Opening and filling Pandora's box – addressing agent-based simulation challenges

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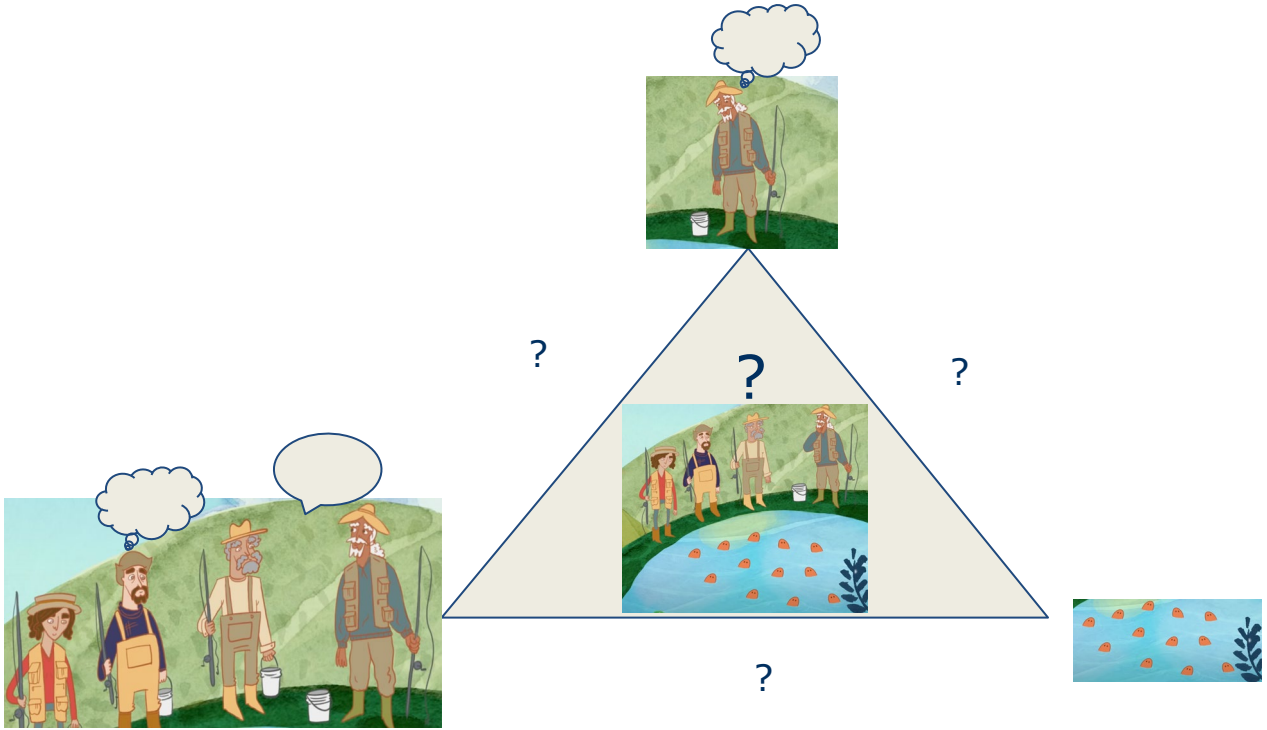
Background

- MSc in Sociology (Amsterdam)
  - Social simulation
  - AI
- PhD in Computer and Systems Sciences (Stockholm)
- Research
  - Social simulation
  - Agent theory and systems
  - Social ontology and philosophy
  - Computer games, social aspects and learning

Basic ABM simulation approach

- Agent + environment = system level effects
  - but also
- system level effects are part of the environment
  - micro-macro and macro-micro link
- Models + data needed on the agent decision making and the interaction between agents + agents & environment
- agent internal decision making = a core model assumption
  - many ABM have one single decision-making model with perhaps inter-agent heterogeneity (“simple complex”)
- complex environments (or contexts) ask for more heterogeneity (“complex complex”)
  - mechanism -> different agents may have different decision-making mechanisms
  - intra-agent -> different mechanisms and parameters over time



What type of simulation exist and for what?

Figure taken from: P. Davidsson, F. Klügl, H. Verhagen. Simulation of Complex Systems. In: L. Magnani, T. Bertolotti (Eds.), Handbook of Model-Based Science, Springer, pp. 783-797.

	human system	natural system	technical system	socio-technical system
theory building/ evaluation				
engineering of complex system				
management of complex system				
understanding of complex system				
training/ education				
entertainment				

real world or not?

study, improve?

……

Pandora’s box

- The internal workings of the agent
- The model of interaction between the agents

ABM agency models

- KISS versus KIDS (Edmonds, B., Moss, S. (2004) From KISS to KIDS–an 'anti-simplistic'modelling approach. In: International workshop on multi-agent systems and agent-based simulation. Springer, pp. 130-144.)
  - Simplicity or complexity inside the agent
  - Agent act and perceive in an environment and all decision-making (of interest) is parsed in the same agent model
  - Macro-level results depends on the interactions, not on the internal agent model

Decision-making frameworks

- Kahneman (Kahneman D. Thinking, fast and slow. Macmillan, 2011): (psychology based)
  - 1x2 modes: fast (S1, 98%) & slow (S2, 2%) thinking
- Consumat (see Janssen, M., Jager, W. (2001) Adoption of new products in a market of changing preferences and social networks. Journal of Economic Psychology 22: 745–77 **and** Jager, W. , Janssen, M. (2012). An updated conceptual framework for integrated modeling of human decision making: The Consumat II. In paper for workshop complexity in the Real World@ ECCS (pp. 1-18)): (psychology based), (un)certainty meets (un)satisfaction
  - 2x2/3, 4-6 modes: (Humat is an related framework, 2*3 as well but different cognitive theories and added explicit social theory – unpublished so far)
- The Model Social Agent (Carley, K., & Newell, A. (1994). The nature of the social agent. Journal of mathematical sociology, 19(4), 221-262): (analytical categories connecting sociology and cognition)
  - 5x6 modes, info processing capacity and knowledge dimension

Consumat

	Automated (high LNS, high BC)	Reasoned (low LNS, low BC)
Individually determined (certainty, private, individualist CP, personal needs)	Habitual - Classical conditioning theory - Operant conditioning theory	Deliberation - Decision and choice theory - Theory of reasoned/planned behaviour (attitude and perceived control)
Social determined (uncertainty, public visibility, egalitarian CP, social needs)	Imitation - Social learning theory - Theory of normative conduct	Social comparison - Social comparison theory - Relative deprivation theory - Theory of reasoned/planned behaviour (social norm)

LNS = level of need satisfaction
CP =cultural perspective
BC = behavioural control

Model Social Agent

Processing

Increasingly Limited Capabilities

Knowledge — Increasingly Rich Situations

	Nonsocial Task (NTS)	Multiple Agents (MAS)	Real Interaction (RIS)	Social Structural (SSS)	Social Goals (SGS)	Cultural Historical (CHS)
Omnipotent Agent (OA)	Goal directed Models of self Produces goods Uses tools Uses language	Models of others Turn taking Exchange theory	Face-to-face Timing constraints	Socially situated Class differences	Social goals Organizational goals	Historical situated motivation
Rational Agent (RA)	Reasons Acquires information	Learns from others Education Negotiation	Scheduling	Social ranking Social mobility Competition	Disillusionment	Social inheritance Social cognition
Bounded Rational Agent (BRA)	Satisfices Task planning Adaption	Group making	Social planning Coercion Priority disputes Miscommunication	Restraints on mobility Uses networks for information Corporate intelligence	Party line voting Delays gratification Moral obligation Cooperation Altruism	Gate keeping Diffusion Etiquette Deviance Roles Sanctions Role emergence
Cognitive Agent (CA)	Compulsiveness Lack of awareness Interruptability Automatic action	Group think	Crisis response Social interaction	Automatic response to status cues	Clan wars Power struggles Group conflict	Develop language Role development Institutions
Emotional Cognitive Agent (ECA)	Intensity Habituation Variable performance	Protesting Courting	Mob action Play Rapid emotional response	Campaigning Conformity	Nationalism Patriotism Team player	Norm maintenance Ritual maintenance Advertising

Opening the box (work together with Corinna Elsenbroich)

Aim:
To integrate different modes of behaviour into one integrated framework.

