OR Training Course 2023 Co-Creation of Agent-Based Simulation Models



Welcome

Personal Introductions (15 min)





Training Course Convenor

- Peer-Olaf Siebers
 - Homepage
 - https://www.cs.nott.ac.uk/~pszps/
 - Email
 - peer-olaf.siebers@nottingham.ac.uk
 - Medical Condition
 - Functional (Dissociative) Seizure







My Research Interests

- Technical Aspects
 - Engineering Social Simulations and other Multi-Agent Systems
 - Using Software Engineering methods and tools to define all sorts of agents and their interactions





My Research Interests

- Applications
 - My Mission: Applying OO-ABM to as many fields as possible
 - Business studies (Risk Assessment; CBA; MCDA)
 - Economics (Game Theory; Agent Based Computational Economics)
 - Social Sciences (Political Science; Social Simulation)
 - Engineering (Manufacturing; Urban Modelling; Energy; Transportation)
 - Computer Science (Robotics; Game Development)
 - Operations Research (Healthcare)
 - Systems Biology (Immunology)
 - Medicine (Digital Technology for Mental Health)





My Research Interests

• Simulating the future of service







• Summary [Siebers 2023]



My Research Interests

Everything you always wanted to know about Dr Siebers (academic details only :) - 2nd Edition Pour present at 04 SOCETY 1111 SMALATION WORKSHOP (SW23) by Peer Old States, School of Compare Science, The University of National peer old Laidensignodinghamac

After more than 10 years of publishing the first edition of my research agenda I felt that it's time for an update. My current research can be subsumed under the umbrella of "collaboratively creating artificial labs for better understanding current and future human and mixed human/robot societies". I am a strong advocate of agent-based simulation, but I am also open to other approaches. My poster provides references to my previous and ongoing work, identifies current gaps, and offers ideas for future collaborations.

My research aligns towards standardisation of methods and towards considering future scenarios of human/robot interactions in an operational and service oriented context. Wherever possible, I aim to introduce techniques from computer science, and in particular software engineering, to come up with a more structured and transparent approach to simulation modelling. I also embed simulation into other analysis tools to enable these to consider uncertainties in a more transparent waynemet way.



What About You?





Agenda

- Introduction
 - 09:30-09:45 Personal introductions (15 min)
 - 09:45-10:45 Lecture: Introduction to AB and Hybrid Modelling (60 min)
 - 10:45-11:00 Short break (15 min)
 - 11:00-12:00 Lecture: A Structured Approach to AB/Hybrid Model Development (60 min)
 - 12:00-13:00 Lunch (60 min)
- Practice
 - 13:00-14:00 Joint activity: Co-creating a conceptual AB model (60 min)



Agenda

- Software
 - 14:00-15:00 Lecture: Introduction to AB modelling in AnyLogic PLE (60 min)
 - 15:00-15:15 Short break (15 min)
- Presentation
 - 15:15-15:45 Research case studies summary (30 min)
- Practice
 - 15:45-16:30 Small groups: Develop modelling ideas for your own problems (45 min)
 - 16:30-16:45 Joint activity: Summarise outcome of previous activity (15 min)
- Wrap Up
 - 16:45-17:00 General discussion and Q&A (15 min)



OR Training Course 2023 Co-Creation of Agent-Based Simulation Models



Lecture

Introduction to AB and Hybrid Modelling (60 min)











Heroes and Cowards

- Consider the following gaming scenario [Wilensky and Rand 2015]
 - 20 people scattered in a room no communication
 - Game 1: Everyone takes on the role of a **Hero** by following a simple rule
 - Pick two participants and always locate yourself between them to shield one from the other



• What happens when everyone starts moving?





Heroes and Cowards

• Heroes and Cowards Game : All heroes

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Heroes and Cowards

- Consider the following gaming scenario [Wilensky and Rand 2015]
 - 20 people scattered in a room no communication
 - Game 2: Everyone takes on the role of a **Coward** by following a simple rule
 - Pick two participants and always use one to shield yourself from the other



• What happens when everyone starts moving?





Heroes and Cowards

• Heroes and Cowards Game: All cowards

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Heroes and Cowards

• Heroes and Cowards Game: Source Code





Heroes and Cowards

- Software used: NetLogo
 - https://ccl.northwestern.edu/netlogo/





• Flocking behaviour







Flocking behaviour modelling by Craig Reynolds [url]





http://ayearincode.tumblr.com/post/107414487116/this-morning-i-added-some-new-rules-to



- In Agent-Based Modelling (ABM), a system is modelled as a collection of autonomous decision-making entities called agents. Each agent individually assesses its situation and makes decisions on the basis of a set of rules.
- ABM is a mindset more than a technology. The ABM mindset consists of describing a system from the perspective of its constituent units. [Bonabeau 2002]
- ABM is **well suited to modelling** systems with heterogeneous, autonomous and proactive actors, such as **human-centred systems**.



