Coordination of Socio-technical Systems

Challenges and Opportunites

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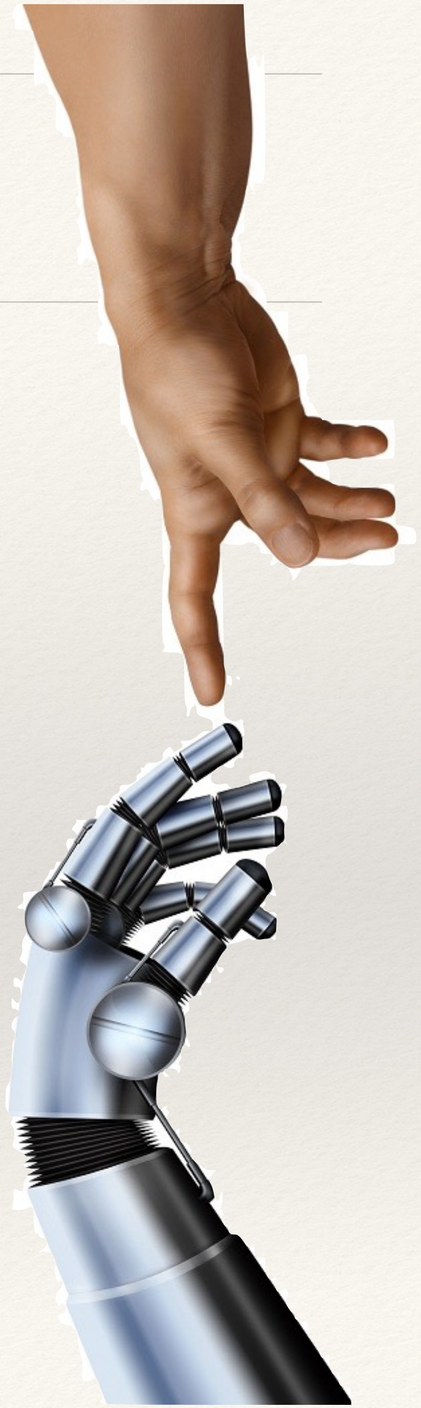
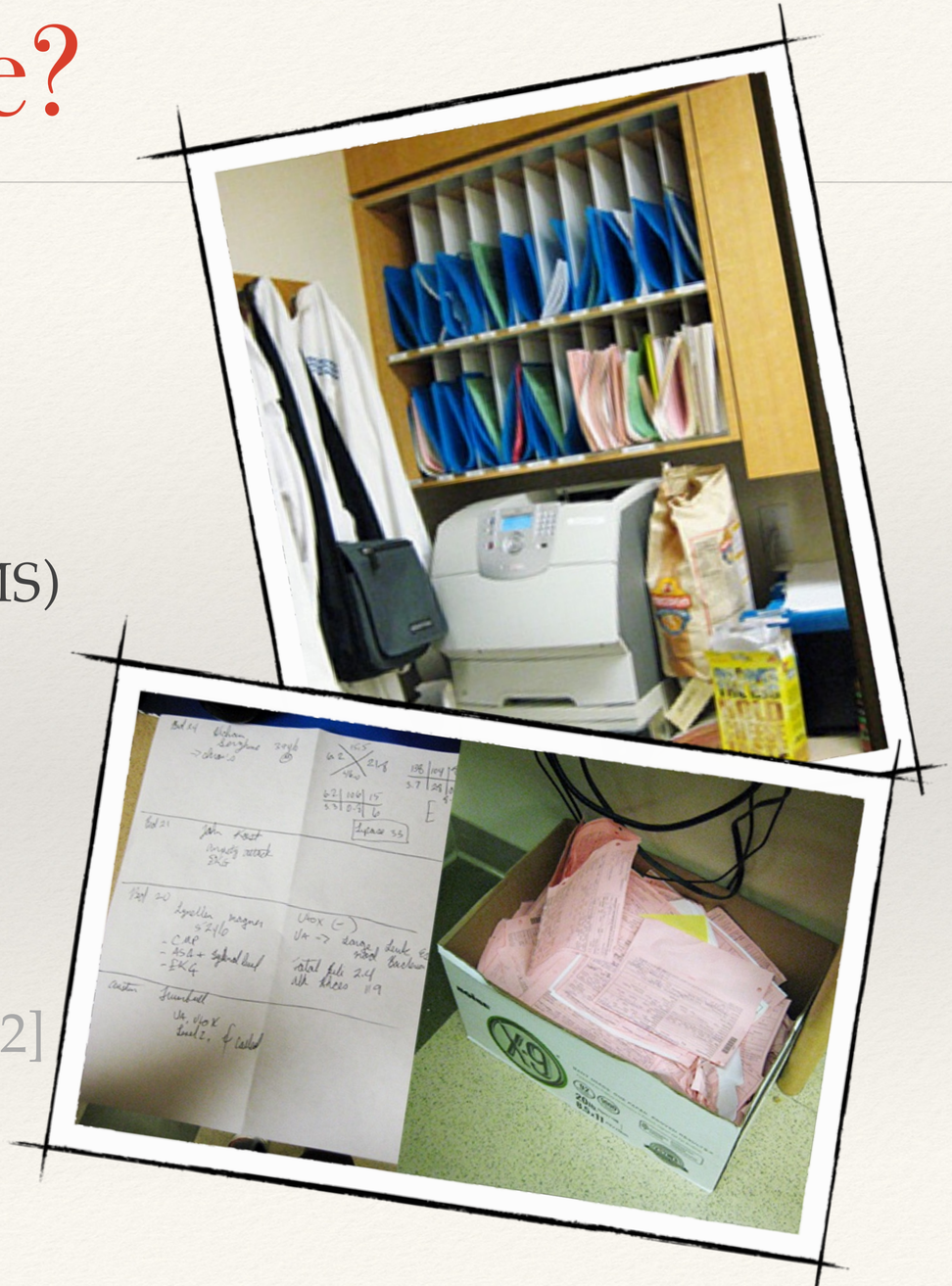
Goal

- Fact: IT systems and society are NOT isolated systems
- **Socio-technical Systems** (STS) as the result of their interaction
- Issue: **socio-technical gap** when STS peculiarities overlooked
- Aim: fresh look on STS engineering, **coordination** perspective
  - NOT exhaustive, NOT optimal: experience on directions worth exploring :)
  - focus on “core”, foundational mechanisms

