adaptation enabler, promotes system autonomy	unpredictability trade-offs, accountability trade-offs, difficult to design, difficult to control

APPROACHES: SOCIAL-TO-TECH

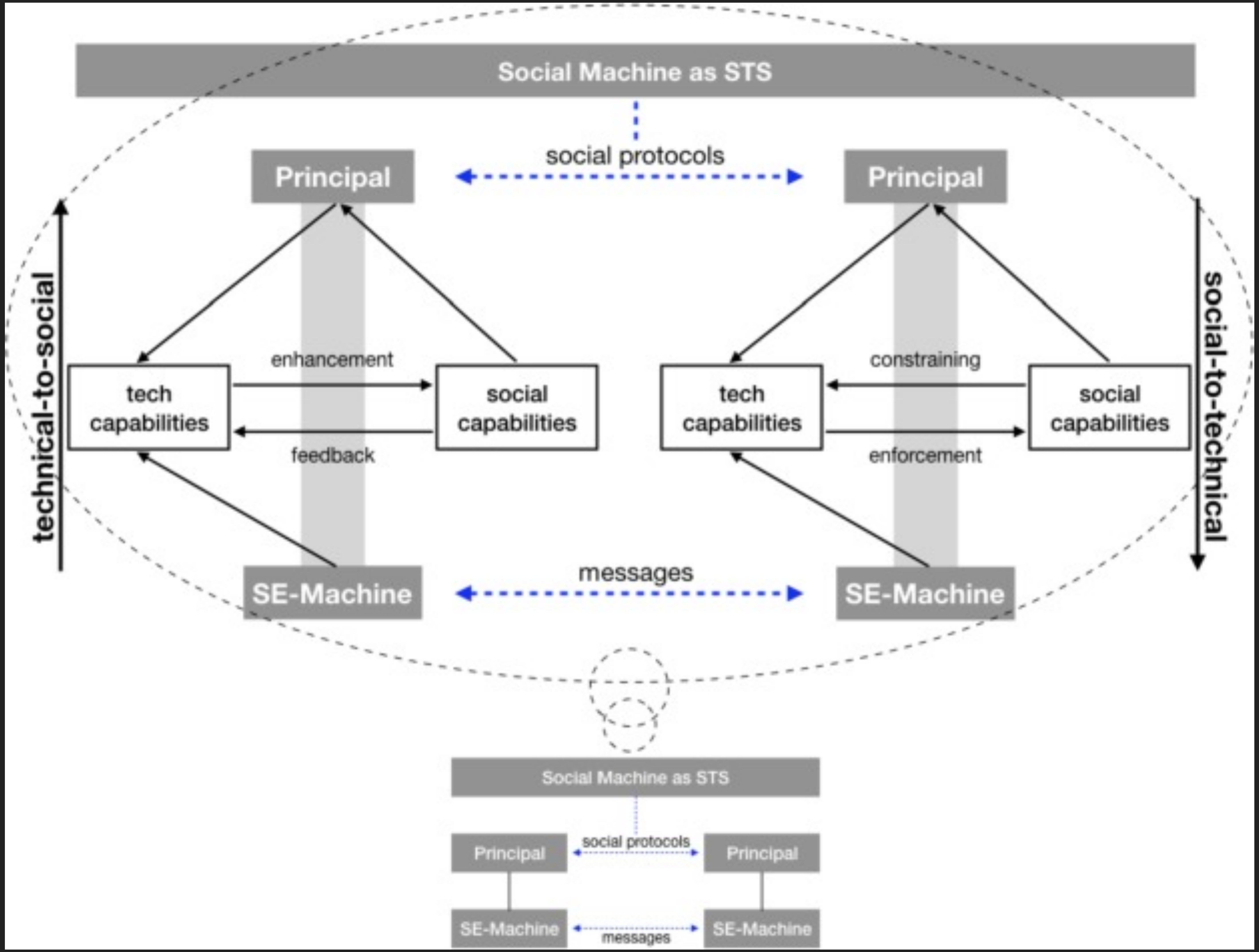


Computationally represent social relationships, protocols, expectations, conventions, norms, etc. so as to let technical components of the STS facilitate, promote, manipulate, and enforce them

- Social protocols
- Argumentation
- e-Institusions and nMAS

Research thread	Strengths	Weaknesses
social protocols	separation of concerns, accountability enabler	no operational formalisations, more theory than practice
argumentation	high abstraction level, well-studied, trust enabler	scalability, computationally expensive, more theory than practice
e-Institutions & nMAS	well-studied, operational formalisations, accountability enabler, fine control	scalability, decentralisation difficult, adaptation difficult

INTEGRATION AS KEY



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DEFINITION

- Ability to **foresee** possible interferences / opportunities for interaction so as to plan coordinated actions
  - observe others' actions
  - "mind-read" the intentions behind them
  - ascribe goals to actions and their effects (signification)
- Behavioural Implicit Communication (BIC) as a socio-cognitive framework

BEHAVIOURAL IMPLICIT COMMUNICATION

- Tacit message: implicit interaction with no specialised signal ("speech act") conveying the message, the message is the practical behaviour itself
  - presence, intention, ability, opportunity, accomplishment, goal, result
- "Observe-mindreading-signification" cycle applied to computational environment
- => **Smart environments**: pro-active working environments autonomously and spontaneously adapting to users' interactions

MOLECULES OF KNOWLEDGE

- Model for information self-organisation, exploiting biochemical coordination as its coordination model to
  - autonomously aggregate data to build more “complex” heaps of information
  - autonomously spread information towards potentially interested consumers
- Exploits BIC tacit messages to let the coordination media perform **perturbation actions** improving the coordination process
  - approach, attract, repulse, boost, wane, strenghten, weaken

CASE STUDY: NEWS SELF-ORGANISATION

- Journalists share a IT platform for retrieving and publishing news stories.
- They have personal devices they use to search the IT platform for relevant information.
- Users' actions leave traces that MoK exploits to attract similar information, actually enacting anticipatory coordination

https://youtu.be/8ibkXdukTfk

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THE BLOCKCHAIN

- What it has to do with coordination?

- Find out in dedicated slides :)

Ciatto G., Bosello M., Mariani S., Omicini A. (2019)
Comparative Analysis of Blockchain Technologies Under a Coordination Perspective.
Communications in Computer and Information Science, vol 1047 (doi: 10.1007/978-3-030-24299-2_7)

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