To show:
a) The different kinds of behaviour exist
b) They are genuinely different kinds of behaviour

Putting the theories together – filling the box

Opening and filling Pandora's box

CAFCA – A Contextual Action Framework for Computational Agents

(C. Elsenbroich, H. Verhagen. The Simplicity of Complex Agents – A Contextual Action Framework for Computational Agents. Journal of Mind & Society, 15 (1), pp. 131 – 143)

- Simulating social phenomena
  - model those aspects of human decision making relevant for the phenomenon at the level of specificity relevant for the purpose of the model.
    - behaviours have to be generalizable across agents,
    - behaviours have to be particular for an individual in a specific situation or context.
- decisions are highly contextual, i.e. dependent on an agent's interpretation of a situation
- two dimensional framework of contexts
  - the social dimension: individual, social and collective
  - the reasoning dimension: automatic, strategic and normative reasoning
- More complex than Consumat, less complex than Model Social Agent

	Individual	*Social*	*Collective*
Automatic	**Habitual**	**Imitation**	**Joining in**
Strategic	**Rational**	**Interdependent**	**Compliant**
Normative	**Behavioural rules**	**Social norms**	**Moral values**

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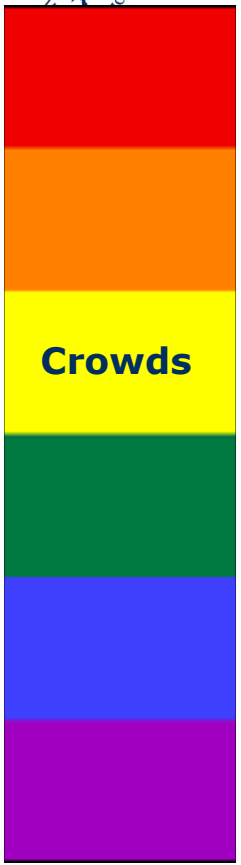

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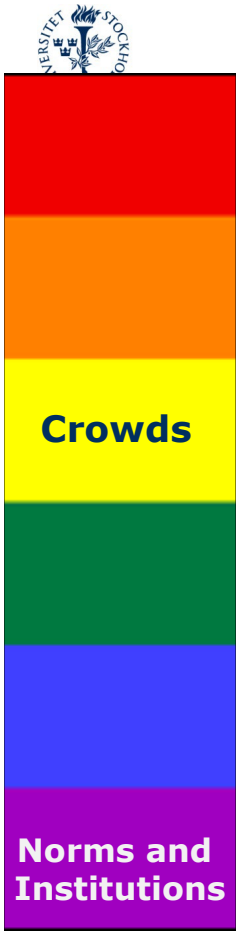