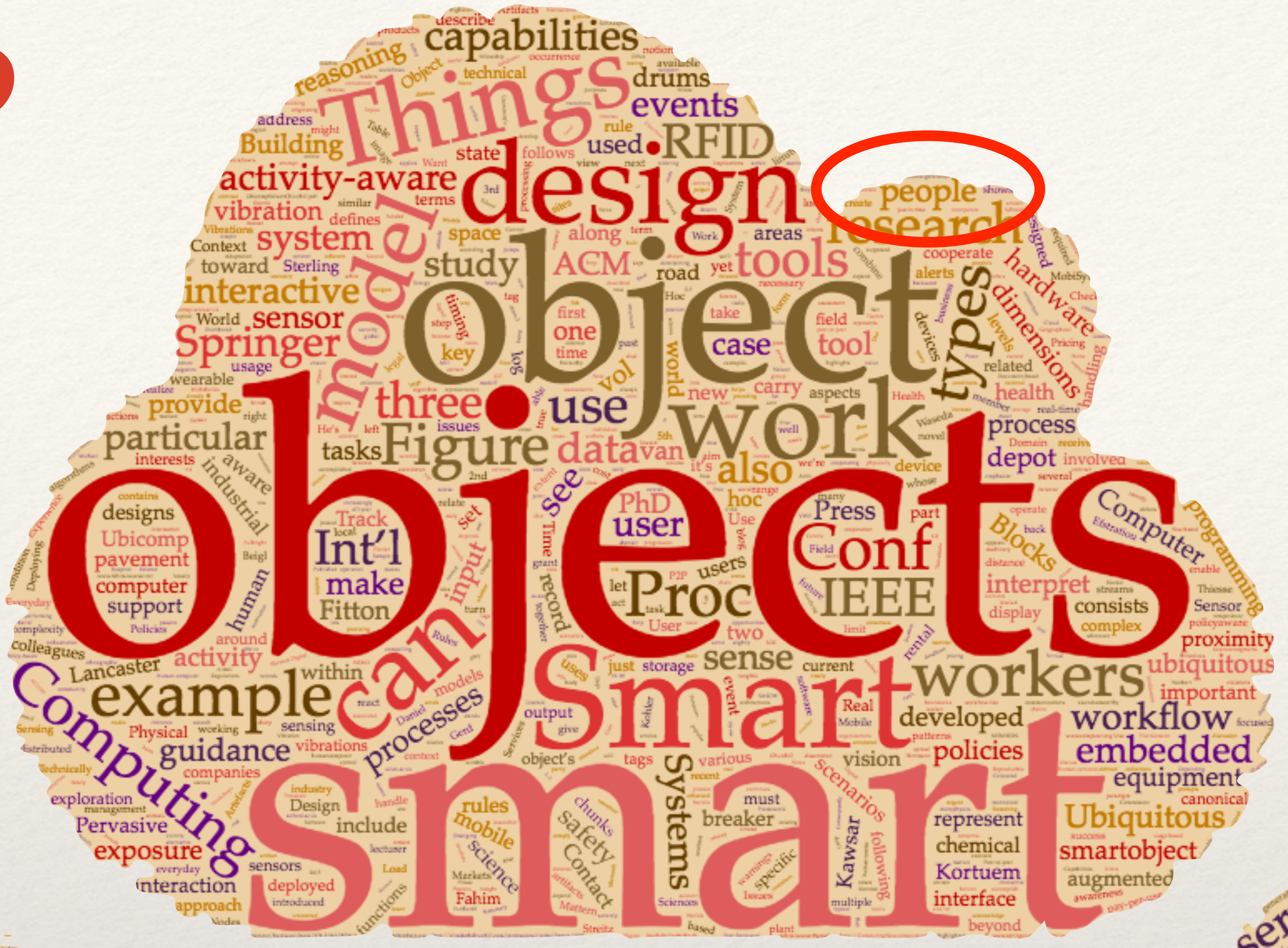


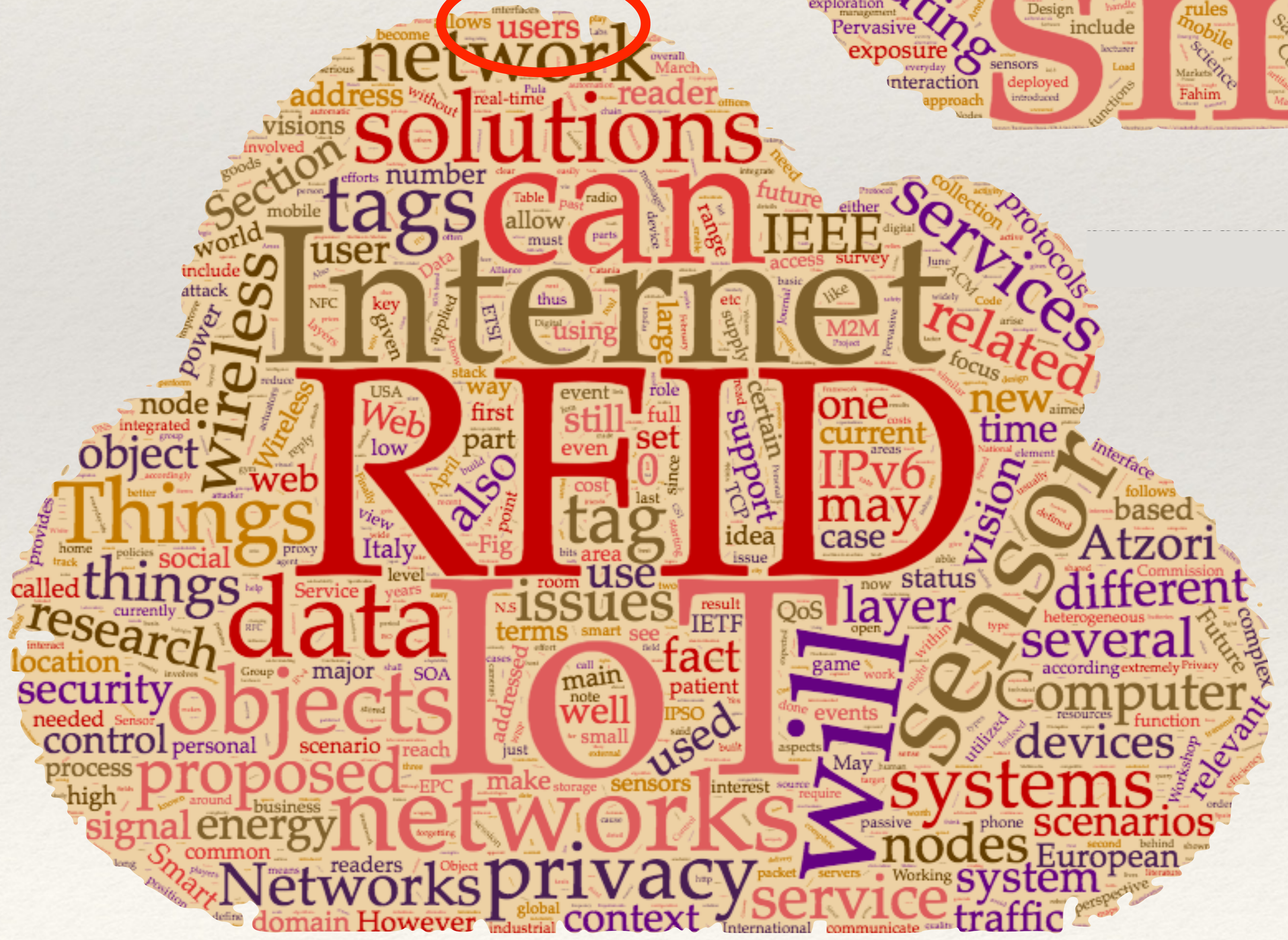
In practice?

- STS examples
  - Internet of Things deployments
  - Computer Supported Collaborative Work (i.e. WfMS)
  - Social Networks
- Gap examples
  - Amazon Alexa funny accidents
  - Electronic Medical Records failures [Park et. al. 2012]



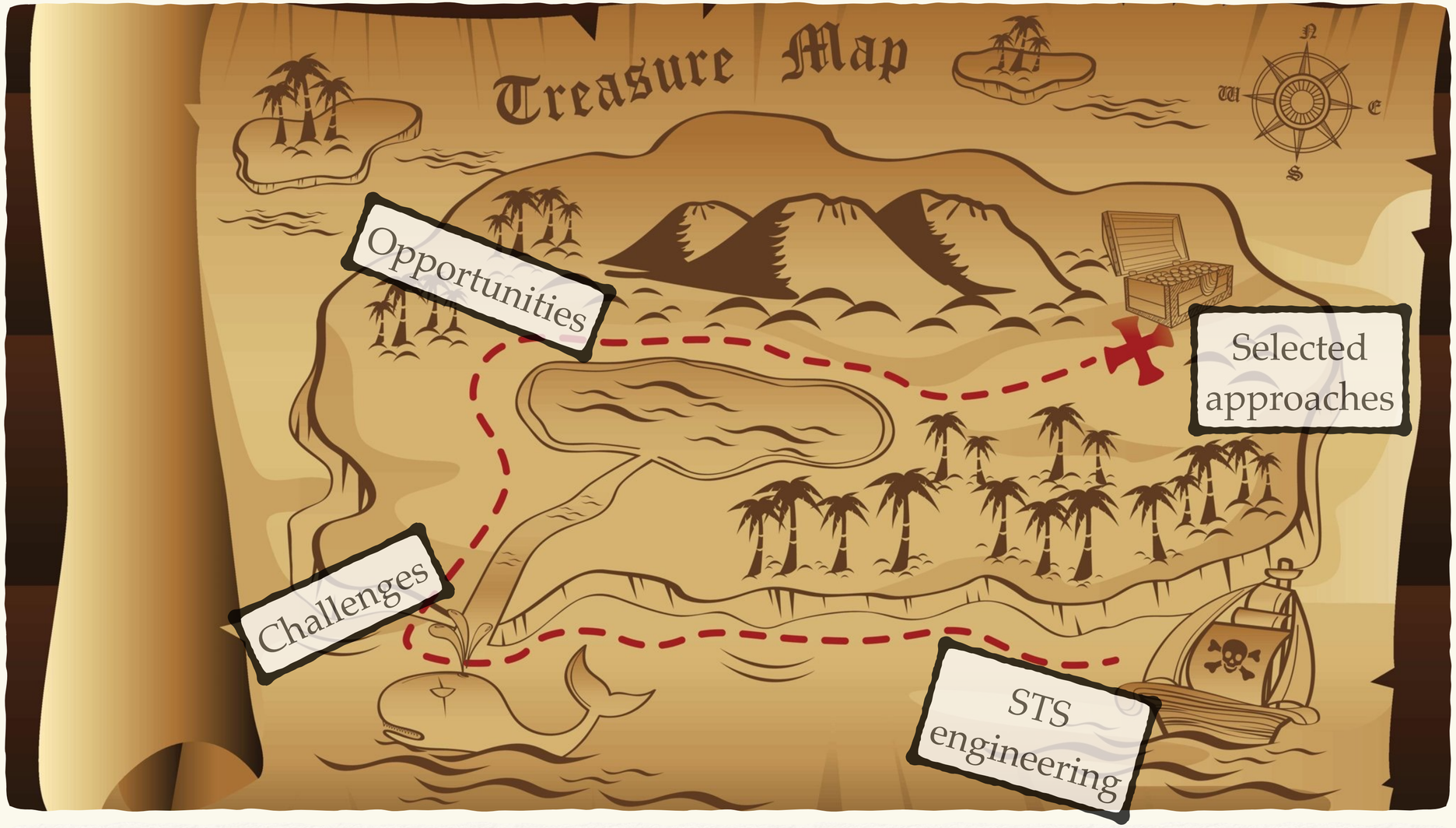
Where are people in IoT?





Where are people in WfMS?

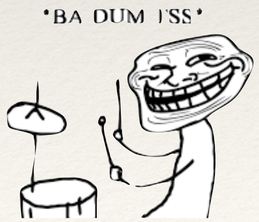
Outline


Treasure Map
Opportunities
Challenges
Selected approaches
STS engineering

Challenges: self-organisation

- STS have **emergent** properties
  - can be designed? how?
  - how to asses them? simulation? run-time?
- **Awareness** is key (“who is doing what”)
  - what about scale? privacy?
- IT platform should **adapt**
  - should users know why?
  - should users know expectations?

Challenges: abstraction gap

- Abstraction gap 1: **goals** vs. actions
  - humans reason in term of goals (“I want to chill”)
  - devices understand actions (“switch music on”, “dim lights”, “light fireplace”, …)
- Abstraction gap 2: **situations** vs. measurements
  - human reason in terms of situations (“is this place on fire?”)
  - devices understand measurements (“is temp > X?”, “is smoke detector triggered?”, …)
- ***How to reconcile?***
  - more intelligent devices? (or more stupid people? 

