CBIM 2024

The Engineering Agent-Based Social Simulation Framework

A Key to Unlocking Agent-Based Modelling in B2B Research?

Peer-Olaf Siebers. School of Computer Science. Nottingham University. UK

peer-olaf.siebers@nottingham.ac.uk

The University of Nottingham
UNITED KINGDOM · CHINA · MALAYSIA

Business Models

- Business Models (BMs) are **static representations** of a system
  - Provide a structured framework to analyse a business to make strategic decisions
  - Offer a snapshot of how things work, but don't fully capture the dynamic nature of a system

- Combining BMs with **data analytics** allows to investigate the impact of changes at different points in time
  - Helps to identify patterns and relationships within data and to understand how changes in inputs (e.g. different marketing budgets) might affect outputs (e.g. sales)
    - Relies on data availability; only works for existing systems

Business Models

- Integrating BMs into **simulation models** allows to incorporate the dynamic nature of complex systems over time
  - Simulation tools can capture the dynamics of complex systems over time, considering factors like feedback loops and potential disruptions
    - Allows to observe how a system evolve (responds to change) over time for different scenarios

- Potential use cases
  - Understanding Customer Behavior
  - Evaluating Market Dynamics
  - Exploring the Impact of Decisions
  - Optimising Sales and Marketing Strategies

Heroes and Cowards Model [Wilensky and Rand 2015]

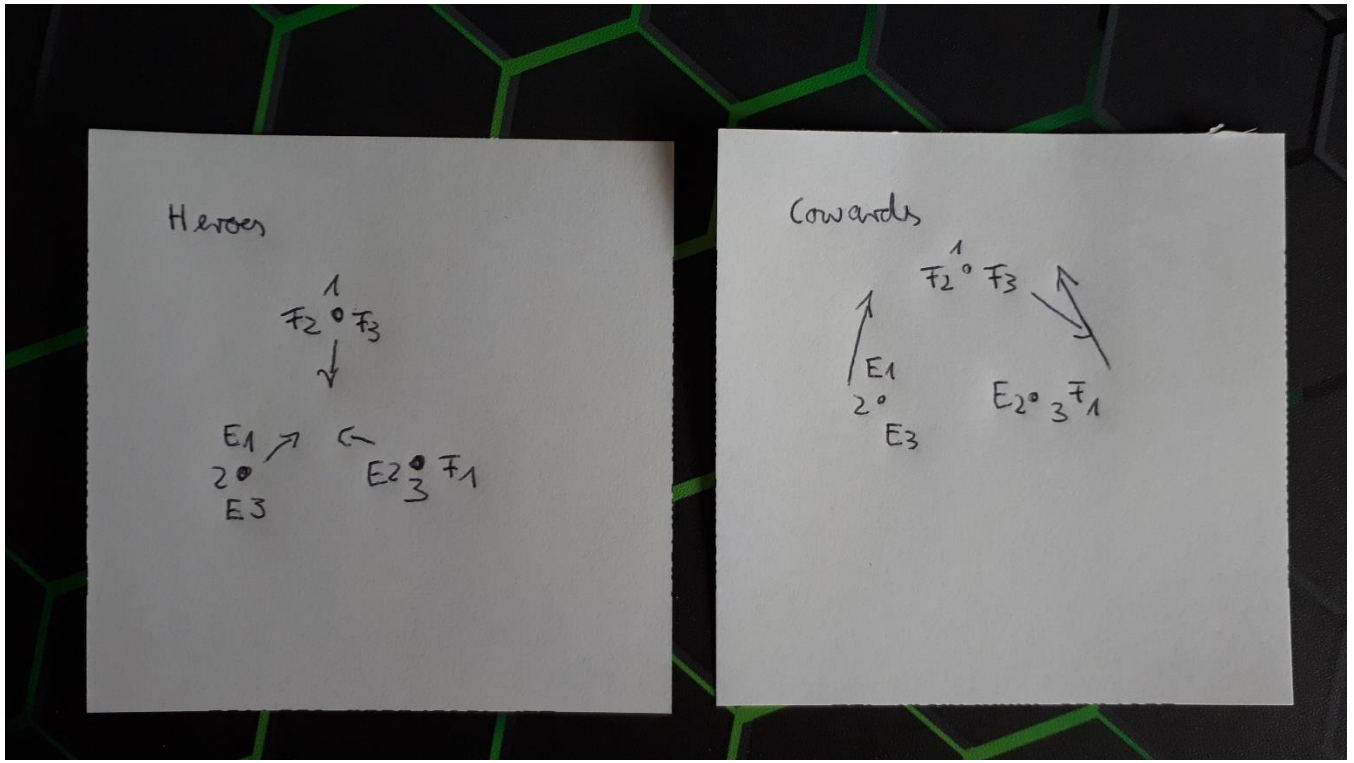
- Conceptual Definition
  - The world consists of heroes and cowards
  - A **hero** would always locate itself between a friend and enemy to shield one from the other