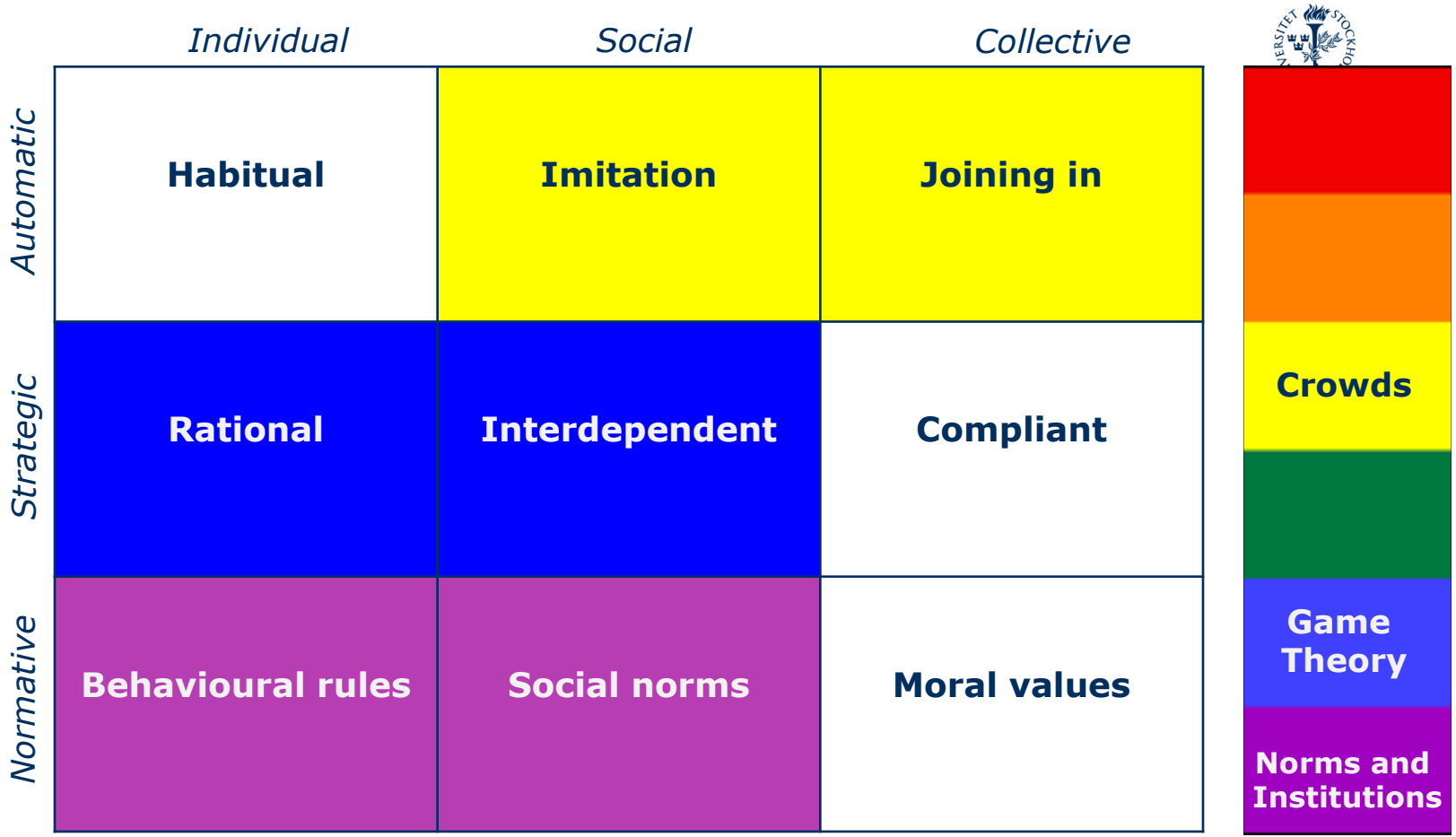
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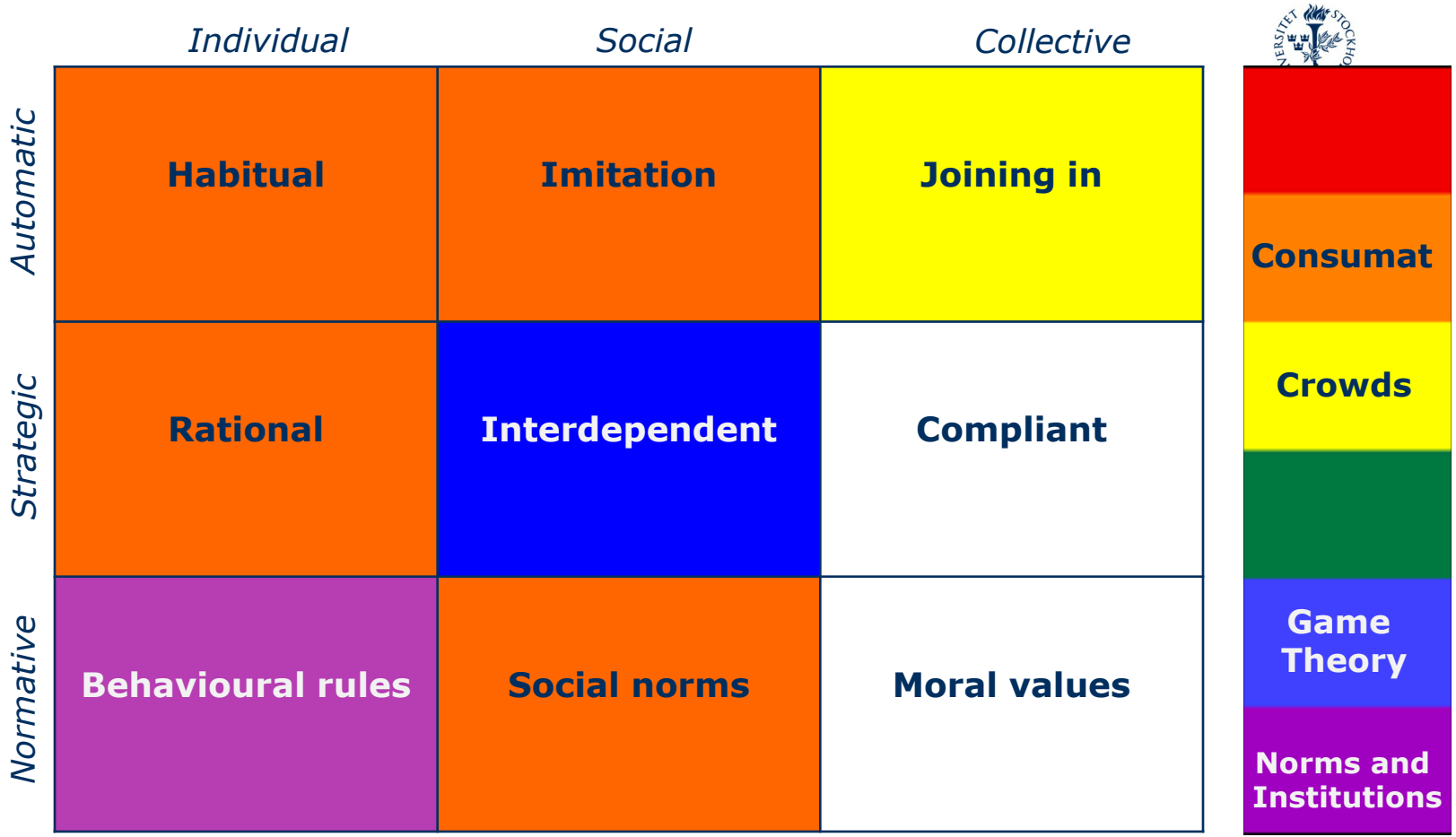
Moral values
Crowds
Game Theory
Norms and Institutions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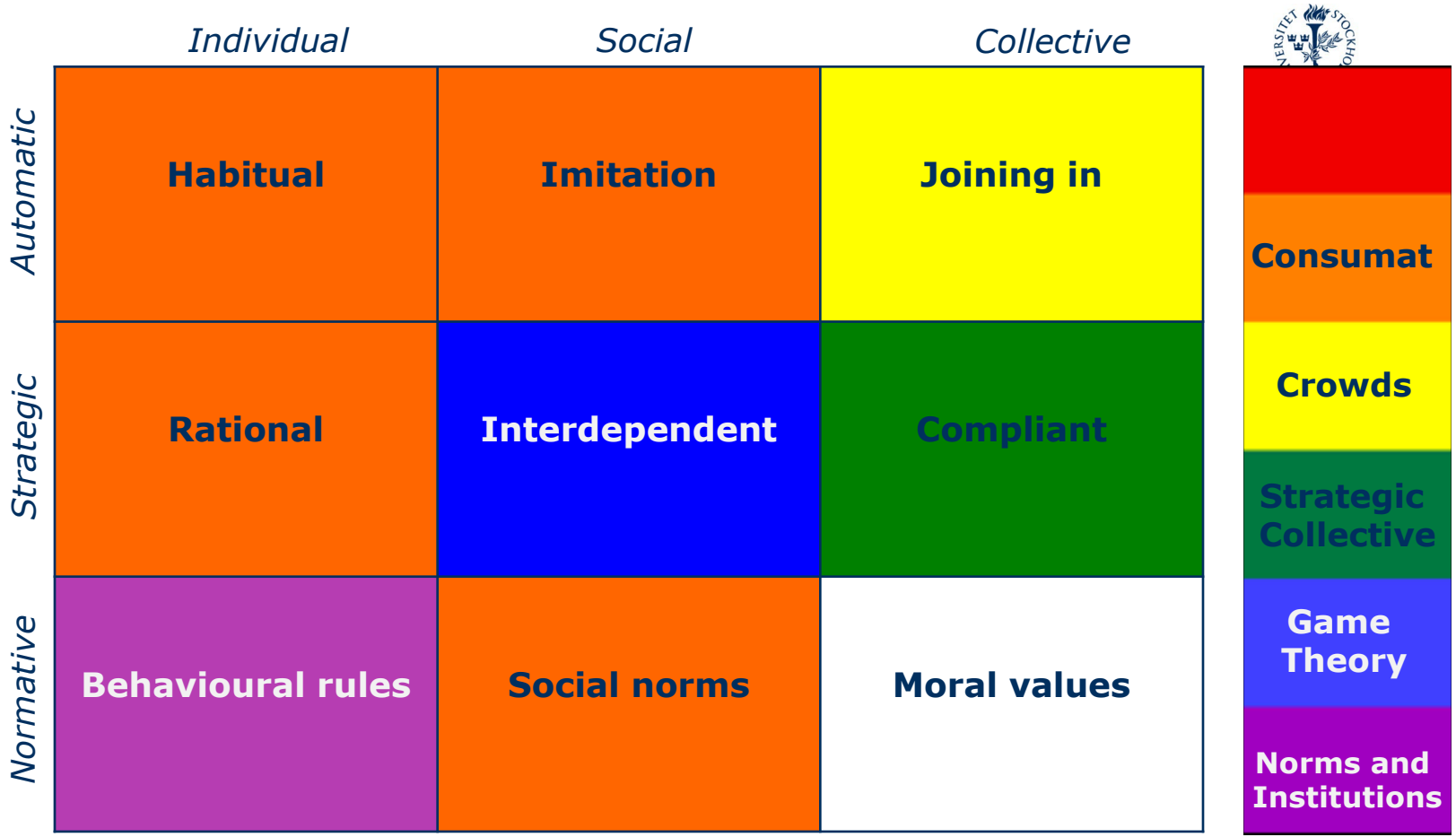
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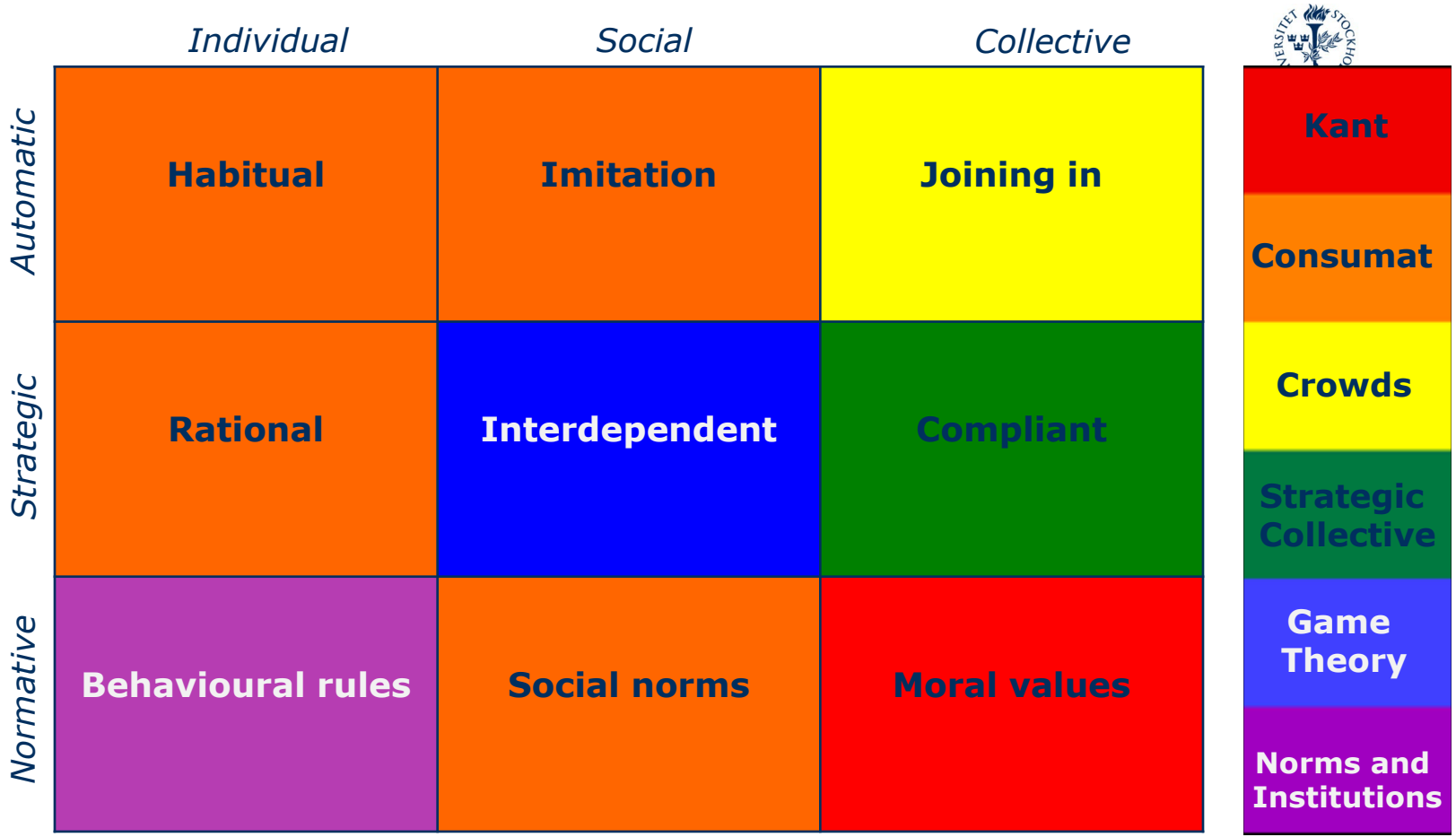
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CAFCA