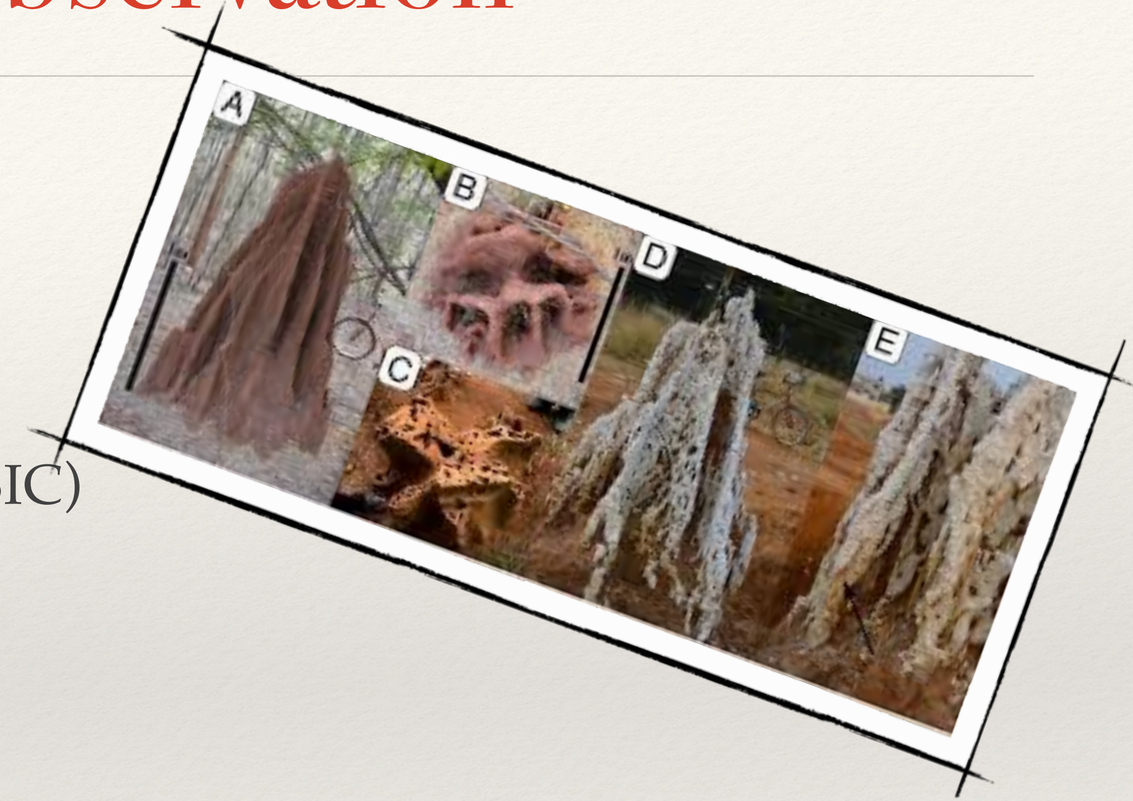
)

Challenges: accountability

- The fear of **algocracy**
  - (“filter bubble” effect, employment chance, insurance profile, healthcare access, …)
  - not an issue on its own
- Lack of **accountability** is!
  - “who to blame”? “what’s going on”?
  - tradeoff: transparency vs. privacy

Opportunities: observation

- **Observation-based coordination**
  - well known example: *stigmergy*
  - less known: *Behavioural Implicit Communication* (BIC)
- Foundational elements:
  - **environment** as mediator of (inter)action
  - **visibility** of actions and their traces (~ effects on environment)
  - notion of **locality** (for observation)

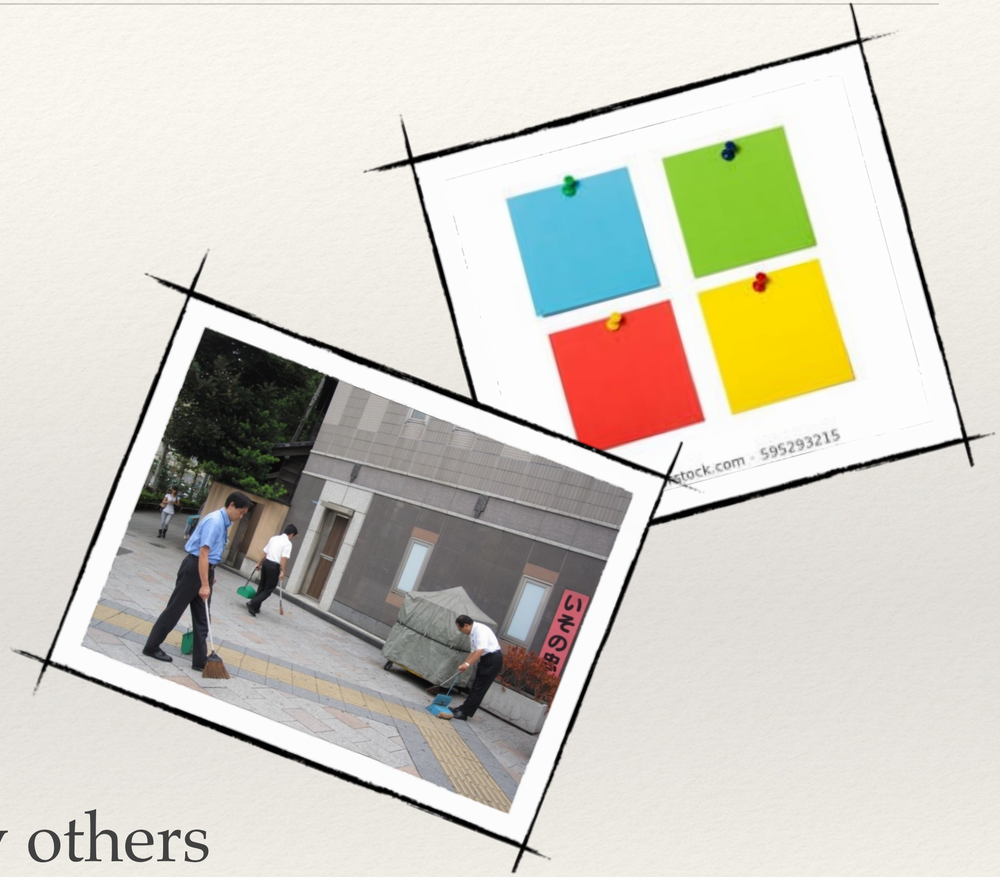


Observation: example

- Main outcome: **self-organisation** (by emergence)
  - agent *X* does action A_0 causing modification M_0
  - agent *Y* sees M_0 and does A_1 causing M_1
  - agent *Z* sees M_1 and does A_2 causing M_2
  - …
- If A_i = "sort brood" –> M_i = "pheromone smell" => *brood sorting* :)
  - **local** = "move item from here to there if similar items there"
  - **global** = partial clustering of items based on similarity

Observation: evolution

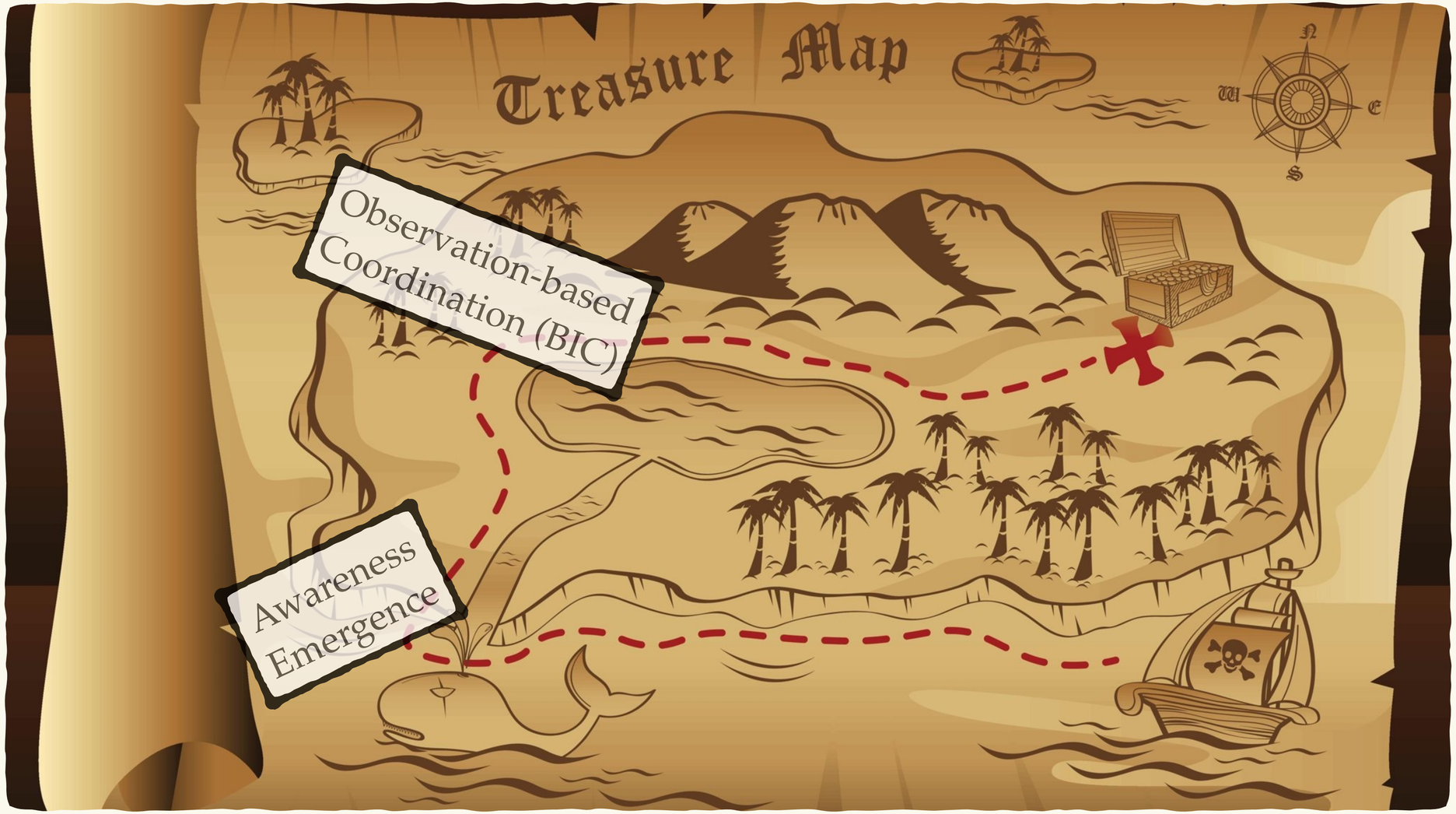
- Further steps:
  - *cognitive stigmergy* = stigmergy + symbolic reasoning
  - *BIC* = cognitive stigmergy + actions + awareness
- **Symbolic reasoning**: traces have meaning
- **Actions**: made observable likewise traces
- **Awareness**: agents know they are observed by others