  - A **coward** would always use a friend to shield itself from the enemy

Heroes and Cowards

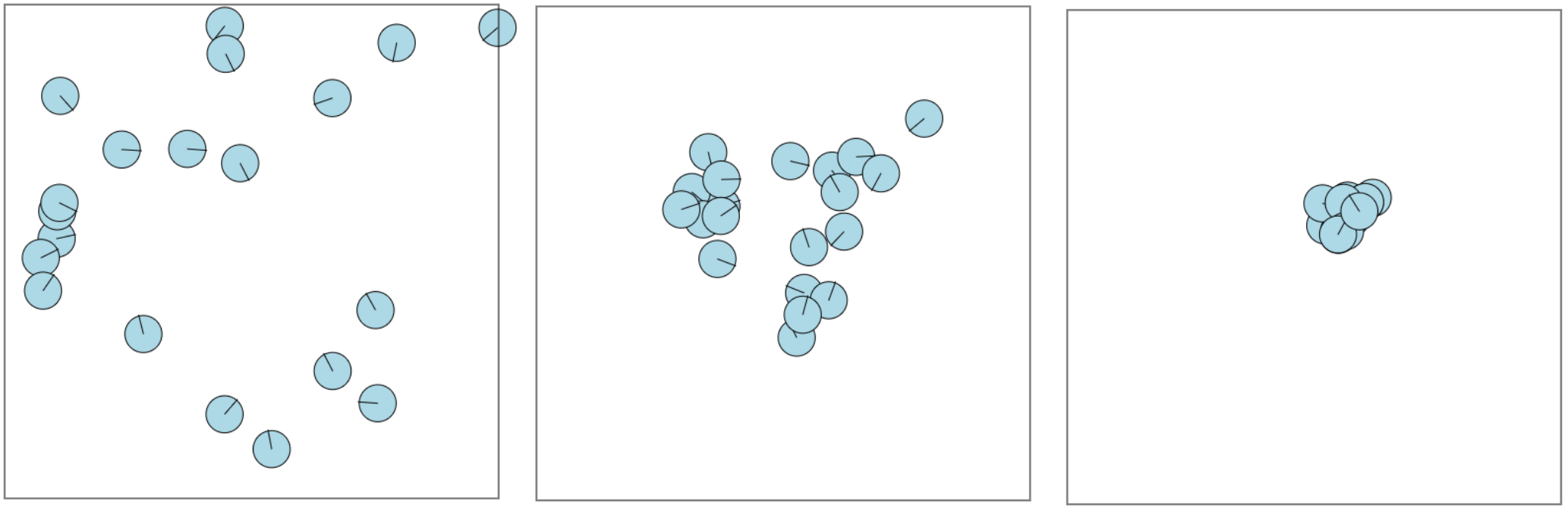
- Clarifying causal relationships

F=friend
E=Enemy



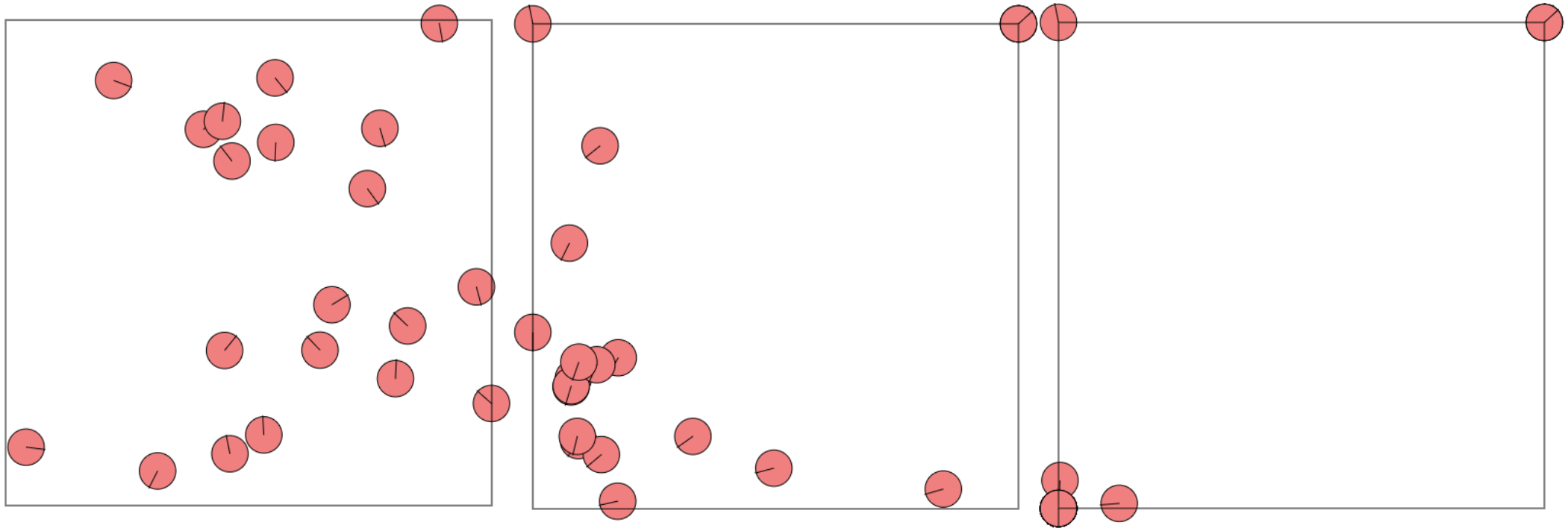
Heroes and Cowards

- Examining theoretical propositions through empirical testing: All heroes



Heroes and Cowards

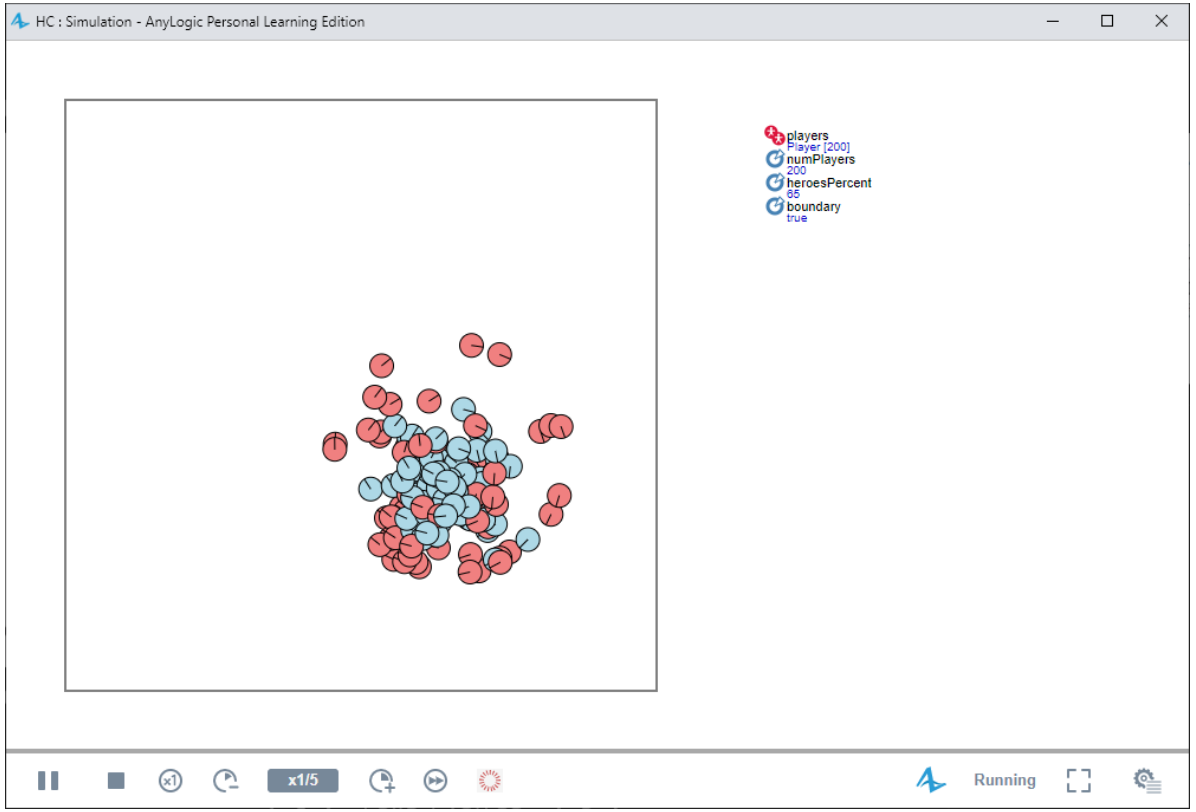
- Examining theoretical propositions through empirical testing: All cowards



Heroes and Cowards

- Sensitivity Analysis
  - Has the proportion an impact?
  - Has stochasticity an impact?
  - Has the number of participants an impact?
  - Are patterns dynamic?
  - Does time play a role?

Once we have an implementation of the model, we can investigate all these questions very easily!



65% heroes 35% cowards - Software: AnyLogicPLE (https://www.anylogic.com/)

Agent-Based Modelling

- Agent-Based Modelling (formal definition)
  - A complex system is represented by a **collection of agents** that are programmed to **follow some behaviour rules** and the **system properties emerge** from its constituent agent interactions

Agent-Based Modelling

- Schematic representation of an agent-based model

Agents can represent individuals, households, firms, organisations, nations ...