- Borrowing from Artificial Intelligence: From simple to complex
 - Simple reflex agent





- Borrowing from Artificial Intelligence: From simple to complex
 - Learning agent





- What do we mean by "agent"?
 - Agents are "objects with attitude" [Bradshaw 1997]
- Properties:
 - Discrete entities
 - With their own goals and behaviours
 - With their own thread of control
 - Autonomous decisions
 - Capable to adapt
 - Capable to modify their behaviour
 - Proactive behaviour
 - Actions depending on motivations generated from their internal state





- Agents can represent individuals, households, organisations, nations ...
 - Discrete entities; autonomous decisions; proactive
- ABMs are essentially decentralised; there is no place where global system behaviour (dynamics) would be defined
- Instead, the individual agents interact with each other and their environment to produce complex collective behaviour patterns



- Benefits of ABM
 - ABM provides a natural description of a system
 - ABM captures emergent phenomena



- Emergence
 - Emergent phenomena result from the interactions of individual entities. The whole is more than the sum of its parts [Aristotle BC] because of the interactions between the parts
 - An emergent phenomenon can have properties that are decoupled from the properties of the part (e.g. patterns appearing)
 - Example: Traffic Jam Dynamics



- When to use ABM (examples)? [Siebers et al. 2010]
 - When the problem has a **natural representation as agents** when the goal is modelling the behaviours of individuals in a diverse population
 - When entities have relationships with other entities, especially dynamic relationships
 - When it is important that entities have **spatial or geo-spatial aspects** to their behaviours
 - When it is important that entities **learn or adapt**, or populations adapt
 - When entities engage in **strategic behaviour**, and anticipate other entities' reactions when making their decisions



Agent-Based Simulation





Agent-Based Simulation

- Little Computer People (LCP) @ C64 @ 1985
 - This "House on a Disk" is based on the theory that every computer has an "occupant"; every occupant is different
 - You could communicate with your occupant by asking him what you want him to do
 - "Please play with me"
 - "Please play piano"
 - "Please write a letter to me"
 - "Please talk to me"





Agent-Based Simulation

• The Sims: Interactive Organisational Agent-Based Simulation





Object Oriented ABM (OO-ABM)





Building and Validating Agent-Based Models

- Different purpose of ABMs [Edmonds et al 2019]
 - Prediction
 - Explanation
 - Description
 - Theoretical exploration
 - Illustration
 - Analogy
 - Social interaction



Building and Validating Agent-Based Models

- Different flavours of ABMs [Achter et al 2022]
 - Theory driven
 - Empirical (data) driven
 - Model driven
 - Participatory



Building and Validating Agent-Based Models

🔂 Main

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Person

- Building an ABM (OR/MS)
 - Identify active entities (agents)
 - Define their states and behaviour
 - Put them in an environment
 - Establish connections •
 - Test the model

AnyLogic Help (2013)

- Validating an ABS
 - System behaviour is an emergent property
 - Validation at micro level
 - Plausibility check of emerging patterns at system level (e.g. comparison to observations)





Graphical Notation to Capture Agent States/Behaviours

- Typical elements of a state chart
 - States
 - Represents a location of control with a particular set of reactions to conditions and/or events

State

- Examples
 - Cup can be in state full or empty
 - Person can be in state idle or busy
- Transitions
 - Movement between states, triggered by a specific event
 - In AnyLogic such event can be: timeout; rate; condition; message; agent arrival



Graphical Notation to Capture Agent States/Behaviours

• Typical elements of a state chart



- Shallow History: Reference to the most recently visited state on the same hierarchy level within the composite state
- Deep History: Reference to the most recently visited simple state within the composite state





Building Simple State Charts Step-by-Step

• Simulating an office scenario

- What question would you like to answer?
 - Consider "What-If" or "How Many" type of questions and choose one to continue
- Who are the actors relevant to your question?
 - Come up with 2-3 actor types based on their roles
- What are the key locations you can find them?
 - Keep it simple (approx. 3 locations)
- What are key time consuming activities they get involved in?
 - Keep it simple (approx. 3 activities)
- Define a state chart for one of your actor types
 - Consider key locations and key time consuming activities relevant for this actor type




Building Simple State Charts Step-by-Step





Hybrids: AO-DES

Agent Oriented Discrete Event Simulation





Concept of AO-DES

- AO-DES is a hybrid simulation paradigm; we represent the process flow with the help of a discrete event simulation model and add some active entities to replace the passive entities commonly used in discrete event simulation
 - Passive entities are told what to do
 - Active entities can act autonomously and can (often) be proactive





Concept of AO-DES

Direct interactions Network activities



Let entities interact + communicate



Replace passive entities by active ones

Active entities Behavioural state charts

Agent layer



Passive entities Queues Processes Resources

DES layer



AO-DES Example

Modelling Staff Proactiveness in Retail Simulations [Siebers and Aickelin 2011]

• Modelling a department queuing system





AO-DES Example

Modelling Staff Proactiveness in Retail Simulations [Siebers and Aickelin 2011]

Modelling proactive customer/staff behaviour





AO-DES Example

Modelling Staff Proactiveness in Retail Simulations [Siebers and Aickelin 2011]