Observation: BIC

- **BIC** bottom line:
  - practical behaviour is a means for communicating
  - no specialised signal needed (i.e. speech acts)
- **Tacit messages**: implicit communicative meaning conveyed by actions
  - “turn on lights while leaving home” –> “somebody is in” (to potential intruders)
  - “process X does action A” –> “actions based on A now enabled” (synchronisation)
  - taxonomy with examples in [Castelfranchi et. al. 2010]

Outline: 1st opportunity

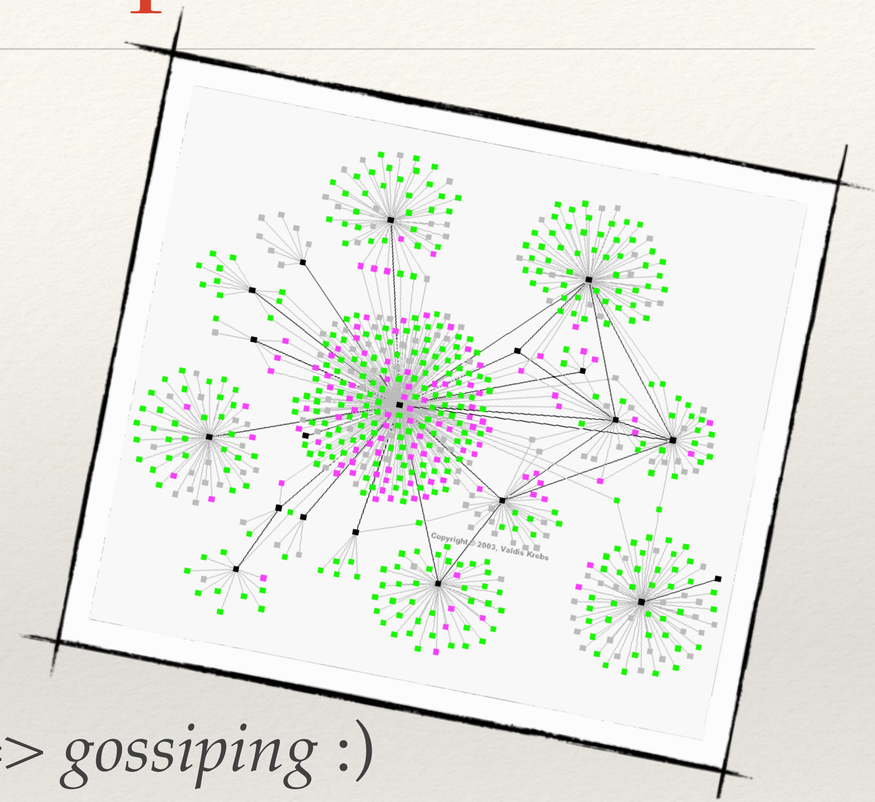


Opportunities: self-organisation

- **Self-organising coordination**
  - decentralised approach to coordination (no coordinator)
  - well known examples: birds flocking, ants foraging, wolves sorrounding prey, …
  - less known (?): (*bio)chemical coordination*

- Foundational elements:
  - actions sensitive to context (**situatedness**)
  - notion of **locality** (for interactions)
  - (often) **probabilistic** decision-making (or stochastic = probability changes with time)

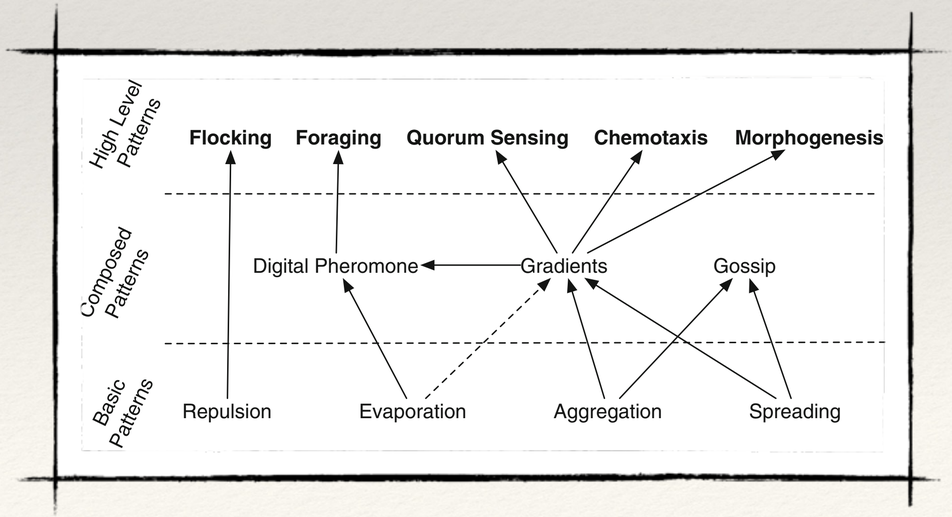
Self-organisation: example



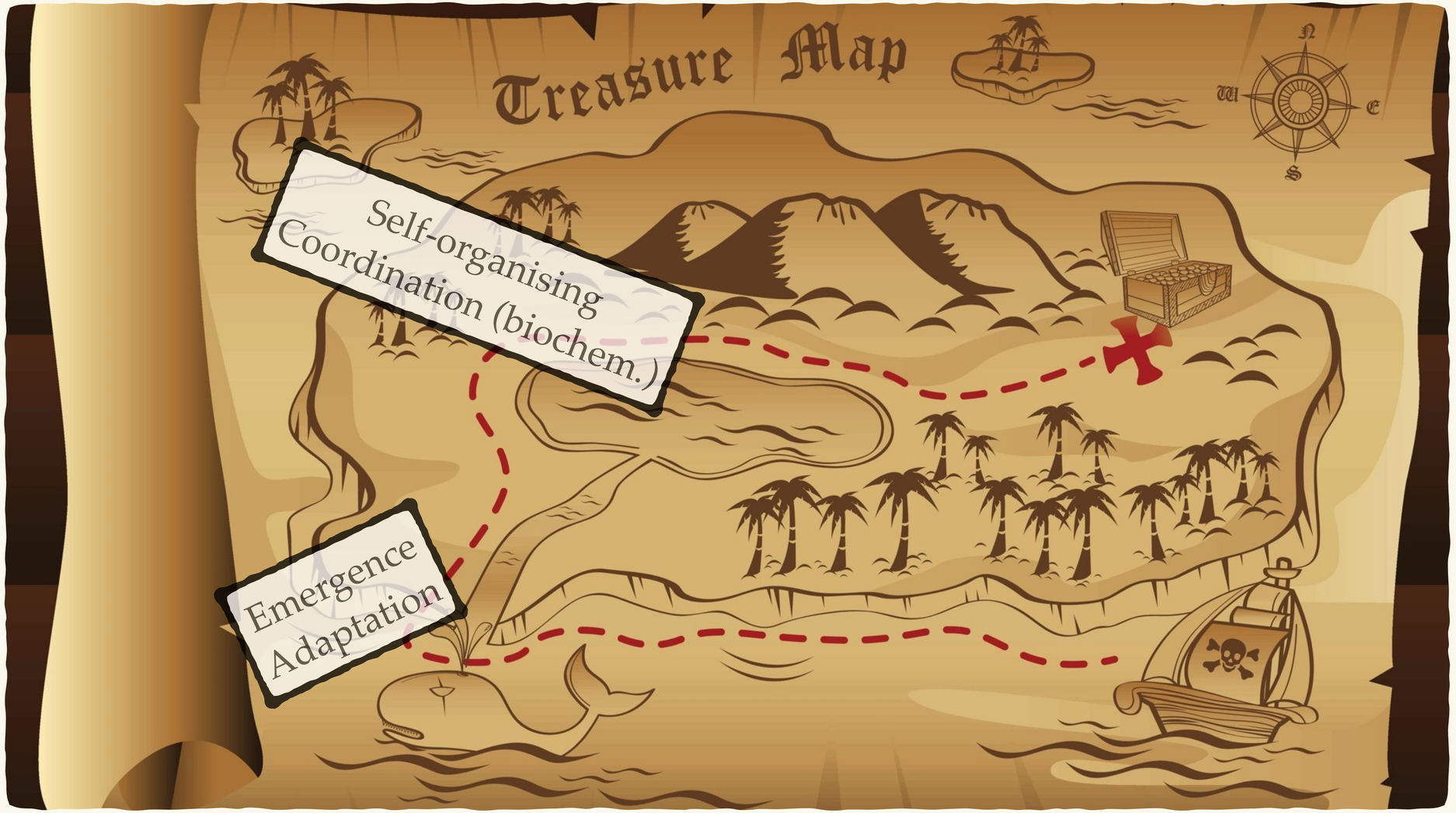
- Main outcome: **adaptation** (by emergence)
  - if local context is C_0 then do action A_0 with $p_{00} = 1$
  - if local context is C_0 then do action A_1 with $p_{01} = 0.8$
  - if local context is C_1 then do action A_1 with $p_{11} = 0.2$
  - …
- If *C* = "info (un)known" + *A* = "store / forward" => *gossiping* :)
  - **local** = "probabilistically forward or not info based on context"
  - **global** = broadcast resilient to failures and network (re-)configuration