Models can be formulated mathematically or by using software engineering

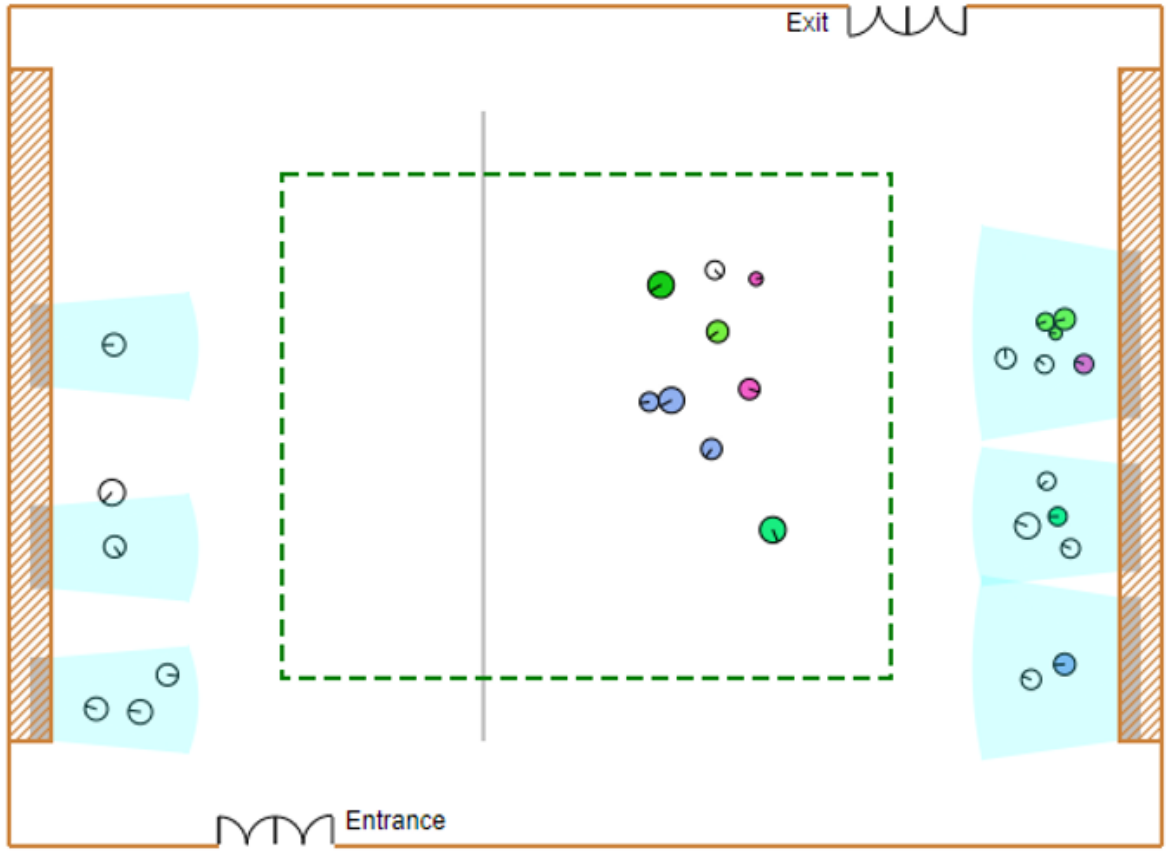
Develop agent-based models

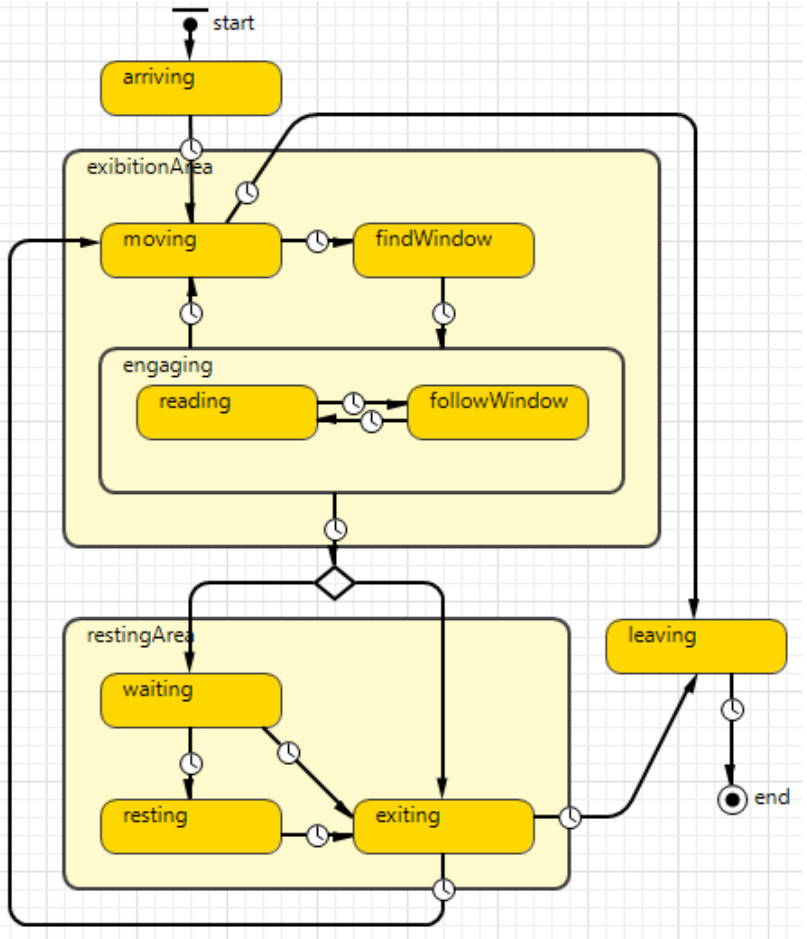
- Define the problem
- Identify active entities (agents)
- Define their states and behaviour
- Put them in an environment