• Implementation

S Model Animation _ 🗆 × ► || |< 1/5 1/2 ×1 ×2 ×5 VT To technolo Department: Audio & TV (A&TV) Sunday: Shop open for 8 hours *1 = number of people queueing for this service *2 = % of those leaving the gueue red: cashier green: normal staff member blue: expert staff member *3 = considering accumulated history [number] lighter colours: free darker colours: serving very dark colours: supporting (expert advice) *4 = considering accumulated history [satisfaction growth] *5 = experience per visit [number] *6 = experience per visit [satisfaction growth] Current customer population: real planned vears weeks days hours minutes 8000 21 52 73 (73)0 5 Average arrival rate per hour: Runtime: 0 Customers in store: 27 Overall customers: 86255 100 % Transactions: 29101 - browsing: q - leave happy (transaction or refund): 29101 34 % *1 *2 Av. Transaction [£]: 149.7 0 - leave not waiting for normal help: Sales [£]: 4,356,420 - seeking help: 2464 3% 19921 12 % 0 - queuing for help: leave not waiting for expert help: 826 1 % 1907 43 % Missed [£]: 8,551,912 - standard: leave not waiting to pay: 10855 13 % 39001 28 % - leave without finding anything: 42982 50 % - expert: - refund author .: n leave unhappy (no refund): 0 0% Customers left: 86228 477406 getting help: 7 *3 100 % *4 *5 100 % *6 Till queue length: mean: 3.78; max: 17.0 - standard: - satisfied (> 0): 61697 72 % 518960 35188 41 % 101567 - don't know (= 0): 47 % - expert: Normal help queue length: mean: 1.25; max: 14.0 10574 12 % 40652 - not satisfied (< 0): 16 % -41554 10388 12 % -26726 - refund author .: Expert help queue length: mean: 0.08; max: 4.0 13957 - wait at till: 8 Overall refunds: 100 % - to pay: Overall Satisfaction Level Index: 477406 - refunds accepted: 0% *2 - for refund: 0 - shopping: 477406 - refunds denied: 0% *1 - served at till: 3 - refund: 0 - leave not waiting for refund decision: 0 0% 0 0% 0% - to pay: 3 - leave not waiting for author. decision: 0 0% 0 - for refund: 0 Overall decisions by cashier 0 Important parameters: Overall decisions by authorised person: 0 Finite population: - Replication number: 3 1 served 255 11 served 0 - shopping enthusiasts: 400 - Empowerment level of cashier for refunds: 0.7 2 served 435 12 served 0 - solution demanders: 3200 - Probability that refund is granted by cashier: 0.8 3 served 265 13 served 0 - service seekers: 3200 - Probability that refund is granted by authoriser: 0.7 4 served 164 14 served 0 - disinterested shoppers: 400 - Probability that staff stay with customer: 0 5 served 74 15 served 0 - Points required to become an expert: - internet shoppers: 800 100000 6 served 47 16 served 0 - Word of mouth adoption fraction: 0.5 7 served 25 17 served 0 intNumProactiveOpportunity: 0 - Word of mouth contact rate: 0 8 served 17 18 served 0 intSumProactiveOpportunity 30741 9 served 10 19 served 0 intSumCustomersPickedProactively: 3740 10 served 11 20 served 0 50.0% 100.09 En 196 100 0



Hybrids: ABM & SDM

Agent-Based Modelling and System Dynamic Modelling





ABM & SDM

- Agents in an SD environment
 - AnyLogic Help Example Model: "Basic Health Economics"





ABM & SDM

- SD inside agents
 - AnyLogic example: "Population" (Population/Housing Model)





Agent-Based Modelling and Simulation Tools

Eile Edit View History Bookmarks Tools Help

- Design
 - EABSS
- Implementation
 - NetLogo
 - AnyLogic
 - AgentPy

The EABSS Toolkit	× +			~	README.md
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This toolkit helps peo jointly develop conc simulating systems w	ple from academia, non-governmental (eptual agent-based models in a struc here humans and their behaviours and martice foreground have been the CADEC of	organisations, governmer tured way for the purp decisions play a key rol	ital organisations, a ose of better und e. At its heart, the	nd industry, to erstanding and toolkit uses a	JOSS pu
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ntPy - Agent-based modeling in Python

3-Clause docs passing JOSS 10.21105/joss.03065

s an open-source library for the development and analysis of agent-based models in Python. The framework the tasks of model design, interactive simulations, numerical experiments, and data analysis within a single ent. The package is optimized for interactive computing with IPython, IPySimulate, and Jupyter.

this software as follows:

tti, J., (2021). AgentPy: A package for agent-based modeling in Python. of Open Source Software, 6(62), 3065, https://doi.org/10.21105/joss.03065

on: pip install agentpy

ntation: https://agentpy.readthedocs.io

lication: https://doi.org/10.21105/joss.03065

n forum: https://github.com/JoelForamitti/agentpy/discussions

and examples: https://agentpy.readthedocs.io/en/latest/model_library.html

on with other frameworks: https://agentpy.readthedocs.io/en/latest/comparison.html







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Lecture

A Structured Approach to AB/Hybrid Model Development (60 min)





What is this all about?

- Social Simulation (formal definition)
 - Studies socio-economic phenomena by investigating the social macrostructures and observable regularities generated by the behaviour and relationships between individual social agents, and between agents and the environment in which they act.
- Agent-Based Social Simulation (ABSS)
 - Example from the Gaming World
 - SIMS4: Promotion Video (<u>https://www.youtube.com/watch?v=dcDy1CCd-F8</u>)
 - SIMS4: Hands-On Gameplay (<u>https://www.youtube.com/watch?v=pXLEAHpzFks</u>)









The EABSS Framework

• A structured approach





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: 8h (but there is a shorter version of 2h)
 - Socrates vs Confucius
 - Collaborative brainstorming
 - Information capturing
 - Debates only when needed
 - Moderators
 - Will guide
 - Will act as stakeholder (modeller)
 - Iterative process
 - Reuse of information
 - Important to go forward and backwards







Focus Groups

- A focus group is ...
 - A small group getting together for a carefully planned discussion in order to obtain perceptions of a defined area of interest in a permissive and non-threatening environment, organised either by specific stakeholder type or as mix of relevant stakeholder types, conducted by a trained interviewer (moderator; facilitator) to collect qualitative data that allow to determine feelings, perceptions and manner of thinking of participants regarding products, services, and programs or opportunities, and to promote self-disclosure among participants
- A focus group is not ...
 - A debate; group therapy; a conflict resolution session; a problem solving session; an opportunity to collaborate; a promotional opportunity; an educational session