Self-organisation: biochemical coordination

- **(Bio)chemical coordination** bottom line:
  - chemical-like reactions as coordination rules
  - interplay of reactions running locally originates global patterns
- May implement many coordination "patterns" (like OO design patterns)
  - basic: aggregation, spreading, repulsion, …
  - composite: digital phermones, gossiping, foraging, …
  - catalogue with methodology in [Fernandez-Marquez et. al. 2013]



Outline: 2nd opportunity

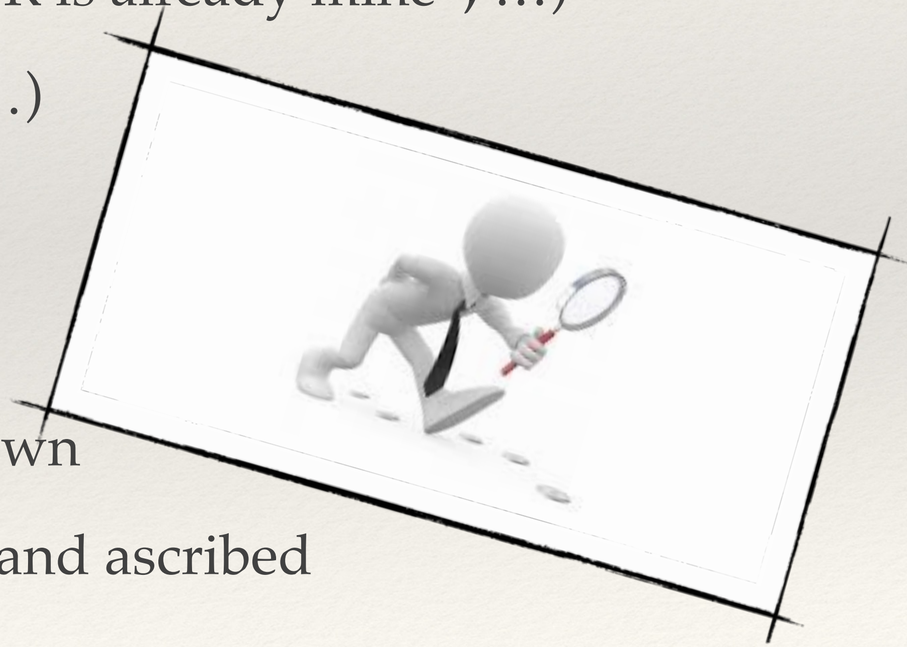


Opportunities: argumentation

- **Argumentation-based coordination**
  - well known example: *agreement technologies*
  - less known (?): *argumentation-based negotiation*
- Foundational elements:
  - **argumentation framework** (reasoning over arguments)
  - **rational** agents (i.e. stay on topic)
  - **arbiter** (i.e. decide winning argument)

Argumentation: example

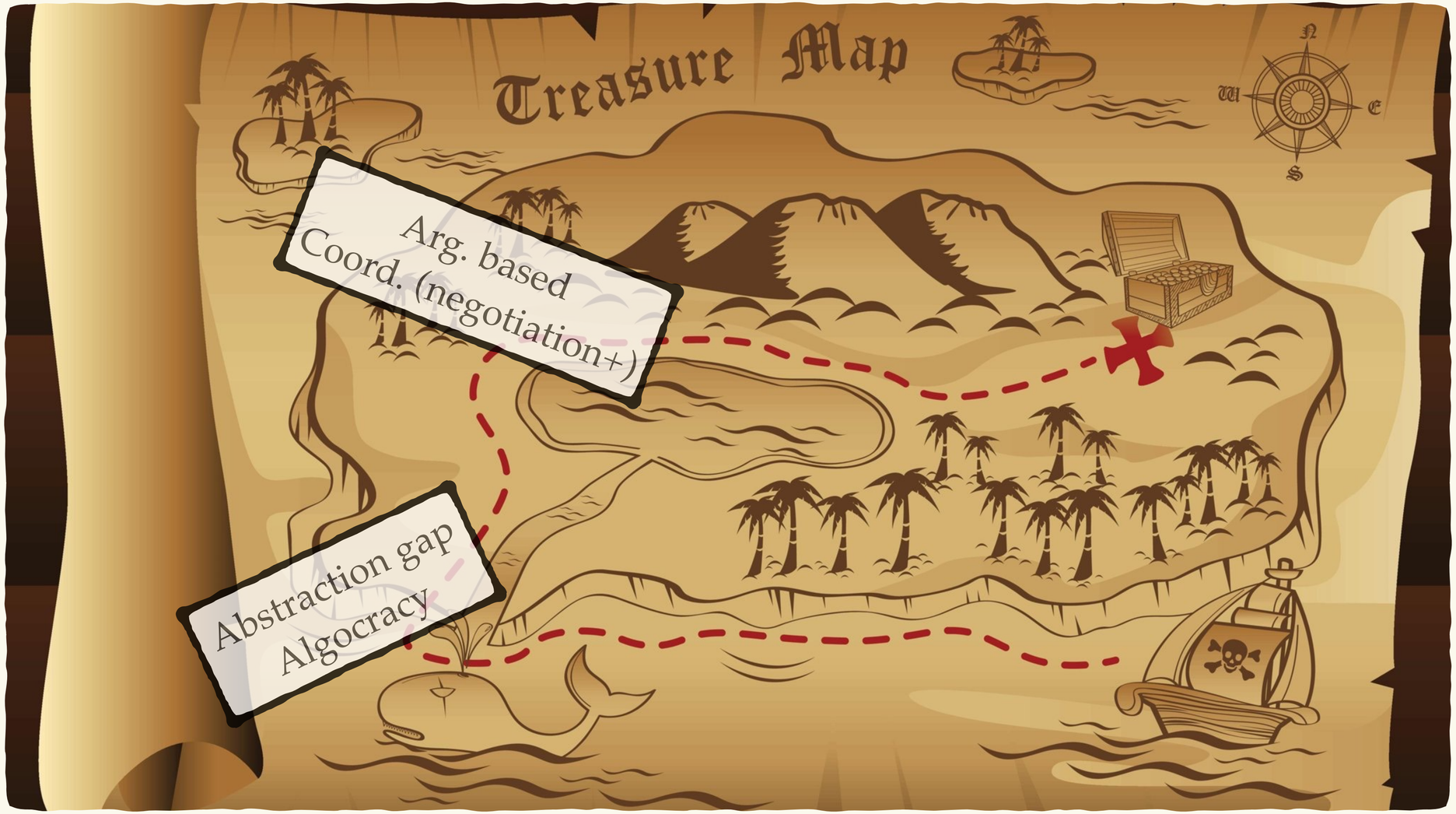
- Main outcome: **accountability**
  - agent X makes assertion A (“*S* is the state of the world”, “I want resource *R*”, …)
  - agent Y challenges A (“State is S’ for sensor Z”, “Resource R is already mine”, …)
  - agent X defends itself (“Z is faulty”, “Agent W is lying”, …)
  - …
- To win debate, agents have to *disclose* information
  - **transparency** = argumentation / negotiation rules are known
  - **accountability** = faults and malicious behaviours spotted and ascribed



Argumentation: coordination

- **Argumentation-based negotiation** bottom line:
  - argumentation framework as coordination rules
  - arguments as complex info driving negotiation (i.e. strategy behind bid)
- *Not only negotiation!*
  - many different dialogue games with own goals, requirements, engagement rules, …
  - agents engage in dialogues depending on goal (i.e. joint planning, info collection, …)
  - reference categorisation in [Walton, Krabbe 1995]