- Establish connections

Ramadiah et al (2021)

Example: Adaptive Architecture Simulation

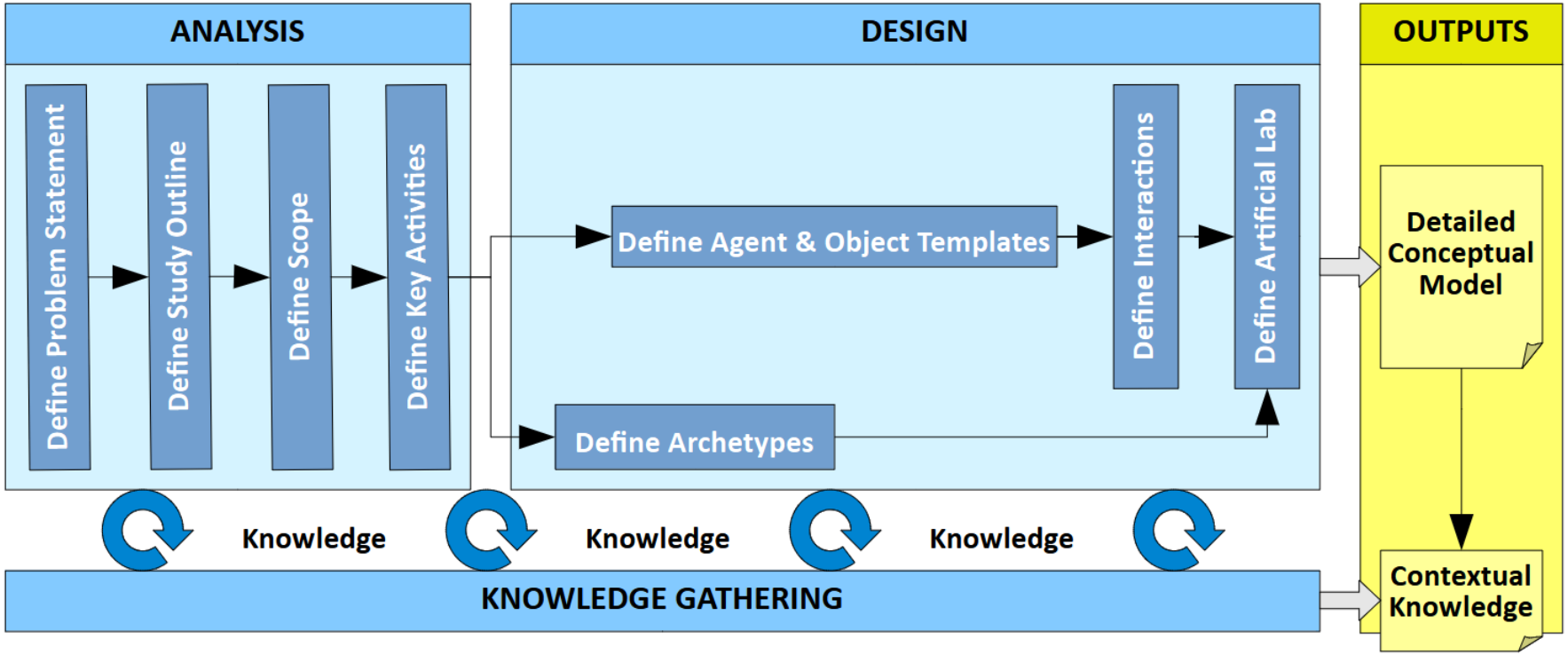
- Museum-Adaptiv-Wall*
  - AdaptiveWall
  - Group
  - Main
  - Person
  - Room
  - Screen
  - Simulation: Main
  - Run Configuration: Main
  - Database
  - Resources