- helps to conceptualise model specifications
- supports modelling of genuine sociality
- takes away the need for complicated black-box cognitive agents

CAFCA “toy problems test”

- 2 simulations models developed
  - Prisoner’s dilemma
  - Tragedy of the commons
- Reconceptualisation of classic models through CAFCA
- Aiming to see
  - How kinds of collective reasoning change the outcomes in an Axelrod type Iterated Prisoner’s Dilemma tournament
  - If collective reasoning could resolve a Tragedy of the Commons

CAFCA charged – challenging Tit-for-tat

(H. Verhagen, C. Elsenbroich, K. Fällström. Modelling Contextual Decision Making in Dilemma Games. In: W. Jager, R. Verbrugge, A. Flache, G. de Roo, L. Hoogduin, Ch. Hemelrijk (Eds.), Advances in Social Simulation 2015, Springer, pp. 121-12)

- Standard prisoner's dilemma for the Axelrod tournaments
- Implemented in Repast
- Results of individualist strategies validated against the available NetLogo implementation
- 200 rounds in 5 games with the outlier removed as in the original tournament
- 3 different collective strategies were tested
  - Previous outcome and local outcomes (self and neighbours)
  - Previous set of outcomes (self history)
  - Set of local outcomes (neighbours)

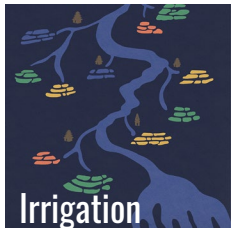
Tournament results for CAFCA

	Collective strategies				TfT
	self and neighbours	self history	neighbours	Combined	
Experiment 1	2,12	1,96	2,64	2,24	2,21
Experiment 2	2,05	2,09	2,29	2,14	2,32
Experiment 3	2,06	2,03	2,05	2,05	2,26
Experiment 4	2,04	2,11	2,36	2,16	2,14

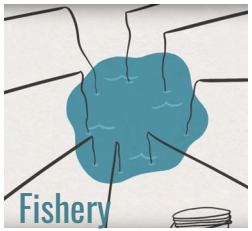
Common pool resources (type of good)

… are natural or human-made resources characterised by **subtractiblity** and (very) costly **excludability** (Ostrom 1990)

- Subtractability = use of the resource decreases the availability for all users
- Excludability = difficult, very costly, infeasible, or undesirable to exclude others from using the resource



Examples



Ostrom, E. 1990: Governing the Commons. The evolution of institutions for collective action. Cambridge University Press, Cambridge

CAFCA in the meadow – team reasoning and Tragedy of the Commons (Elsenbroich, C., Payette, N. (2020) Choosing to cooperate: Modelling public goods games with team reasoning, Journal of Choice Modelling, 34, 100203)

Following Schindler (2012) virtual landscape made up of a grid (33 × 33) of pixels/patches representing the pasture, non-mobile agents representing herdsmen, and mobile agents representing cattle owned by the herdsman agents, which are both initially randomly distributed on the landscape. In each time step, herdsmen agents modify their number of cattle agents on the pasture, cattle agents graze, and grass regrows, these processes forming a repeated time loop

Variables	Values
Herdsmen	6
Regrowth-rate	0.0005
Cow-grazing	1
Cow financial benefit	150
Learning factor	0.25
Initial number of cows	50
Team-reasoning	On, Off
Selfishness	0, 0.25, 0.5, 0.75, 1
Cooperativeness	0, 0.25, 0.5, 0.75, 1