Focus Groups

- Moderator's role
 - Stays relaxed and sets tone; introduces and guides the discussion; actively and carefully listens; does NOT participate, or share views, or engage in the discussion; does NOT editorialise comments; promotes everyone's participation; is non-judgmental and respectful
- Limitations
 - Risk of biases introduced by the moderator(s)
 - Domineering and/or passive participants
 - Usually does not provide depth of information compared to other methods, such as key informant interviews





Focus Groups

- Types of questions
 - Engagement questions
 - Introduce participants to and make them comfortable with the topic of discussion
 - Exploration questions
 - Get to the meat of the discussion
 - Exit questions
 - Check to see if anything was missed in the discussion



https://www.youtube.com/watch?v=Auf9pkuCc8k



UML

• Different views



documented





billed



How the programmer wrote it



How the business consultant described it

















UML

- Advantages of using UML
 - Enhances communication and ensures the right communication
 - Captures the logical software architecture independent of the implementation language
 - Helps to manage the complexity
 - Enables reuse of design



UML

findingDoor

exitina

leaving

exitPoint





Available Guidance (Siebers 2019a)

Engineering Agent-Based Social Simulations

User Guide v2023-02-21

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

Brief Summary

What is it all about? What are successful model development strategies for complex social systems modeling? How does modelling work in large, collaborative, and multi-disciplinary projects in academia, non-governmental and governmental organisations, and industry? How do we derive new and general insights from modelling complex social systems? Anecdotal evidence suggests that the community of agent-based modellers partially suffers from a lack of structured and standardised ways for model development. In order to close this gap, we have created a model development framework, namely the Engineering Agent Based Social Simulation framework (or EABSS for short) which supports model development and model documentation in a structured way. Figure 1 shows a high level overview of the latest version of the framework. Full details together with an illustrative example can be found in Siebers and Klügl (2017) and some guidance on how to use the framework can be found in Appendix A.



How does it work? The EABSS is grounded in the concept of co-creation (Mitleton-Kelly 2003) and ideas from Software Engineering (Sommerville 2015). In addition it draws on elements of Kankainen's focus group approach to service design (Kankainen et al 2012). The framework implicitly provides ground rules, which is something commonly done when working with children but often forgotten when working with grownups. These grounded rules are in line with De Bono's philosophy of parallel thinking (De Bono 1985), and state that people are going to listen to each other and that people respect each other's point of view. To capture information it uses predefined table templates, and UML (a graphical notation used in Software Engineering) as main forms of stimulating and documenting contributions from all participating stakeholders during problem analysis and model design. It is this combination of tools and methods that makes it approachable for everyone. use it? The EABSS can be used for two different purposes: (1) for collaborative model (from scratch or to extend/validate existing models) and (2) to stimulate and formally sistons about philosophical questions of societal issues that need to be addressed. We the framework in several domains, including Architecture, Geography, Organisational bers et al 2020), and Digital Mental Healthcare (Vallejos et al 2019; Siebert et al 2020; bers 2020). It is designed with the aim to look at a complex system in more detail with step. There is always information from previous steps that can be used to get started t step. This principle serves validation, as getting stuck in the current step is a good something in previous steps is not quite right and needs to be amended.

set out of it? The outcome of an EABSS session is a structured record of the key points of up discussions, in a format that is easy to understand by all stakeholders, and easy to a little effort this can often be translated into an agent-based social simulation model, no be used by the stakeholders as a "what-if" analysis tool.

xperience so far? Interestingly we found that each of the academics involved in running ups finds EABSS supportive in a different way, perhaps embedded within the research in their domain. So the concept itself can be seen as interdisciplinary, while it was y intended to support social simulation model development. It has now been used for opment, reverse engineering of existing models for validity checking, discussions to ng models and confirm their validity, debates to analyse research topics and work on directions for research.

e going from here? More recently I got interested in the philosophical debates of Richard a German Philosopher who debates about "the digital revolution of society". I would like BSS to test some of his future visions and to see if we can visualise his worlds with the I would like to approach this in a more systematic way - i.e. to build a kind of toolbox is to build this new genre of models easier. In the end we could have a collection of at allow the community to put together models for tackling philosophical questions rm of a toolbox as an extension to existing simulation packages.

ences

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ABSS Guidance

remarks are meant to guide the focus group moderator regarding the re-use of le remarks list the tools to be used in that particular step

clarify terminology and come up with a common pool of term definitions

"Purpose" of the model st of "Hypotheses" to be tested ist of "Experimental Factors" to allow creating scenarios relevant to testing those st of "Responses" to accept/reject hypotheses {look at objectives/hypotheses to work these out} e level of abstraction es (key actors - represented by the role they play, and key objects) and concepts these should be included/excluded in the model and justify your decision efined table (headers: Category; Sub-Category; Element; Decision; Justification {while provided, sub-categories are flexible and depend on the context); categories: Actor; Physical ent; Social and Psychological Aspects; Other) es {actors come from scope t actors to relevant activities (use cases) use case diagram Stencils {these allow to define behaviour of actors} with categorisation schemata for relevant key actors (agents) that will allow to simulated population into behaviourally different groups template(s) and/or demographics and/or utility function(s) nt/Object) Stencils (attributes can be derived from arc e charts] {states can often be derived from use cases} nplates by defining key states an entity can be in, how these are linked, and what ansitions (note that this might not be required for all entities) les that ought to be tracked at the micro/meso level in order to gain insight about identified during the problem analysis state machine diagram(s); transition table(s); class definition(s)/diagram(s) S (all elements defined in the agent/object stencil step need to be listed on the horizontal axis) (use ca uences of interactions that can take place between agents and between agents and specific use case realisations

sequence diagram(s)

b (attributes provide storage for all agents/objects and i

se that need to be created; listing variables that ought to be tracked at the macro der to gain insight about the issues identified during the problem analysis fer of execution (if relevant)

class definition(s)/diagram(s) and sequence diagram(s)