Conceptualising Agent-Based Models

- The Engineering Agent-Based Social Simulation Framework

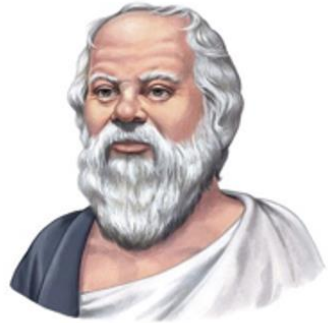


https://www.cs.nott.ac.uk/~pszps/eabss-toolkit/

Adapted from Siebers & Klügl (2017)

The EABSS Framework

- Using mini focus groups
  - Group sizes of **4-5 participants** (including moderator) work best
  - Estimated time to get through the whole process: **4 hours** (or more)
  - Confucius vs Socrates
    - Collaborative (inclusive) brainstorming
    - Mainly discussions (information gathering)
    - Debates only when needed
  - Moderators (usually the modeller)
    - Will often also act as a stakeholder
    - Will guide the discussions
  - Iterative process
    - Reuse of information from previous steps
    - Important to go forward and backwards

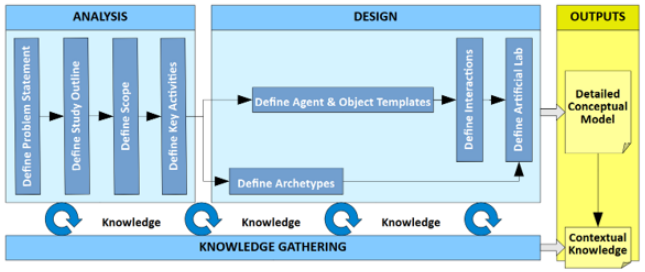


Engineering Agent-Based Social Simulations

Peer-Olaf Siebers
School of Computer Science, University of Nottingham, UK
Email: peer-olaf.siebers@nottingham.ac.uk

Brief Summary with Example Snippets

High level overview of the EABSS-2



Small print orange remarks are meant to guide the focus group moderator regarding the re-use of information; purple remarks list the tools to be used in that particular step.

Define Problem Statement (also clarify terminology and come up with a common pool of term definitions)

- Clarify the "Purpose" of the model, if not provided by the client:
  - Study title
  - Broad theme(s) (Blue Sky; Toy; Organisation Studies; Social Studies; Operations Research; Operations Management; Economics; Ecology; …)
  - Sub-theme(s) (Service Systems; Emergency Modelling; Organisational Cognition; Human/Natural Systems; Occupant behaviour; …)
  - Study approach (level of abstraction [strategic …]; purpose [exploratory …]; driver [theory …])
  - Study context (background information that provides a framework for understanding the research problem and its significance)
  - Study aim (a broad statement indicating the general purpose of your simulation study; consider title + themes + context)

Define Study Outline (also clarify terminology and come up with a common pool of term definitions)

- Define a list of "Objectives" (and constraints) to be fulfilled and/or "Hypotheses" to be tested (objectives: how you plan to achieve your aim; hypotheses: an attempt at explaining a phenomenon or the relationships between phenomena/variables in the real world)
- Define a list of "Experimental Factors" (parameters) to allow creating scenarios relevant to testing objectives and/or hypotheses (look at objectives/hypotheses to work these out)
- Define a list of "Responses" (outputs/statistics) for measuring if objectives have been achieved and to test if hypotheses should be accept/reject (look at objectives/hypotheses to work these out)

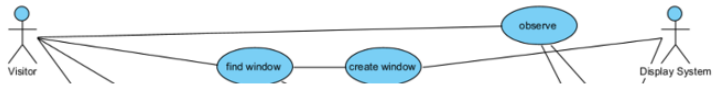
Define Scope (what do we need to represent to fulfil the aim; use "Context" words captured and "nouns" from the previous answers)

- List entities (key actors - represented by the role they play, and key objects) and concepts (key actors can also represent social/economic units, as for example families or firms)
- Indicate if these should be included/excluded in the model and justify your decision
- Use pre-defined table (COLUMNS: Category; Sub-Category; Element; Decision; Justification; CATEGORIES: Actor; Physical Environment; Social and Psychological Aspects; Misc)

Category	Sub-Category	ID	Element	Decision	Justification
Actor	Human	A01	Visitor	Include	Main research subject
		A02	Group	Include	Important for capturing group behaviour
		A03	Staff	Exclude	Have no impact on the dynamics
	Intelligent	A04	Content window	Include	Intelligent artefact that can make proactive decisions

Define Key Activities (actors come from scope table; key activities come from objectives/hypotheses and by creating user stories)

- Formulate user stories: As <actor>, I want to <what?> (so that <why?>)
- Assign key actors to relevant key activities (use cases)
- Use UML use case diagram



Define Archetypes (these allow to define behaviour of actors; units and values are not really required at this stage, but should be captured if they emerge from the discussion)

- Come up with categorisation schemata for relevant key actors (agents) that will allow to separate a simulated population into behaviourally different groups
- Use habit template(s) and/or demographics and/or utility function(s)

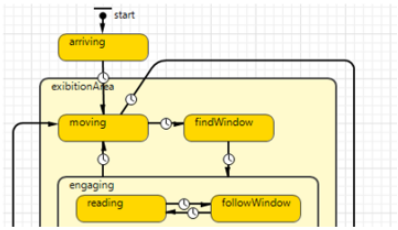
Visitor: Interest-related behaviour

Archetype	Reading time [seconds]
Disinterested visitor	3-10
Average visitor	10-40
Researcher	40-90

Define Agent & Object Templates (AGENT LEVEL) (state charts: states can often be derived from use cases; state variables are often a level of something, e.g. tiredness level; state transitions: transition start/end can be derived from state chart; agent & object classes: attributes can be derived from archetype criteria and by looking at the scope table; operations can be derived from the states in the related state charts)

- The following is done in parallel
  - Create state chart templates by defining key states an entity can be in and how these are linked
  - List State variables (dynamic variables representing entity states)
  - Create a table that defines triggers for transitions
  - Create classes (3 sections) providing a name, listing attributes, and listing activities and conditional checks
  - Use UML state machine diagram(s); transition table(s); class definition(s)/diagram(s)