CAFCA in the meadow – set-up and run

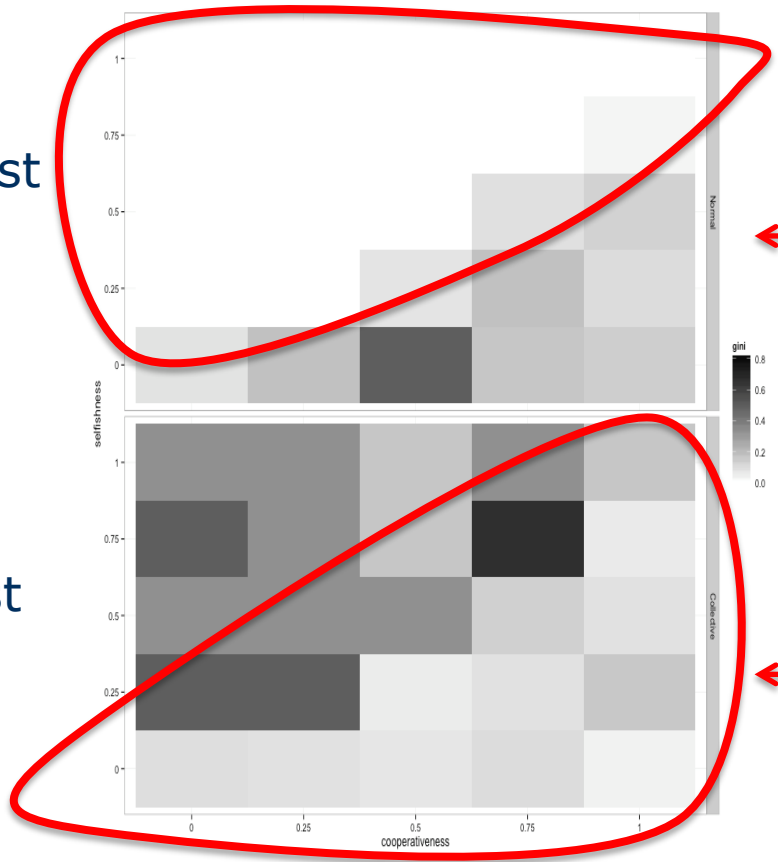
- To investigate the influence of team-reasoning on levels of sustainability, inequality and efficiency.
- Sustainability was assessed by the number of runs until the system runs out of grass.
- Inequality was measured by the Gini-coefficient plus an absolute measurement of herdsmen with 2 cows or less (an arbitrary minimum level).
- Efficiency was assessed by comparing the number of cows and the levels of grass.
- The variables that were varied were selfishness and cooperativeness. Each combination was run 10 times.

CAFCA in the meadow - results

- Schindler's results
  - selfish scenarios are not sustainable
  - explores several psychological amendments to the payoff function, showing that some lead to sustainable outcomes
- Our results
  - team reasoning simulations are sustainable even if the levels of selfishness are high
  - team reasoning has a positive effect on society in that it lowers the Gini-coefficient whilst lowering profits marginally

CAFCA in the meadow - results

Individualist Runs



Collectivist Runs

Gini low due to unsustainability of the commons.

Gini lower than in the individualist runs.

Preliminary findings

- Simulations to investigate alternatives to the classical rational choice decision making to model the empirical phenomenon of social dilemmas being resolved
- Iterated prisoner's dilemma
  - collective strategies perform similarly to Tit-for-Tat
  - neighborhood focused collective strategy overall outperforms Tit-for-Tat.
- Tragedy of the common
  - team reasoning renders dilemmas sustainable and has positive consequences for the equity of society, without relevant reduction in profits.

”Real world” CAFCA application (work together with Nanda Wijermans)

(see Wijermans, N., Verhagen, H. (2022). Fishing together? Exploring the murky waters of sociality. In: K. Van Dam, N. Verstaevel (eds.), Multi-Agent-Based Simulation XXII Proceedings, LNAI 13128, Springer, pp. 180-193 and N. Wijermans, H. Verhagen. (2022) Formalising agent reasoning – the Paso Doble of data and theory. Unpublished yet.)

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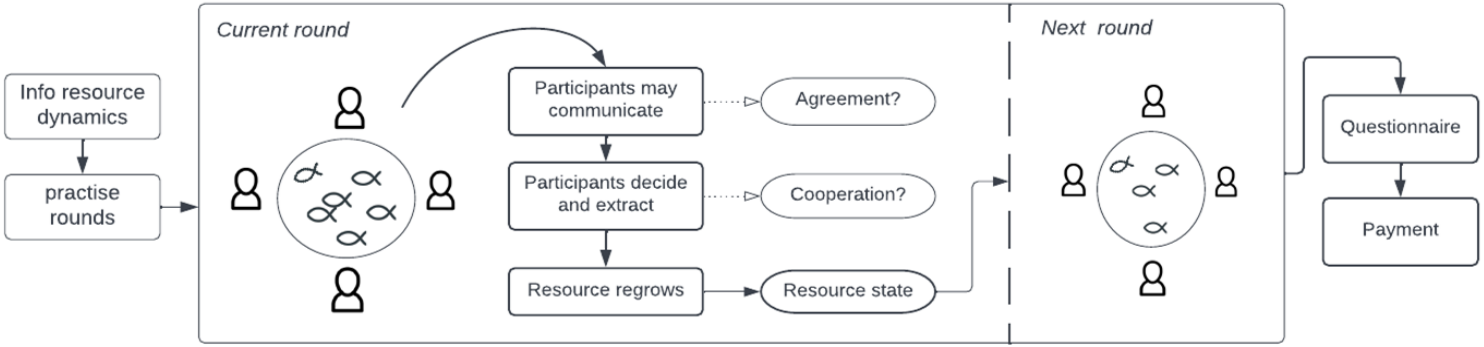
- Social dilemma research
  - individual interest versus the collective benefits, vast domain (theory, empirics & models)
  - usual agent decision -making model is bounded rationality
  - decision context is (in experiments) relatively simple wrt what but complex when why includes social level and time
- Complex domain – quite often relatively simple agent models

Our struggle with theory and data

- reflect on multi-reasoning frameworks to investigate decision-making heterogeneity
- finding clues in empirical data for this
  - Empirical study on group dynamics
  - Contextual Action Framework for Computational Agents (CAFCA) to structure the decision-making mechanisms

Decision context - *behavioural experiment*

Field work context = collecting data around controlled behavioural experiment with Thai fishers



Untangling reasoning

- reanalysing data, rethinking elicitation

Data = 6 debrief Interviews about group dynamics for an ABM of sustainable and collective CPR use. With experiment teams

Looking for reasoning clues

For each group:

- Summary of events
- Reasoning Clues
  - CAFCA reasoning

    levels
- Reflection for each choice
  - 1) communicate or not?
  - 2) how much?

	Groups				
	G1	G2	G3	G4	G5
Habitual	x	?			
Strategic	x	x	x	x	?
Normative	x		x	x	

Group 1: making it happen together *— strategic, habitual & normative*

Focus on ‘how much’ decision

- Strategic: those that understand communicate
- Habitual: over time seems so, reinforcing mechanism?
- Normative: for one that do not understand the resource dynamics, **choose** to stick to the agreement *(my interpretation)*

Only those that talk we can use to derive hints of their reasoning mode.

Group 3: silence is not golden

— normative and strategic reasoning

- Strategic: #4 who understands and to convince everyone what to do (bending rules of engagement),
- Normative: 2 and #3 seem concerned with what is appropriate

Thai cultural context, the younger ones listen to the older ones

Reflections on data gathering and analysis

- Challenge of language and culture
- Reasoning dims *(automatic/habitual,strategic, normative)*
  - Not straightforward, much reading in between the lines
  - strategic explicit *(how much choice)*,
  - habitual less explicit, over time observation needed
- How to improve collection & analysis:
  - getting to the why behind the result of a reasoning modes
  - approach to confidently detect normative-habitual decisions/reasoning?

Reflections on CAFCA

- May Need more (than 2) context dimensions
  - *history, culture, emotions*
- Role systemic constraints (e.g poverty)
- …..

Games and Agent-based modelling – another way to fill the box?