Available Guidance (Siebers 2019b)





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Practice

Joint Activity: Co-Creating a Conceptual AB Model (60 min)

Small printed orange remarks in the following are meant to guide the moderator





Example: Exploring Adaptive Architecture Design [Siebers et al 2018]

- Context
 - The purpose of the study is to explore Adaptive Architecture design in the context of a novel museum visit experience, in particular the idea of having a large screen with a set of intelligently adaptive moving content windows that adapt position and size in response to movement and grouping of people in front of them.
- Aim (of the simulation study)
 - Study the impact of an adaptive screen (including several display windows) in a museum exhibition room







Engineering ABSS





Example: Analyse Problem

- Objectives
 - Study the interaction of "artificial intelligent" windows and visitors' movement
 - Use the model to demonstrate to architects the idea of adaptive screens (artificial intelligent windows)
- Hypotheses
 - A larger window size has a positive effect on visitor engagement
 - Space availability has a positive effect on visitor engagement
 - Screens with artificial intelligent windows attract viewers for longer



Example: Analyse Problem

- Experimental factors (look at objectives/hypotheses to work these out)
 - Visitor arrival rate {derived from hypothesis; relates to space availability}
 - Initial number of windows {derived from hypothesis; relates to space availability}
 - Window size {derived from hypothesis}
 - A subset of parameters of the underlying theoretical movement model (Note: This was added later)
- Responses (look at objectives/hypotheses to work these out)
 - Number of groups of visitors (visitor clusters) {derived from objective; relates to demonstrating to architects}
 - Average time of visitors spend in the museum {derived from hypothesis; measures visitor engagement + attraction}
 - Visual representation of the system and its dynamics {derived from objective; relates to demonstrating to architects}



Case Study

- Title (usually given)
 - Exploring Future Scenarios of Health Service Provision
- Context (usually given)
 - We want to discuss ideas about the evolution towards a mixed human/robot society in an operational and service-oriented context, focusing on health service provision. We want to uncover what it means to have a future where health services will be provided by doctors (GPs and Hospital) and nurses and (or in collaboration with) proactive machines. What is the impact of technology on the mental state and the opinion of staff/patients?



Case Study: Analyse Problem



Let's define aim, objectives, hypotheses, experimental factors and responses

For experimental factors and responses: Look at objectives/hypotheses to work these out



Example: Define Scope

• Scope: What and Why? (what do we need to represent to fulfil the aim; look for nouns in previous text)

Category		Element	ID	Decision	Justification
Actor	Human	Visitor	A01	Include	Main research subject
		Group	A02	Include	Important for capturing group behaviour
		Staff	A03	Exclude	Have no impact on the dynamics
	Intelligent Object	Window	A04	Include	Intelligent display unit that can make proactive decisions
		Display system	A05	Include	Controls the life cycle of each window
Physical	Service	Projector	PE01	Exclude	Considered by the windows
Environment		Screen	PE02	Include	Home of the windows
	Structure	Wall	PE03	Include	Required for motion algorithm of visitors
		Door	PE04	Include	Required for motion algorithm of visitors
		Lighting	PE05	Exclude	Not necessary for testing hypotheses
		Furniture	PE06	Exclude	Not necessary for testing hypotheses
	Weather	Temperature	PE07	Exclude	Not necessary for testing hypotheses
		Natural light	PE08	Exclude	Indoor environment
	Building	Exhibition room	PE09	Include	Location where visitors move around
		Corridor	PE10	Exclude	Not necessary for testing hypotheses
		Toilet	PE11	Exclude	Not necessary for testing hypotheses
Category		Aspect/Phenomena	ID	Decision	Justification
Social and	Visitor behaviour	Movement	SPAP01	Include	Required to trigger the window AI
Psychological		Vision area	SPAP02	Include	Will affect visitor movement behaviour
Aspects /	Window behaviour	Movement	SPAP03	Include	Part of the AI to be tested
Phenomena		Vision area	SPAP04	Include	Defines area that visitors are able to read clearly
Category		Detail to be modelled	ID	Decision	Justification
Other		N/A	O01	N/A	N/A



Case Study: Define Scope



Let's define the scope for our case study

What do we need to represent to fulfil the aim? Look for nouns in previous text



Example: Define Key Activities

• Key activities (actors come from scope table; use cases come from objectives/hypotheses and by creating user stories)



User Stories: As <actor>, I want to <what?> (so that <why?>)



Case Study: Define Key Activities



Let's define the key activities for our case study

Actors come from scope table; use cases come from objectives/hypotheses and by creating user stories



Engineering ABSS





Example: Define Archetype Stencils

• Categorisation schemata for key actors (these allow to define behaviour of actors; use habits/demographics for characterisation)

Stereotype	Reading time(second)		
Not-interested	3-10		
General-visitor	10-40		
Researcher	40-90		

Stereotype	Speed(meter per second)	Collision radius(meter)
Child	1.4-1.8	0.11-0.15
Adult	1.2-1.4	0.20-0.25



Note: The values are not really required at this stage, but you should capture them if they emerge from the discussion


Case Study: Define Archetypes Stencils



Let's define the archetype stencils for our case study

These allow to define behaviour of actors. Use habits/demographics for characterisation.