Visitor: State chart

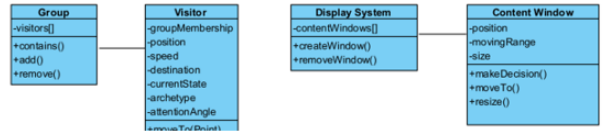


Visitor: State transitions

From State	To State	Trigger Type	Notes
arriving	moving	Timeout	Pseudo state; takes no time; adds transparency
moving	findWindow	Condition	Choose window
findWindow	engaging	Timeout	Pseudo state; takes no time; adds transparency
engaging/reading	engaging/followWindow	Timeout and Condition	Linked to archetype

Visitor: State variables: Location; mood; interest/fatigue/satisfaction level

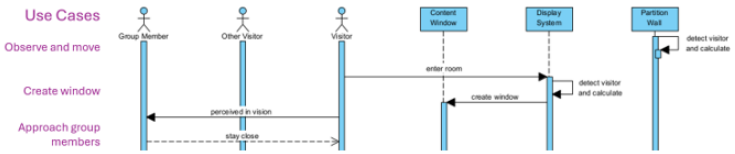
System: Classes and relationships



[] indicates a collection of elements
() indicates that we are dealing with an operation

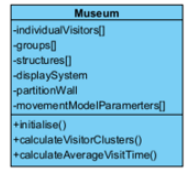
Define Interactions (SYSTEM LEVEL) (all elements defined in the Agent and Object Templates step need to be listed on the horizontal axis; use cases could be listed on the vertical axis; alternatively, a separate diagram could be created for each individual use case)

- Define sequences of interactions that can take place between agents and between agents and objects in specific use case realisations
- Use UML sequence diagram(s)



Define Artificial Lab (attributes provide storage for all agents and objects and initialisation parameters required for experimental factors; operations are related to responses; averages of agent and object dynamic variables could also be calculated)

- List entities that need to be created; listing variables that ought to be tracked at the macro level to gain insight about the issues identified during the problem analysis
- Define order of execution (if relevant)
- Use UML class definition for capturing class content and sequence diagram(s) for capturing execution order



Paga Case Study based on Ehret and Olaniyan (2023)

DEFINE PROBLEM STATEMENT

Title: Empowering Communities: The Paga Payment Revolution.
Broad Theme: Marketing.
Sub-Theme(s): Service Systems.
Study Approach: Strategic + Exploratory + Theory
Context (provided): Paga is a mobile payment platform based in Nigeria. It allows users to make payments, transfer money, and perform other financial transactions using their mobile devices. Paga serves as a digital wallet that enables individuals to link their bank accounts and make transactions without the need for physical cash. Users can access Paga services through a mobile app or by visiting authorised Paga agents. In this study, we focus on the adoption of the Paga Payment System in Nigeria.

Aim:
- Improving financial services in Nigeria
- Success of financial services in Nigeria
@ Adoption of mobile payment service

Remark(s): @ = chosen element

DEFINE STUDY OUTLINE

Objectives:
- Model adoption behaviour
- Find out why we have adopters/refusers
- Improve service so everyone has access
- Social … (?)

Experimental factors:
- Number of user
- Proportion of users
- Number of stores to pay
- Connectivity of people
- Money available for business to improve things
- Demographics of users

Hypotheses:
- Without mobile payment service the economy would not grow
- The more possibilities there are to use the system, the more people would use it
- Users need to get to the website for adoption rate to grow

Responses:
- Service status
- Satisfaction of users
- Number of website users (?)
- Amount of payment done
- Number of adopters

Remark(s): We should have made a choice here, while debating the Scope table and choosing the relevant elements

DEFINE SCOPE

Actors:
@ User (adopters/refusers)
- Stores
- Holder of the system (platform)
- Shop assistant
@ Regulation authorities
- Sales team
@ Other banks (competitors)
- Government
- Technical staff
@ Businesses (adopters/refusers)
- Media
- Marketing team
- Negotiators
- Bus driver

Physical environment:
- Banks
- Shops
- Public transport
@ Infrastructure (payment system availability)
- Mobile phone
- Bitcoin
- Retailers
- 4G/5G network
- Cash

Social and psychological aspects / phenomena:
- Word-of-mouth
@ Marketing (to individuals/companies)
- Interest in innovation of new products
@ Adoption behaviour
- Technical knowledge of people
- Willingness to adopt
- Separation from work and home locations
- Social connectedness
- Convenience to get access to a mobile phone
@ Mobile phone distribution
- Network quality

Other:
- Network connectivity

Paga Case Study


PREPARATION

Title:
- Adoption of the Paga Payment System

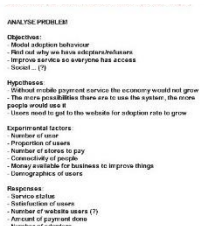
Broad theme:
- Marketing

Sub-theme(s):
- Service Systems

Context
- Paper Abstract: Researchers identify institutional voids as serious roadblocks to economic development. Mobile payment systems offer a promise to fill institutional voids in emerging economies. Financial technology companies can help to "bank the unbanked" by leapfrogging financial services found in more developed economies. However, both, economic regulations as well as technological solutions for institution building, such as cryptocurrencies, show mixed results. Institutional Theory extends institutional voids research by acknowledging the social dimension of institutions. Constitutive rules help to conceptualize the cultural-cognitive dimension of payment institutions. The study of Paga, the premier mobile payment platform of Nigeria, reveals the emergence of constitutive rules through the interplay of technology development and social action. Constitutive rules are vital for financial technology innovation, and more generally in the institutionalization of service ecosystems. The case demonstrates the central role of partner-networks in establishing mobile payment institutions.
- Words from Michaela Cortez: presentation; Payment: systemic; mobile phone; shops; bus driver; user; other user; adopter; refuser; payment service hardware; infrastructure; regulator; server; (business); payment service; bitcoin; network (physical (GRIG) + social); partner; companies (micro / macro); other companies (competitors); marketing (for individuals + companies); marketing (using word-of-mouth + ads); behaviour; adaptation; growth through word-of-mouth; government; insurance; government (institutional interventions); insurance; trust; location (Nigeria + UK); culture; partners; recruitment of new partners; diffusion of innovation

Aim:
- Improving financial services in Nigeria
- Success of financial services in Nigeria
@ Adoption of mobile payment service

Remark(s):
@ = chosen element


ANALYSE PROBLEM

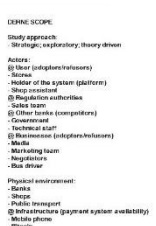
Objectives:
- Model adoption behaviour
- Find out why we have adopters/refusers
- Improve service so everyone has access
- Social ... (?)