- As an alternative to surveys, interviews, observation and a stand alone ABM, the Games and ABM method (GAM) could be used to collect data on individual agents and their interactions amongst each other and with the environment

INTERNATIONAL JOURNAL OF SOCIAL RESEARCH METHODOLOGY
https://doi.org/10.1080/13645579.2022.2050119

GAM on! Six ways to explore social complexity by combining games and agent-based models

Timo Szczepanska[a], Patrycja Antosz[b], Jan Ole Berndt[c], Melania Borit[a], Edmund Chattoe-Brown[d], Sara Mehryar[e], Ruth Meyer[f], Stephan Onggo[g] and Harko Verhagen[h]

[a]Norwegian College of Fishery Science, UiT The Arctic University of Norway, Tromsø, Norway; [b]Department of Health and Social Science, NORCE Norwegian Research Centre AS, Kristiansand, Norway; [c]Smart Data & Knowledge Services - Cognitive Social Simulation, Deutsches Forschungszentrum für Künstliche Intelligenz GmbH, Kaiserslautern, Germany; [d]Department of Sociology, University of Leicester, Leicester, UK; [e]Department of Economics, London School of Economics, London, UK; [f]Centre for Policy Modelling, Manchester Metropolitan University, Manchester, UK; [g]Southampton Business School, University of Southampton, Southampton, UK; [h]Department of Computer and Systems Sciences, Stockholm University, Stockholm, Sweden

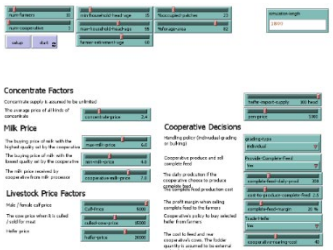
What are games?

"When you strip away the genre differences and the technological complexities, all games share four defining traits: a goal, rules, a feedback system, and voluntary participation." Jane McGonigal (2011)

Games as data collection tools

- Games provide **imaginary settings** in which players take on roles in a defined situation.
- The imaginary settings of games allow players **to explore, cooperate, or compete (without experiencing real-life consequences)**.
- The act of playing a game can be interpreted as a mode of communication in which players use a **rule-based language to transmit and receive messages**.

ABM and GAME correspondence



ABM	GAME
Agents	Game characters OR Players
Model rules	Game rules
Model time steps	Game turns
Simulation runs	Game sessions
Model interface	Game world

GAM: Combining Games and ABMs (1)

… benefit from both their **individual strengths** and the **synergy between** them !

ABM offers opportunities to:

1. create **what-if scenarios** (including counterfactual)
2. **scale up** gaming sessions (expanding spatial and temporal dimensions)
3. **update the characteristics** of the environment and agents to react to player actions
4. provide **generative** properties and the ability to model **dynamics**

GAM: Combining Games and ABMs (2)

Games can:

- provide **a platform for players to discuss** and agree on how to tackle real-life challenges
- help **understand behavioural strategies, interactions** among players, and biases.

Bonus:

- both can input and output qualitative as well as quantitative data
- data can feed from the game to the ABM or vice versa.

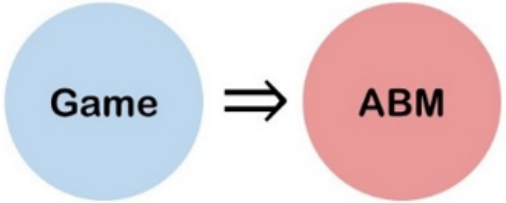
Method

- Literature review + analysis

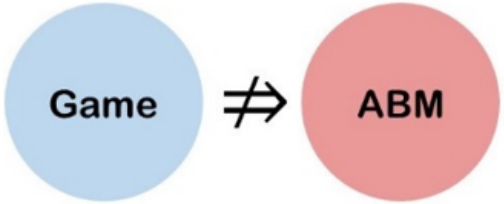
Initial screening	Final selection
In-team- knowledge: 17 Scopus & ScienceDirect : 300 Collected: 317 Papers	Inclusion: • research papers • mixed methods Game and ABM • English language Exclusion: • ideas without application • only one tool/method described Remaining: 52 Papers

Six Research Design Types

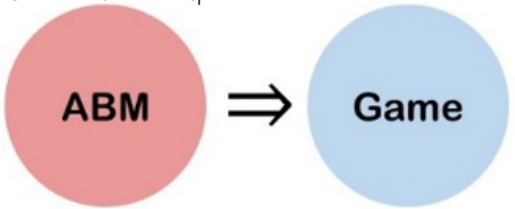
Type 1: Game => ABM
(n = 9, 17%)



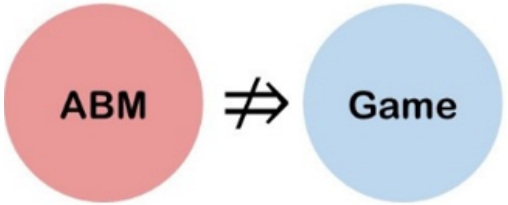
Type 2: Game ≠> ABM
(n = 3, 6%)



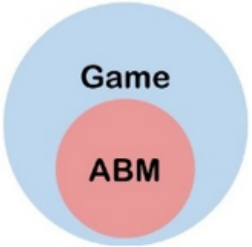
Type 3: ABM => Game
(n = 8, 15%)



Type 4: ABM ≠> Game
(n = 9, 17%)

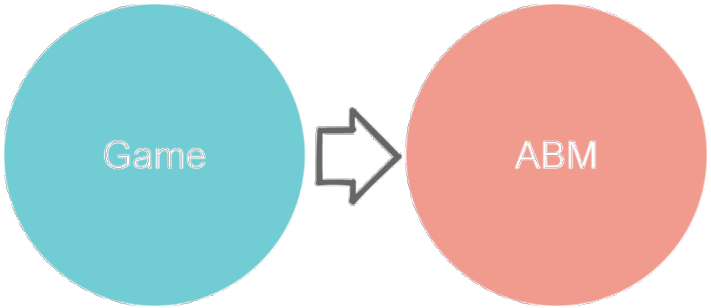


Type 5: ABM + Game
(n = 6, 12%)



Type 6: ABM = Game
(n = 17, 33%)

Type 1: Game -> ABM



Sequence

1st Game

2nd ABM, based on observations or discussions with the players.

Target system

- Game and ABM explore the same target system

Purpose

- Game as a data collection tool
- ABM integrates stakeholder knowledge of the system
- community-based scientific approaches to facilitate dialogue between different stakeholders

Dependency

- Game and ABM are closely linked

Type 2: Game -/-> ABM

Sequence

1st Game

2nd ABM, developed based on data gathered from a Game.

Target system

- Game and ABM explore different target systems

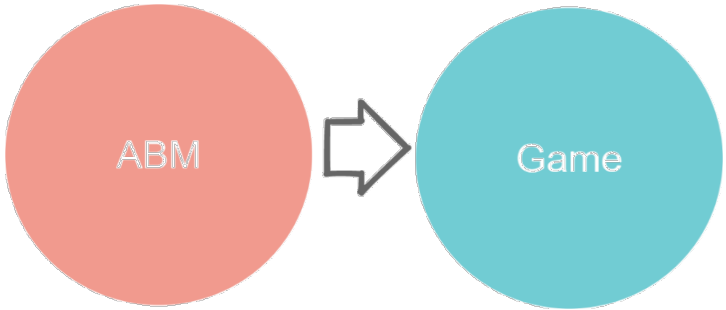
Purpose

- explore a Game with (theory driven) ABM
- enhance Game experience / performance

Dependency

- Game independent from the ABM
- ABM built to enhance the game

Type 3: ABM -> Game



Sequence

1st ABM

2nd Game, built to mirror the ABM and validate / enhance the initial ABM

Target system

- ABM and Game explore the same target system

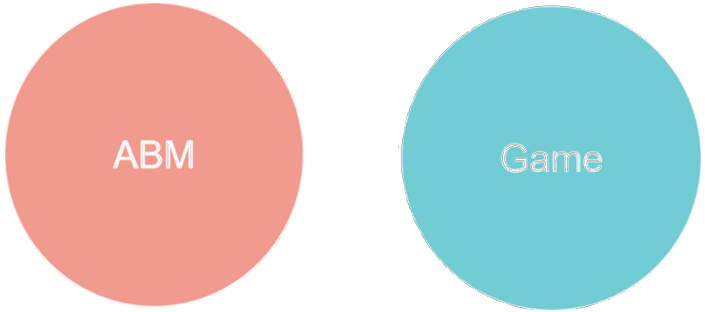
Purpose

- community-based scientific approaches to facilitate dialogue between different stakeholders

Dependency

- Game and ABM are closely linked

Type 4: ABM -/-> Game



Sequencing

1st ABM

2nd Game, developed to address one aspect of the ABM.