Example: Agent and Object Stencils

- The following are generated in parallel (or iteratively)
 - Classes for defining attributes and possible operations of individual/group agents/objects
 - State charts for defining possible states/transitions of agents/objects
 - Transition tables for detailing transitions in these state charts



Example: Agent and Object Stencils

• Agent and 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)



Note: Some of the attributes/operations will only be known once the implementation strategy is known (e.g. implementing "Movement" by using the Social Force Model)



Example: Agent and Object Stencils

- State chart of visitor agent (states can often be derived from use cases)
- Transition table of visitor agent

To state	Triggered by	When?
moving	Condition	Agent arrived at destination
reading	Condition	Agent arrived at destination
reading	Timeout (Internal)	Agent follows the nearest window
waiting	Timeout+Condition	After reading time elapsed and agent needs to wait for group members
resting	Condition	Agent arrived at destination
resting	Condition	Agent is close to destination and is part of a group
exiting	Condition	All group members have finished reading
exiting	Timeout+Condition	After reading time elapsed and agent is individual
findingDoor	Condition+Condition	There are other rooms available
findingDoor	Timeout (Internal)	Agent looks for nearest door
moving	Condition	Agent arrived at destination
leaving	Condition+Condition	This was the last room to go
	To state moving reading reading waiting resting resting exiting exiting findingDoor findingDoor moving leaving	To stateTriggered bymovingConditionreadingConditionreadingTimeout (Internal)waitingTimeout+ConditionrestingConditionrestingConditionexitingConditionexitingTimeout+ConditionfindingDoorTimeout+ConditionfindingDoorTimeout+ConditionfindingDoorTimeout (Internal)movingConditionleavingCondition+Condition





Case Study: Define Agent and Object Stencils



Let's define the agent and object stencils for our case study

Agent and object classes: Attributes can be derived from archetype criteria and by looking at the scope table. Operations can be derived from looking at the states in the related state charts.

State charts: States can often be derived from use cases



Example: Define Interactions



Case Study: Define Interactions



Let's define the interactions for our case study

All elements defined in the Agent and Object Stencils 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.



Example: Define Artificial Lab

• Artificial Lab (attributes provide storage for all agents/objects and initialisation parameters required for experimental factors; operations are related to responses)

Museum -visitors[] -groups[] -structures[] -visitorArrivalRate -initialNumberOfWindows	Includes all relevant structural objects (walls, points, areas, etc.)
-movementModelParameterSet[] +initialise() +calculateAverageVisitingTime() +calculateNumberOfVisitorClusters()	Includes a collection of parameters of the underlying theoretical movement model



Case Study: Define Artificial Lab



Let's define the artificial lab for our case study

Attributes provide storage for all agents/objects and initialisation parameters required for experimental factors. Operations are related to responses.



Example: The Implementation Strategy





Siebers et al (2018)

Example: The Implemented Model



Example: Extended Version (Moving Wall)



Case Study: How Others Solved It



There were actually two very different outcomes. We will look at these later!

Service provision in the hospital of the future Service provision in the GP practice of the future



OR Training Course 2023 Co-Creation of Agent-Based Simulation Models



Lecture

Introduction to AB Modelling in AnyLogic PLE (60 min)









- The latest version available for download is AnyLogic 8.8.1 PLE
 - Win: <u>https://files.anylogic.com/anylogic-ple-8.8.1.x86_64.exe</u>
 - Mac: <u>https://files.anylogic.com/anylogic-ple-8.8.1.dmg</u>
 - Linux: <u>https://files.anylogic.com/anylogic-ple-8.8.1.linux.x86_64.tgz.bin</u>
- In AnyLogic you are not writing the full code of Java classes from the beginning to the end; instead you are entering pieces of code and expressions in numerous small edit boxes in the properties of various model elements



• AnyLogic Blog

<u>https://www.anylogic.com/blog/</u>



• AnyLogic Blog (new releases)

<u>https://www.anylogic.com/blog/?tag=new+release</u>





• Free tutorial book

Ilya Grigoryev
-AnyLogic 8
in Three
Days ——
anylogic.

https://www.anylogic.com/upload/book.php?lang=English



AnyLogic "Hello World!"

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The University of Nottingham

AnyLogic Process Modelling





AnyLogic Process Modelling

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AnyLogic IDE



AnyLogic Personal Learning Edition [PEF View Draw Model Tools File Edit 🕂 🗝 🖯 🕼 🖓 💛 of 🖹 🖻 🎦 Projects 🙀 Palette 🔀 System Dynamics 88 23 Ð Stock Ø Show ■ Dynamic Variable × Ø 🐴 Link ### Parameter 🕞 Table Function (R J Loop 4 Shadow 08 🗶 Dimension 0 24 Y **d**hi OK 1 • C, C) ÷



Things to Remember

- Important things
 - F1: Help
 - Ctrl-Space: Code completion support
 - Ctrl-Enter: Perform refactoring (replace name occurrences)
 - Make sure you select the correct model when pressing "Run"
 - Make sure you set up model time units correctly in the "Model"
 - Use the "magic lightbulb" ...