Hypotheses:
- Without mobile payment service the economy would not grow
- The more possibilities there are to use the system, the more people would use it
- Users need to get to the website for adoption rate to grow

Experimental factors:
- Number of user
- Proportion of users
- Number of stores to pay
- Connectivity of people
- Money available for business to improve things
- Demographics of users

Responses:
- Service status
- Satisfaction of users
- Number of website users (?)
- Amount of payment done
- Number of adopters

Remark(s):
- We should have made a choice here, while debating the Scope table and chosing the relevant elements


DEFINE SCOPE

Study approach:
- Strategic; exploratory; theory driven

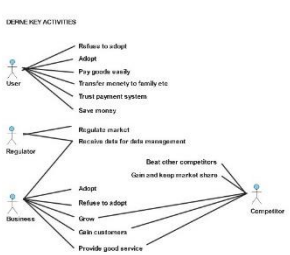
Actors:
@ User (adopters/refusers)
- Stores
- Holder of the system: (platform)
- Shop assistant
@ Regulation authorities
- Sales team
@ Other banks (competitors)
- Government
- Technical staff
@ Businesses (adopters/refusers)
- Media
- Marketing team
- Regulators
- Bus driver

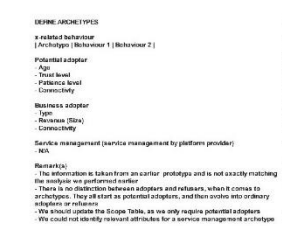
Physical environment:
- Banks
- Shops
- Public transport
@ Infrastructure (payment system availability)
- Mobile phone
- Bitcoin
- Retailers
- 4G/5G network
- Cash

Social and psychological aspects / phenomena:
- Word-of-mouth
@ Marketing (to individuals/companies)
- Interest in innovation of new products
@ Adoption behaviour
- Technical knowledge of people
- Willingness to adopt
- Separation from work and home locations
- Social connectedness
- Convenience to get access to a mobile phone
@ Mobile phone distribution
- Network quality

Other:
- Network connectivity

Remark(s):
@ = chosen element




DEFINE ARCHETYPES

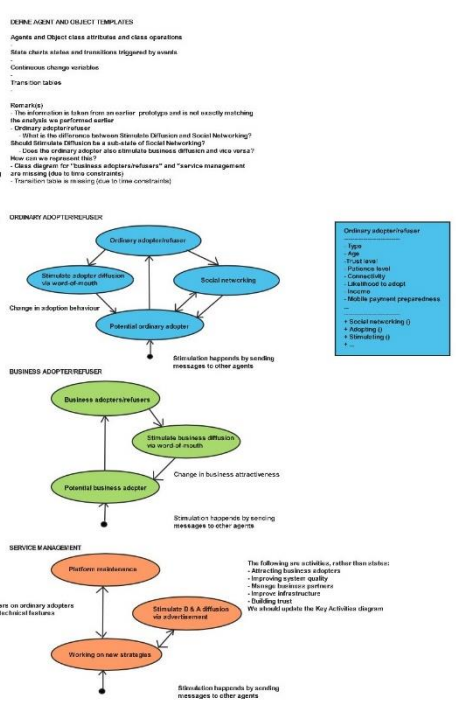
x related behaviour
| Archetype | Behaviour 1 | Behaviour 2 |

Potential adopter
- Age
- Trust level
- Patience level
- Connectivity

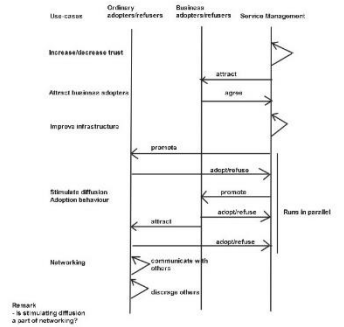
Business adopter
- Type
- Revenue (Size)
- Connectivity

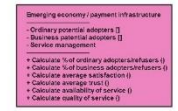
Service management (service management by platform provider)
- N/A

Remark(s):
- The information is taken from an earlier prototype and is not exactly matching the analysis we performed earlier
- There is no distinction between adopters and refusers, when it comes to archetypes. They all start as potential adopters, and then evolve into ordinary adopters or refusers
- We should update the Scope Table, as we only require potential adopters
- We could not identify relevant attributes for a service management archetype