Target system

- Game and ABM have different target systems

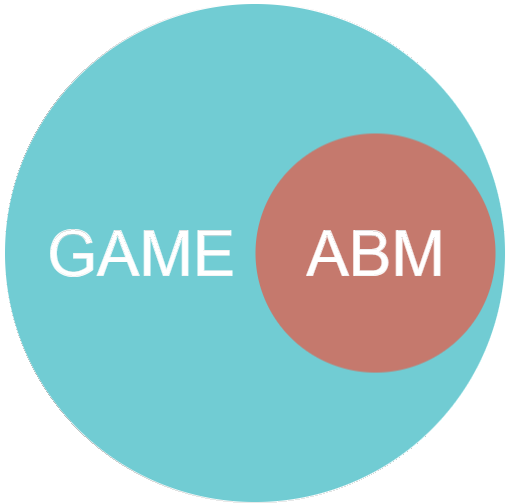
Purpose

- Study human behavior, socio technological systems, business games

Dependency

- Game is independent from ABM
- ABM enhanced through observations during gameplay

Type 5: Game + ABM



Sequence

ABM is an element of the Game (Game and ABM built at the same time)

Target system

- Depending on the purpose of the ABM as a tool, the target system can be the same or it can be different

Purpose:

- community-based scientific approaches to facilitate dialogue between different stakeholders

Dependency:

- Game depends on the ABM
- players play a Game, consequences of actions are calculated with an ABM

Type 6: ABM = Game

Sequence

ABM built as a Game (Game and ABM built at the same time)

Target system

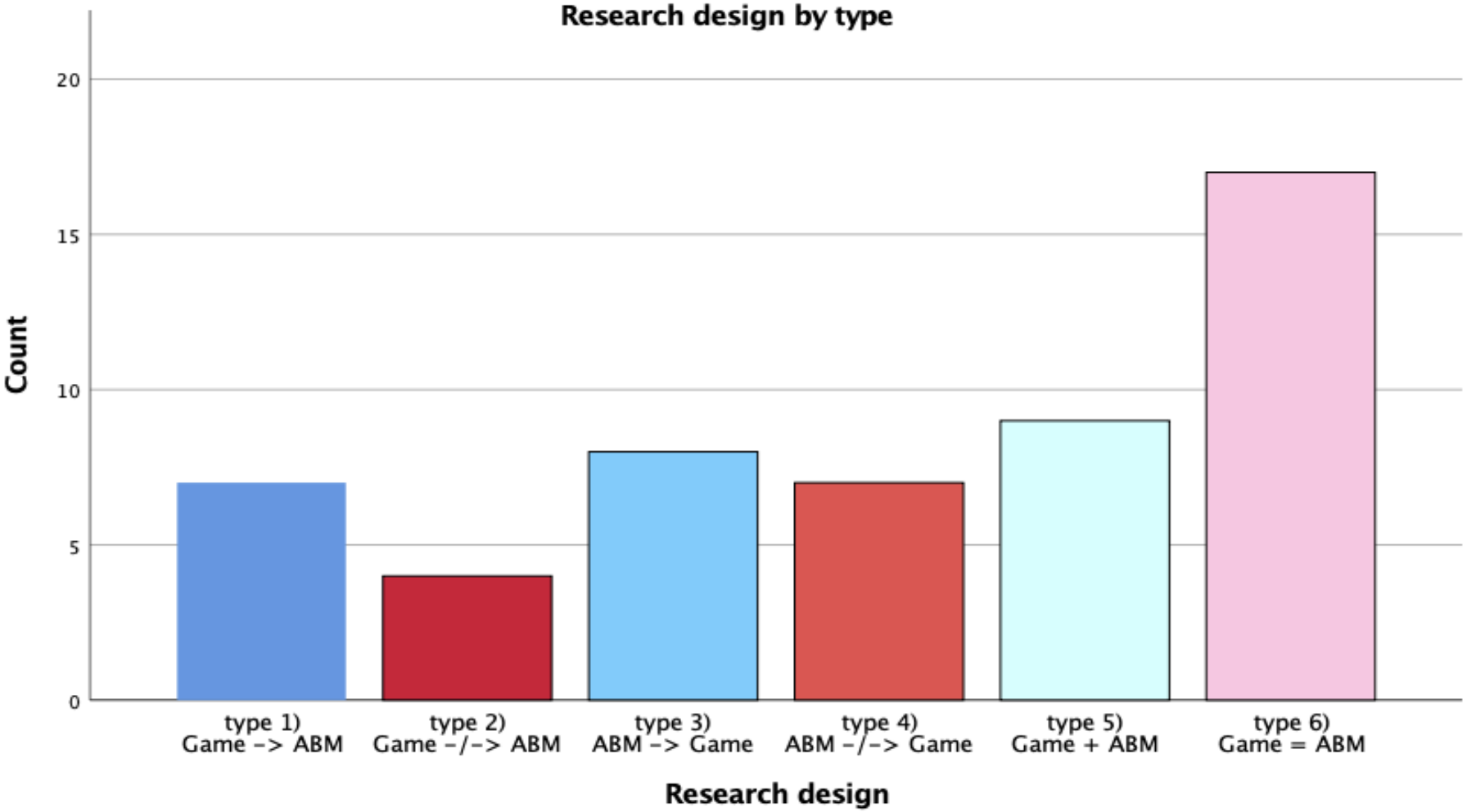
- There is only one target system (the one of the ABM=Game)