Outline: 3rd opportunity

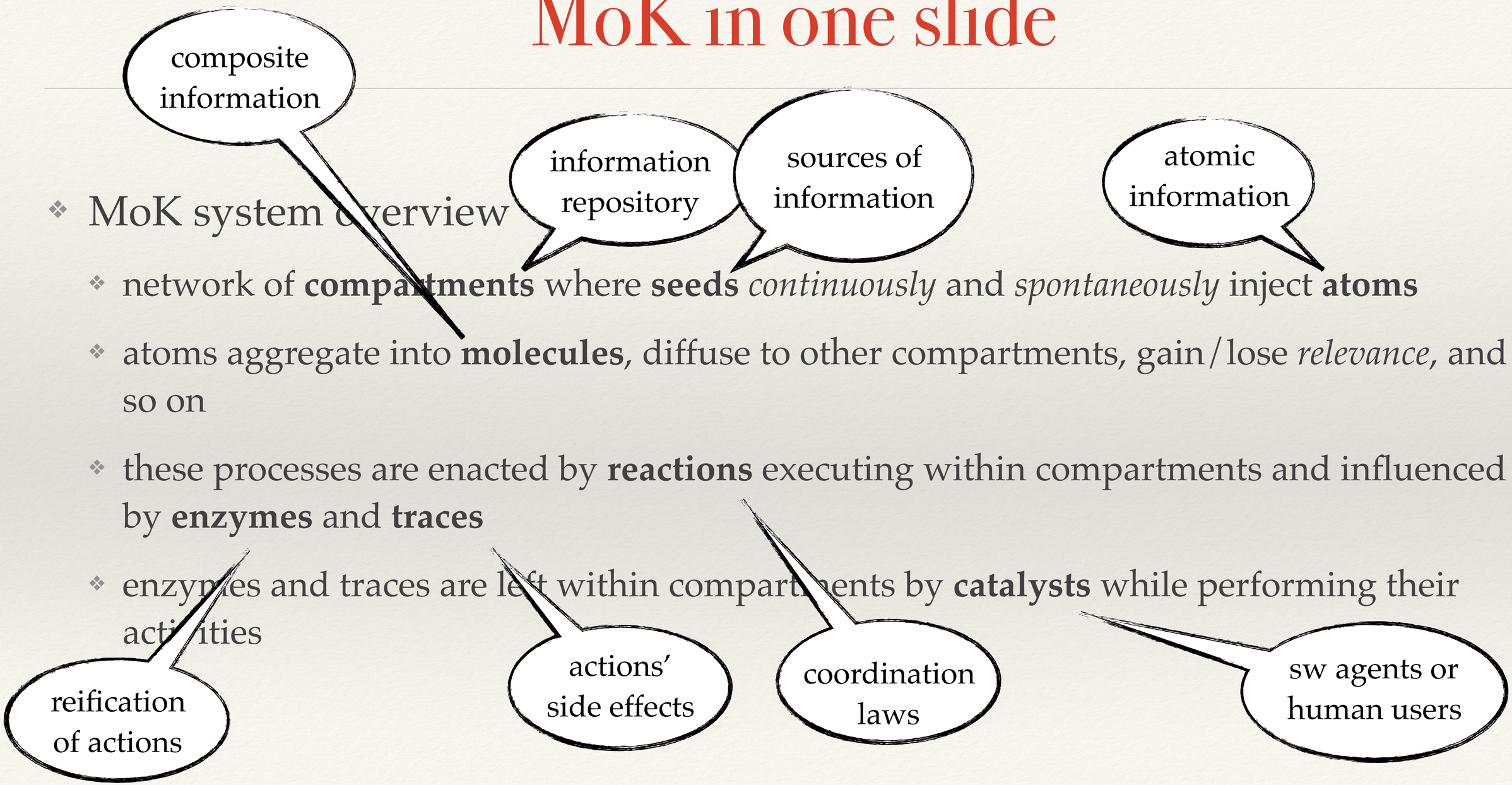


Approaches: Molecules of Knowledge

- Main idea:
  - exploit users' interactions to *continuously* and *spontaneously* **(self-)organise information**
  - promote *aggregation* of related information and *diffusion* to interested prosumers
- Pillars:
  - **biochemical coordination** –> computational model
  - **behavioural implicit communication** (BIC) –> interaction model

Mariani, S. (2016)
"Coordination of Complex Sociotechnical Systems: Self-organisation of Knowledge in MoK"
Artificial Intelligence: Foundations, Theory, and Algorithms

MoK in one slide



- MoK system overview
  - network of **compartments** where **seeds** *continuously* and *spontaneously* inject **atoms**
  - atoms aggregate into **molecules**, diffuse to other compartments, gain/lose *relevance*, and so on
  - these processes are enacted by **reactions** executing within compartments and influenced by **enzymes** and **traces**
  - enzymes and traces are left within compartments by **catalysts** while performing their activities

MoK: peculiarities

- Reactions leverage **decentralisation** and **situatedness** to promote self-organisation
  - **contextual** to information **local** to their compartment and can only affect neighbours
  - scheduled according to dynamic **rate expressions** inspired by natural chemical reactions
  - few “foundational” reactions detected through simulation
- Enzymes and traces exploit the BIC theory
  - make agents **aware** of what others are doing
  - environment **pro-actively** acts to improve coordination of agents’ activites

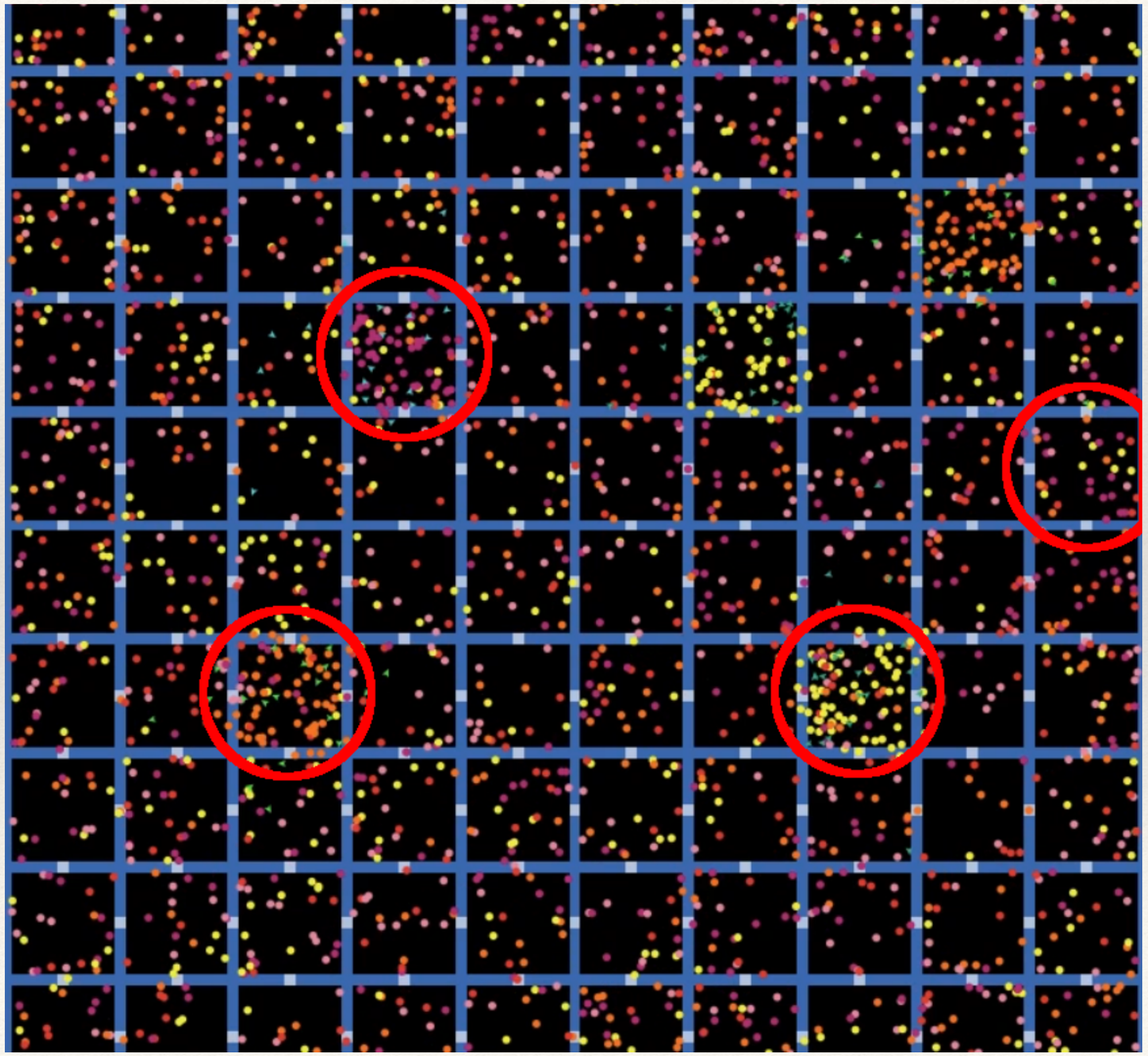
MoK: Information Management

- Citizen journalism scenario
  - MoK-coordinated platform for retrieving, assembling, sharing news stories
  - while users carry out their activities, MoK processes self-organise information
- In particular:
  - (user action) whenever users mark relevant info…
  - …MoK attracts similar one from neighbours (system re-action)

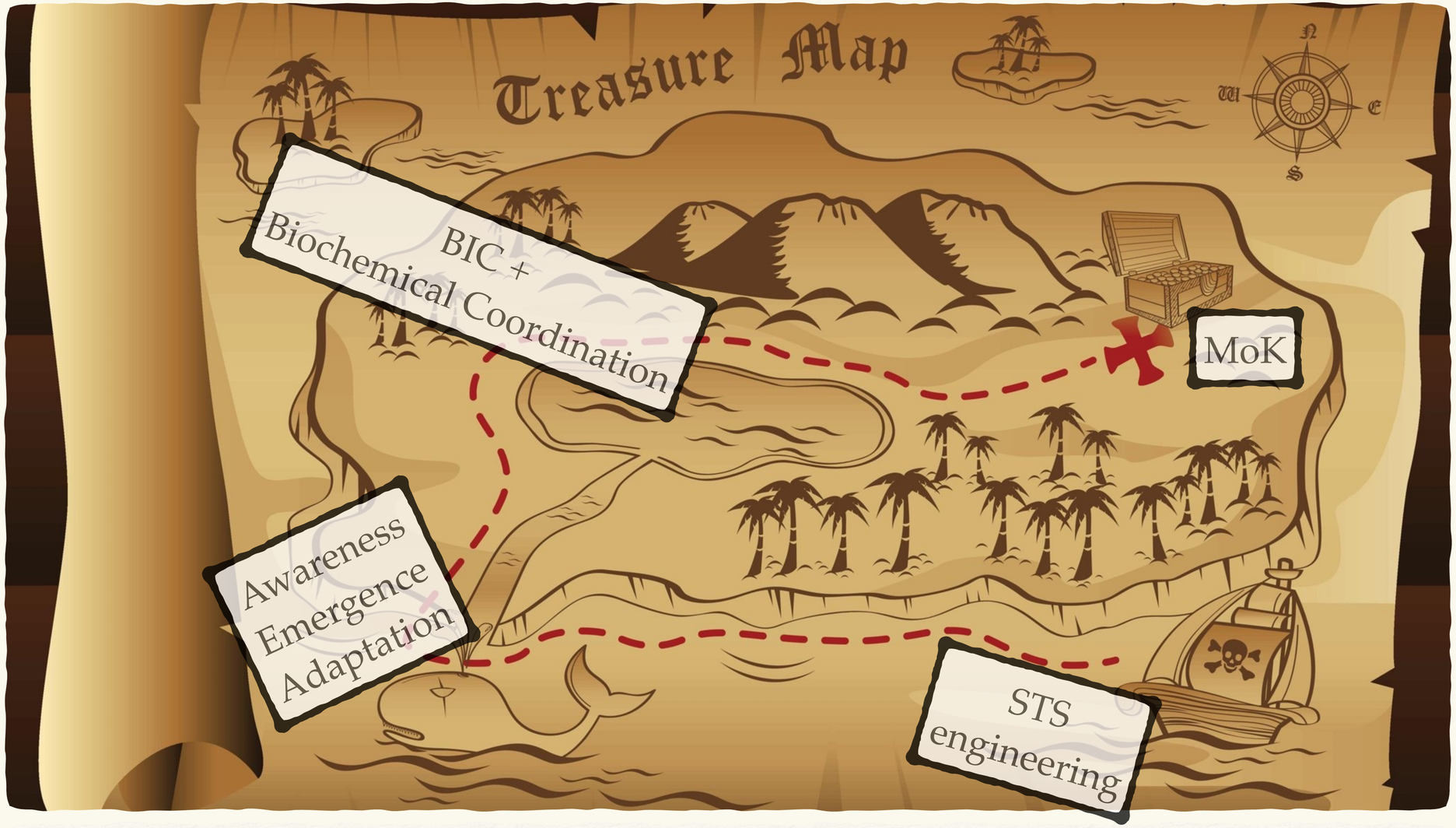
Mariani, S. and Omicini, A. (2015)
"Anticipatory Coordination in Socio-technical Knowledge-intensive Environments: Behavioural Implicit Communication in MoK"
Advances in Artificial Intelligence, Lecture Notes in Computer Science