- Since AnyLogic v7
 - Everything is called "Agent" (entities; resources; agents; ...)
 - PLE version limits number of agents per simulation run to 50000 (but you can reuse them)



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Running AnyLogic



AnyLogic IDE



Press {Ctrl+J} to go to the point in the Java code that is associated with the current code snippet highlighted in the Properties window



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Show name

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AnyLogic Help





Where am I and how do I get to...?







Objects and Java in 10 Minutes ;-)



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(2)Objects in Java (instatiations of clamer) (encapsulation) to access Fields ofter wed to separate Millods unally public, unless helper methods Is accerrible from other objects



(3)Interitance (of fieldy and methods) Super clan (includes serve of the code (often abstract) you want) parent. Sub clam Furniture dan <unally concrete il you want to use it directly erabitry for further in hirst ag Risel Rains) Bed =) In Java only sigle in deritance class Worker



class TeamLeader experience

class TeamMember

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(ampile time Polymorphism (static binding) (4) is method overloading is multiple methods with some name but different parameter list Public boolean order () pubic boolean order (int num, (olor col) Run time Polymorphism is method overriding could be abtract Furniture to force overriding requirer ()) (requirer () Bad requirer () matoen + duvit cumon + pillow

Polymorphism (many forms) in Java is a concept by which we can perform a single action in different ways



Free Java Course

- Amigoscode: Java Full Course Java Tutorial for Beginners
 - https://www.youtube.com/watch?v=j9VNCI9Xo80





Java Basics for AnyLogic

- For useful advice see Nathaniel Osgood's YouTube videos
 - Check "Agent Based & Hybrid Modeling Bootcamp for Health & Health Care" playlist
 - https://www.youtube.com/playlist?list=PLcAxwev2PmV-pMtyHFtfj7DizkfvzUAPB
 - Towards the bottom of the playlist (video 42 to 46) you find "Java for AnyLogic" tutorials





BlobWorld Tutorial





OR Training Course 2023 Co-Creation of Agent-Based Simulation Models



Presentation

Research Case Study (30 min)




Service Provision in the Hospital of the Future





Stroud et al (2019)



Motivation

 Proactive machines are an idea that in the future hospitals will have automated machines as well as Doctors and Nurses that can help and treat patients. This project uses the idea of proactive machines to test the impact of technology on mental state and opinions of hospital patients.



Analyse Problem

- Aim and objectives
 - Reflect on the consequences of digital mental healthcare
- Hypotheses
 - Trust between machines/humans will affect human-human relationships in a negative way
 - Machine-look influences our decisions



Analyse Problem

- Experimental factors
 - Number of doctors, proactive machines and patients
 - Number of beds
- Responses
 - Mental state of patients, e.g. happiness
 - Opinions of each patient on the doctors and robots
 - The trust of the patients on the robots



Define Scope

Category		Element	Decision	Justification					
		Patient	Include	Patients are the ones who are being tested					
	Human	Doctor	Include	Doctors need to be compared against the Robot doctors					
Actor	numan	Visitor	Include	Visitors can be used to influence	Category		Element	Decision	Justification
		Nurse	Exclude	patients Nurse can be viewed as the same as		Robot	Decide how long to treat patient for	Include	Needed for more accurate results
		indi se	Exclude	doctors in the simulation		doctor	Acourata		Novement is not needed to test the
	Proactive machine	Robot doctor	Include	Need to be compared against doctors		behaviour	movement of robot	Exclude	hypotheses
	Buildings	Hospital	Include	Location where the model is held	Doctor Social and behaviour	Doctor	Decide how long to	Include	Needed for more accurate results
		Home Inclu	Include	Location where agents are held when			treat patient for		
			menuac	they are being used			Accurate		
Physical Environment	Furniture	Beds	Include	Patients need somewhere to stay		movement of	Exclude	wovement is not needed to test the	
	Structure	Walls Exclude		Not needed because we are not	psychological		doctor		nypotneses
			Exclude	interested in agents movements or	aspects	Patient Ra	Random hospital	Include	
				collisions		behaviour	visits	Include	Needed for more accurate results
		Doors	Exclude	Not needed to test the hypotheses			Decide whether		
							the visitor should	Include	Needed for more accurate results

Visitor

Other

behaviour Accurate

visit the patient

movement of

visitor

N/A

Exclude

N/A

hypotheses

N/A



Movement is not needed to test the

Defining Key Activities





Define Archetype Stencils

Doctor

Stereotype	Extra time treating patients (Minutes)
Senior	0
Junior	10

Robot

Stereotype	Humanlike variable	Effect on human opinion
Humanlike	0.5-1	Positive effect
Robotlike	0-0.5	Negative effect



Define Agent/Object Stencils

Patient

-doctorTreatment : double -robotTreatment : double -opinion : double -onCheckupList : boolean -checkupTime : double -satsfaction : double -request : boolean -discharged : boole an -patience : double -inBedBool : boolean -hasFamily : boolean -bed : Bed -condition : double -talkative : double -currentRobot : Robot -currentDoctor : Doctor +moveToAtHome() +moveToInHospital() +connect() +disconnect() +disconnectFromAll() +findFreeBed() +addToCheckupList() +removeFromCheckupList() +moveToDoctorTreatment() +moveToRobotTreatment() +moveToMixTreatment() +moveToNoTreatment() +goingHome()