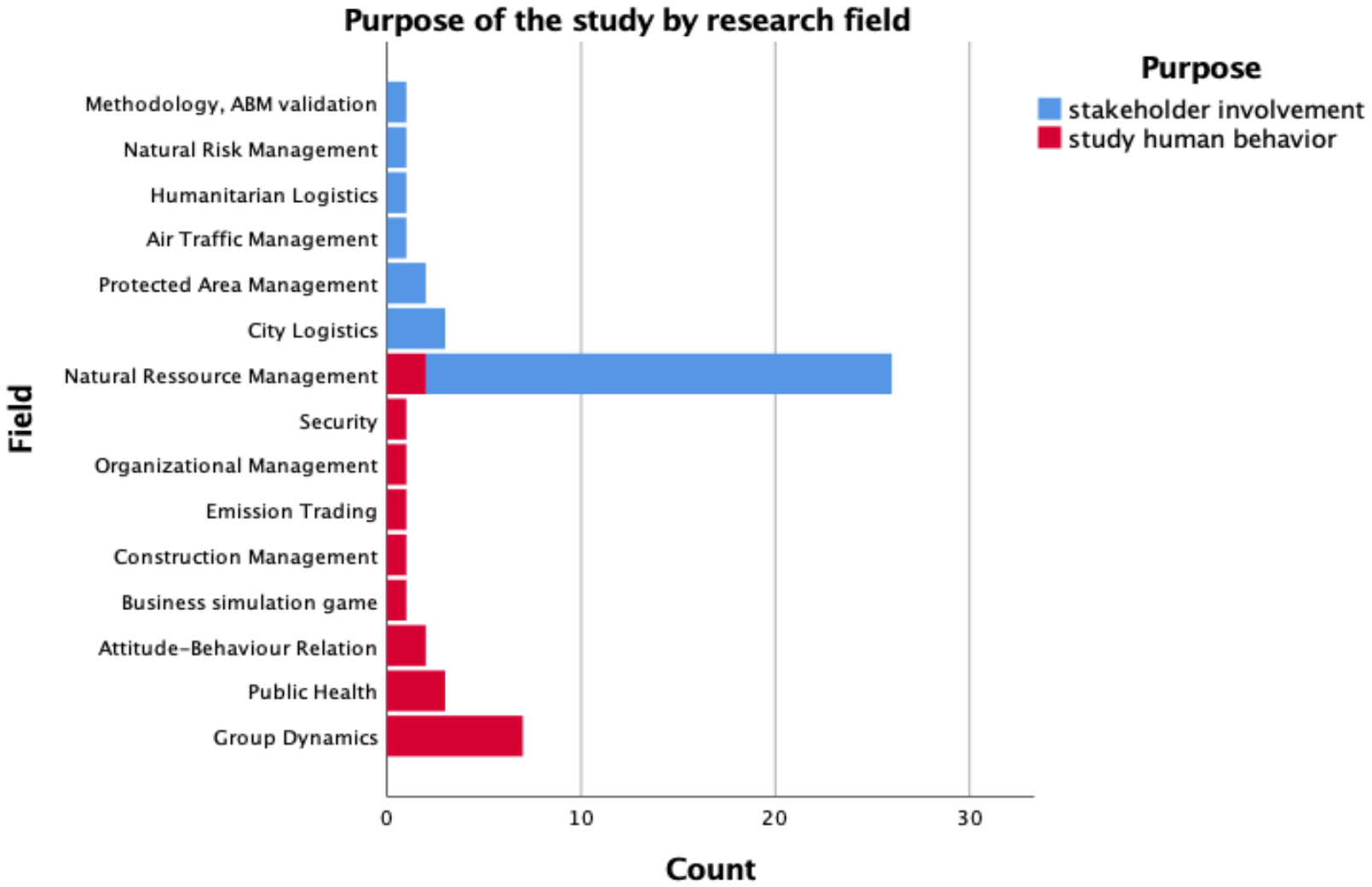
Purpose

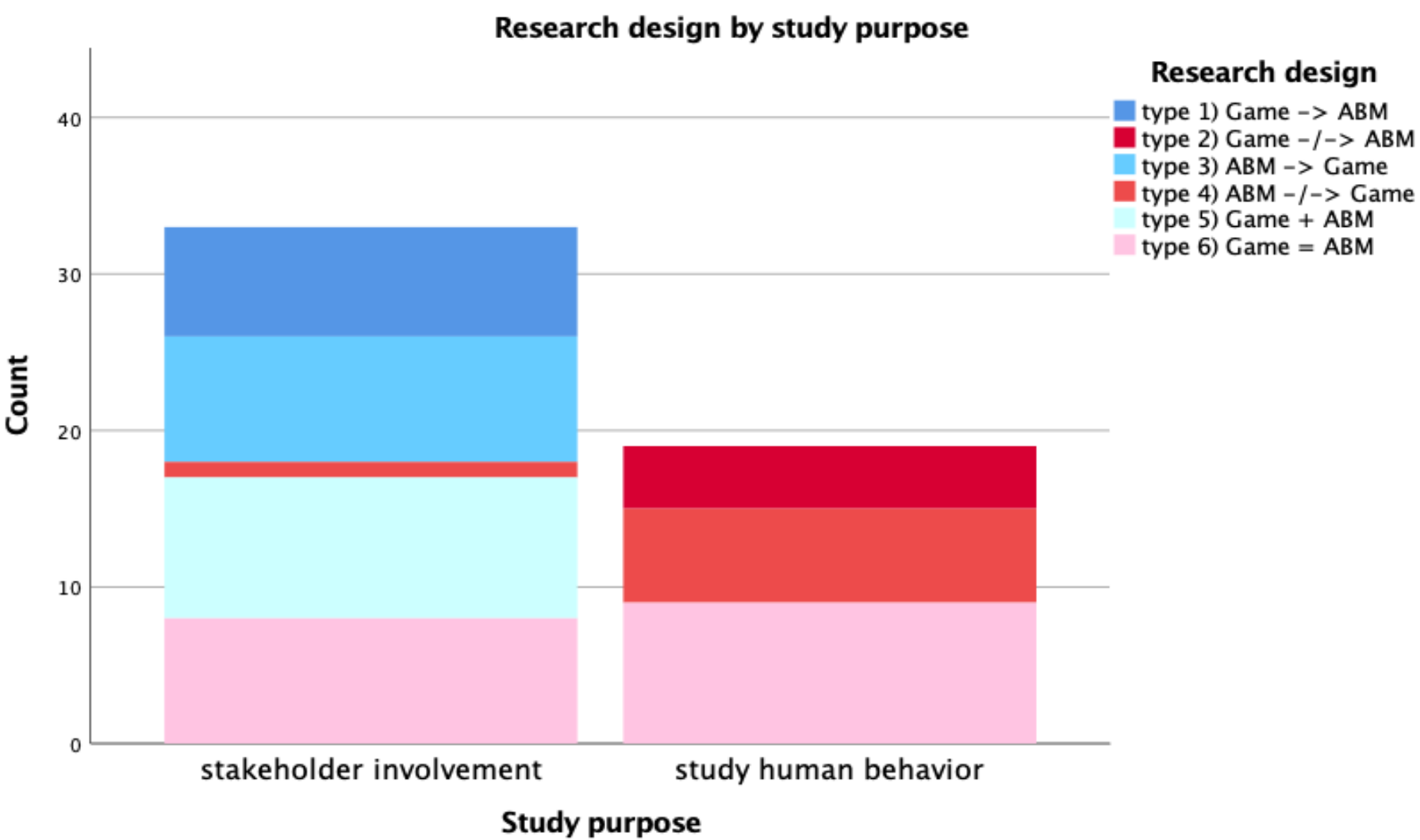
- Study human behavior, socio technological systems, business games
- community-based scientific approaches to facilitate dialogue between different stakeholders

Dependency

- Game = ABM + game related UserInterface + game elements


Research design by type
Count
20
15
10
5
0
type 1)
Game -> ABM
type 2)
Game -/-> ABM
type 3)
ABM -> Game
type 4)
ABM -/-> Game
type 5)
Game + ABM
type 6)
Game = ABM
Research design


Purpose of the study by research field
Purpose
stakeholder involvement
study human behavior
Field
Methodology, ABM validation
Natural Risk Management
Humanitarian Logistics
Air Traffic Management
Protected Area Management
City Logistics
Natural Ressource Management
Security
Organizational Management
Emission Trading
Construction Management
Business simulation game
Attitude-Behaviour Relation
Public Health
Group Dynamics
0
10
20
30
Count


Research design by study purpose
Research design
type 1) Game -> ABM
type 2) Game -/-> ABM
type 3) ABM -> Game
type 4) ABM -/-> Game
type 5) Game + ABM
type 6) Game = ABM
Count
40
30
20
10
0
stakeholder involvement
study human behavior
Study purpose

Big thanks

- to all co-authors and slideshow creators I have worked with, and
- for your attention!

- (slideshow (co-)creators: Corinna Elsenbroich, Stephan Onggo, Timo Szczepanska, Nanda Wijermans
- Any errors in these slides are mine ;-)