MoK: Information Management

- Squares are compartments
- Coloured dots are info
- Coloured flags/arrows are enzymes/traces
- From time to time clusters or simlarly coloured info appear
- *Everything based on users' interactions!*

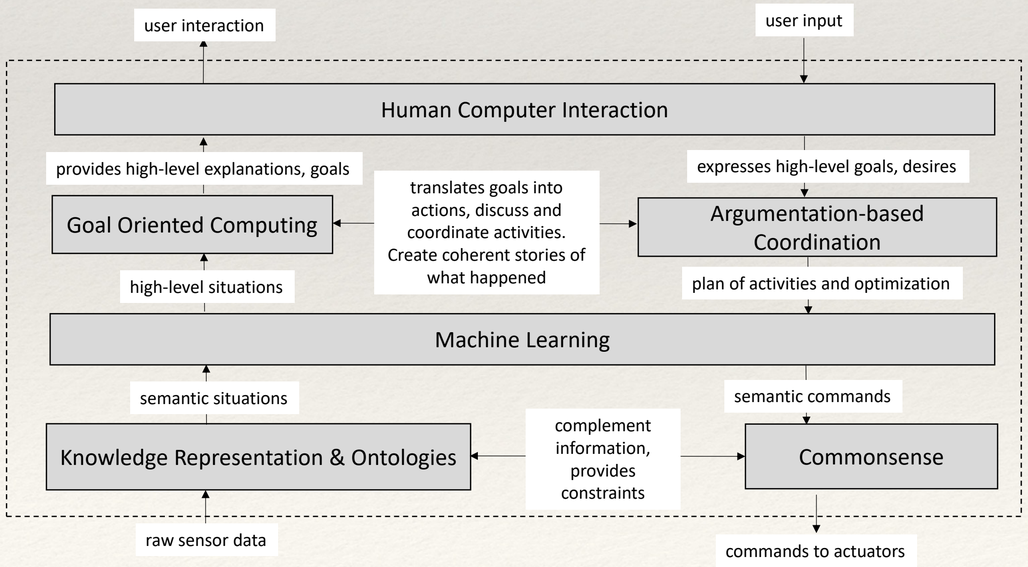


Outline: 1st approach



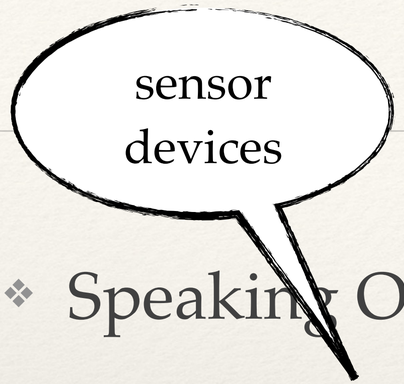
Approaches: Speaking Objects

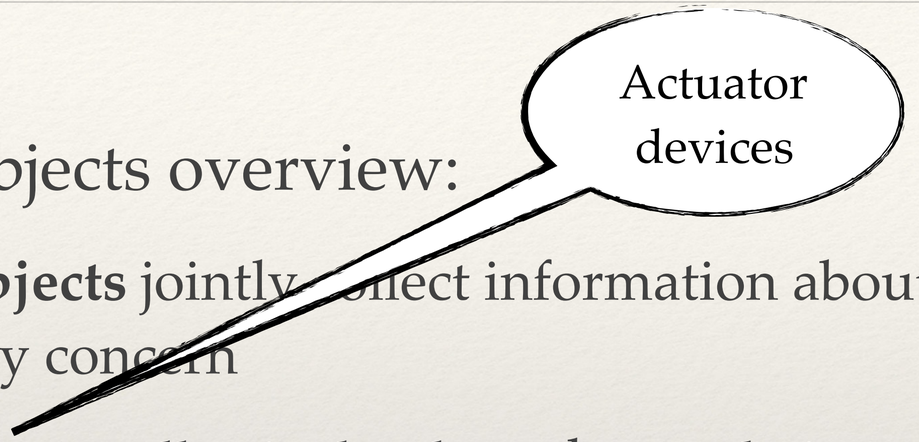
- Main idea:
  - sensor and actuator devices will be able to assert complex situations about the state of the world and to autonomously pursue goals ascribed to users or designed for the system
  - perceptions –> **assertions** & actions –> **goals**
- Pillars:



Lippi, M., Mamei, M., Mariani, S. And Zambonelli, F. (2017)
"Coordinating Distributed Speaking Objects"
International Conference on Distributed Computing Systems

Speaking Objects in one slide





- Speaking Objects overview:
  - **speaking objects** jointly collect information about the state of the world and assert them to whom it may concern
  - **hearing objects** collectively plan what to do in response to the ever-changing situations perceived by speaking objects
  - **conversational coordination** happens via argumentation between speaking and hearing objects
  - information seeking, inquiry, discovery, persuasion, negotiation, deliberation dialogues are re-interpreted
    under the coordination perspective

Speaking Objects: peculiarities

- **Decentralised** coordination by leveraging opportunities for negotiation
- Embraces "**humans-in-the-loop**" by enabling interaction in natural language
- Deals with *trust* and *algocracy* by making **explanations** and justifications of decision making available and amenable of inspection and **interpretation**
- Dialogue types and conversation moves as foundational mechanisms

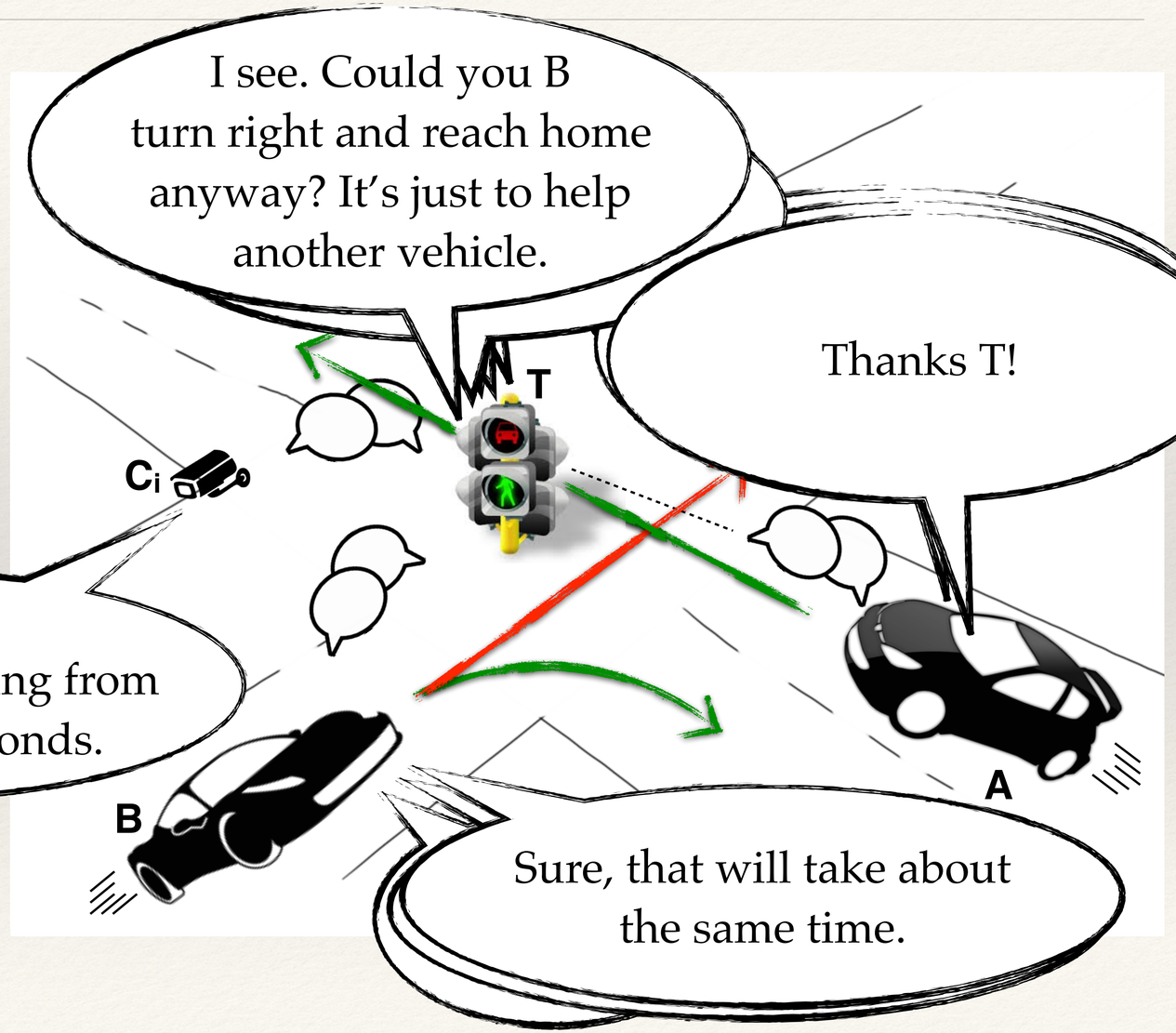
Speaking Objects: Traffic Control

- Intersection management scenario
  - vehicles equipped with an array of speaking and hearing objects, as the intersection itself (i.e., cameras, traffic lights, …)
  - approaching the intersection vehicles start argumenting with the traffic light about who has the right of way
- In particular:
  - negotiation phase where vehicles try to persuade the traffic light to decide in their favour
  - dispute settled when the argumentation process finds a solution for which no vehicle has to stop