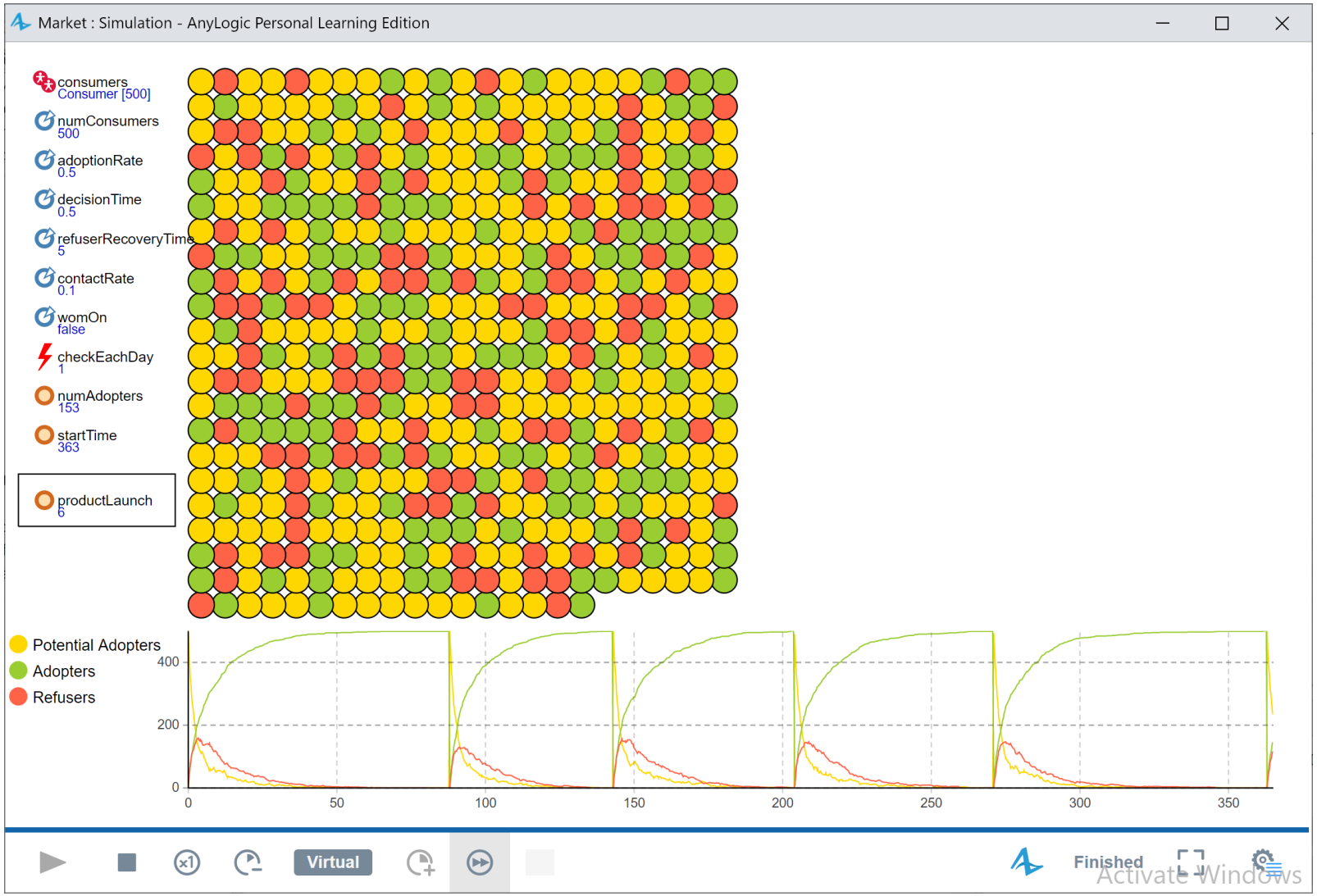


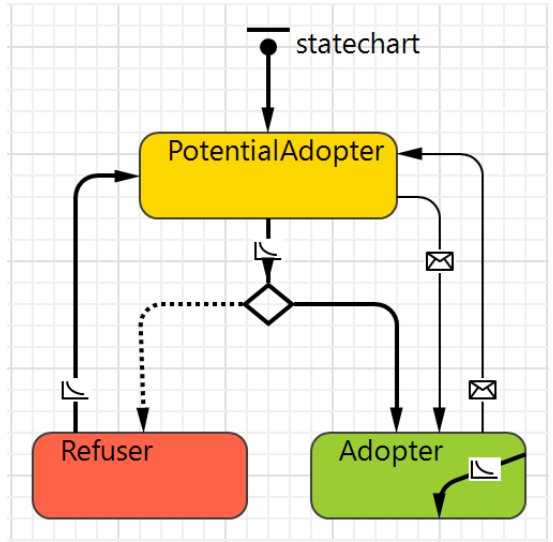
Ordinary adopter/refuser
- Type
- Age
- Trust level
- Patience level
- Connectivity
- Likelihood to adopt
- Income
- Mobile payment preparedness
+ Social networking ()
+ Adopting ()
+ Stimulating ()
+ ...





The University of Nottingham
UNITED KINGDOM · CHINA · MALAYSIA


Market : Simulation - AnyLogic Personal Learning Edition
consumers
Consumer [500]
numConsumers
500
adoptionRate
0.5
decisionTime
0.5
refuserRecoveryTime
5
contactRate
0.1
womOn
false
checkEachDay
1
numAdopters
153
startTime
363
productLaunch
6
Potential Adopters
Adopters
Refusers
400
200
0
0
50
100
150
200
250
300
350
Virtual
Finished
Activate Windows


statechart
PotentialAdopter
Refuser
Adopter

Current Research

- Using Conversational AI for modelling (Siebers 2024)
  - Having EABSS focus group sessions with virtual stakeholders
    - Good for generating innovative ideas (blue sky thinking)
    - Requires minimal information upfront

- Using Conversational AI for creating synthetic populations
  - Creating synthetic populations for simulations by using virtual interviews
  - Creating synthetic populations for simulations by using virtual domain experts

- Both are done by asking the AI to enact different personas
  - Requires well designed prompts and careful validation

References

- Ehret, M., & Olaniyan, R. (2023). Banking the unbanked. Constitutive rules and the institutionalization of mobile payment systems in Nigeria. *Journal of Business Research*, *163*, 113845.
- Ramadiah, A., Galbiati, M., & Soramäki, K. (2021). Agent-based simulation of central bank digital currencies. Available at SSRN 3959759.
- Siebers, P. O. (2024). Exploring the Potential of Conversational AI Support for Agent-Based Social Simulation Model Design. *arXiv preprint arXiv:2405.08032*.
- Wilensky U, Rand W (2015). An Introduction to Agent-based Modeling: Modeling Natural, Social, and Engineered Complex Systems With NetLogo. Mit Press.