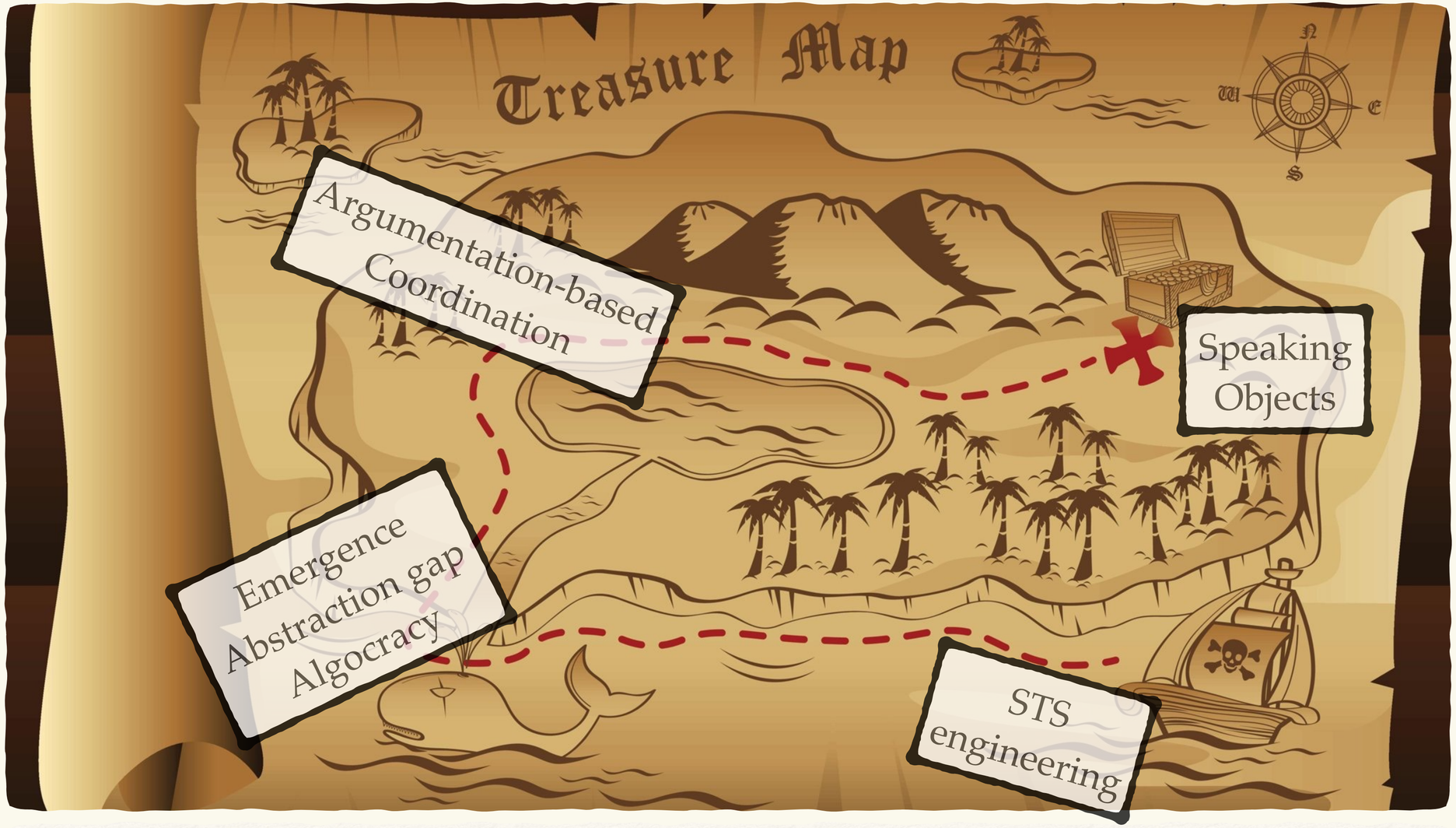
Lippi, M., Mamei, M., Mariani, S. And Zambonelli, F. (2017)
"An Argumentation-based Perspective over the Social IoT"
Journal of Internet of Things

Speaking Objects: Traffic Control

- Inquiry dialogue for asking right of way
- Information seeking for checking
- Negotiation + persuasion to converge
- Deliberation to give right of way and stop
- *Shared argumentation rules!*



Outline: 2nd approach



Conclusion: the bottom line

- Take aways
  - engineering STS is hard, harder if socio-technical gap disregarded
  - technical vs. socio-cognitive perspectives must be taken into account
- So, ***no good news?***
  - we have ways to reconcile the above perspectives
  - MoK and Speaking Objects are examples stemming from personal experience

Conclusion: perspective

Integration as key

as scientists and engineers,
we need to find a way to include socio-cognitive aspects in our technical solutions
since the very beginning of the design phase,
not as an orthogonal dimension to be added later on,
or dealt with in an ad-hoc way

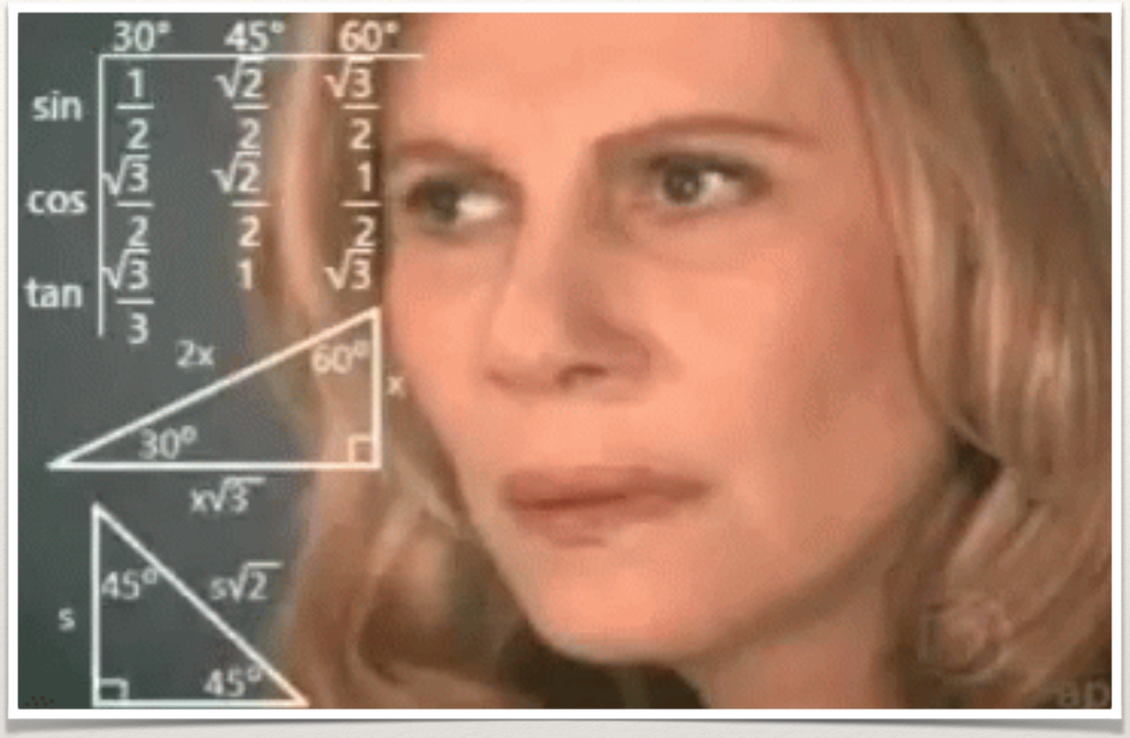
Integration: example

- MoK integrates chemical-inspired coordination (technical) with BIC (socio-cognitive)
- Speaking Objects integrate goal-orientation (technical) with argumentation-based coordination (socio-cognitive)
- They can even work together:
  - Smart City as a large-scale STS
  - MoK as the information handling layer
  - speaking and hearing objects scattered
  - information evolves according to MoK vision
  - speaking and hearing objects exploit it to argue

Conclusion: issues

- Despite efforts, there will always be issues
  - privacy and security clash with awareness
  - self-organisation clashes with predictability
  - decentralisation hinders accountability
  - …
- Fine-tuning integration on application needs is of paramount importance

Thanks for your attention :)



Questions?

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References

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- [Fernandez-Marquez et. al. 2013] Fernandez-Marquez, J.L., Di Marzo Serugendo, G., Montagna, S., Viroli, M., Arcos, J.L.: "Description and composition of bio-inspired design patterns: a complete overview" *Natural Computing* (2013)
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