Doctor -level : double -waitTime : double -fatigue : double -patientGoneHome : boolean -initiallyAtWork : double -timeToStartWork : double -currentPatient : Patient -needsBreak : boolean -requestsWaiting : boolean +moveToAtHome() +moveToInHospital() +moveToAtWork() +moveToWaiting() +moveToWithPatient() +checkCheckupList()

Robot -waitTime : double -price : double -humanLikeVar : double -patientGoneHome : boolean -charge : double -startX : double -startY : double -requestWaiting : double -currentPatient : Patient +moveToCharging() +moveToWaitingToBeCharged() +moveToAtWork() +moveToWaiting() +moveToWithPatient() +checkCheckupList()

Visitor -visiting : boolean -patient : Patient -avgVisitTime : double -visitRate : double -counter : double -recentlyVisited : double -freeTime : double -waitTime : double +moveToAtHome() +moveToInHospital() +contemplate() +moveToPatient()

Bed -i : int -free : boolean -patient : Patient

+changeBedStatus()



Define Agent/Object Stencils





Patient

Doctor



Define Agent/Object Stencils







Robot



Bed



Define Interactions



UNITED KINGDOM · CHINA · MALAYSIA

Define Artificial Lab

ArtificialLab
-visitors : Visitor[]
-robots : Robots[]
-patients : Patients[]
-patientsToSee : Patient*
-patientCheckups : Patient*
-freeBeds : Bed*
-doctor1stShift : Doctor[]
-doctor2ndShift : Doctor[]
-doctor3rdShift : Doctor[]
-beds : Bed[]
-bedl : int
-rand : double
-patientWithFamilies : Patient[
+initializeAgents()
+visitorsEnter()



Implementation



O Patients O humanRobots O robotRobots O visitors O doctors1stShift O doctors2ndShift O doctors3rdShift





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Service Provision in the GP Practice of the Future

Improve the Understanding of Digital Mental Healthcare Scenarios



Barnes and Siebers (2020)



Motivation

- Digital mental healthcare in the context of Social Simulation
 - Digital mental healthcare
 - Consists of AI developed in ways which can help provide alternative methods of treating mental health issues (e.g. depression; anxiety; and dementia) successfully
- Current research focuses on understanding the social and ethical implications of digital mental healthcare, rather than looking at the service provision aspects



Analysing the Problem

- Aim
 - *Case Study*: To better understand how people react towards virtual therapists, with people modelled based on generation groups: Millennials, Generation-X, and Baby Boomers
 - *Methodology*: To test different decision making modelling approaches (crisp vs fuzzy 1/2)
- Hypotheses
 - *Case Study*: Access to social interaction for people increases sensitivity of simulation when certain parameters (e.g. trust) are altered
 - *Case Study*: Competence of the virtual therapists plays a large role in defining the output trust of the population
 - *Methodology*: The different decision making modelling approaches for decision making (crisp vs fuzzy 1/2) deliver similar outputs at micro (individual) as well as macro (population) level



Analysing the Problem

• Experimental factors

- Proportion of different generations of agents
- Initial level of trust of the population tested
- Competence of virtual therapists
- Level of access agents have to the social network
- Responses
 - Trust
 - Macro-level: Aggregated trust of the population
 - Micro-level: Individual agent's trust level evolution
 - Box plots "Trust/Generation" for different decision making approaches (crisp vs fuzzy 1/2)



Defining the Scope

Category	Element	Decision	Justification		
	Person (Patient)	Include	Subject which is being observed		
Actor	Session	Include	A virtual 'therapist' providing services to patients		
	Administrator	Include	Manages waiting lists, organises and creates sessions on demand		
	Hospital	Exclude	No bonefits of representing these elements within the		
Physical Environment	Home	Exclude	onvironment as physical entities		
	Therapy	Exclude	environment as physical entities		
	Spatial pada	Include	Used to measure distance between agents and defining the		
	spatial node		location of agents during the simulation		
	Person social influence	Include	Used to help determine the outcomes of social interactions		
	Derson condition	Include	Tracks the outcome of session treatment, and is what makes		
Social and	Person condition		people admit themselves to care		
	Person trust	Include	Our primary response (and therefore fundamental to the model)		
	Person age	Include	Important for determining social media usage		
Psych. Aspects	Desire	Exclude	Psychological theory was initially considered, but later not used		
	Volatility	Exclude	due to time constraints		
	Arousal	Exclude			
	Stereotype	Exclude	Captured by person age		
	Social notwork	Include	Agents can interact with each other, in a realistic manner through		
Other			using friendLink networks to send messages		
	Therapy system	Include	System boundary used by people who require digital therapy		



Defining Key Activities





Defining Archetype Stencils

Name	Age range	Social media users [% of age range members]	Use of social media [hours per day]
Millennials	1980-1994	90.4	2.38
GenerationX	1965-1979	77.5	1.49
Baby Boomers	1944-1964	48.2	1.12



Defining Agent/Object Stencils



- Objects
 - Spatial nodes in the environment (to measure the distance between Person agents and to graphically represent their location and communication links within a defined space)



Defining Interactions / Artificial Lab

Interaction

- Online communication between Person agents (friend links) effecting opinion dynamics
- Social media network connects agents depending on their proximity and social similarity

• Artificial Lab

- Parameters
 - sessionCompetence; personTrust
 - decisionMethod (crisp; fuzzy1; fuzzy2); debug (on/off)
- Global variables
 - Collections of actors
 - socialFeed (emulates a social media newsfeed)
- Helper methods

Artificial Lab

- people[] - session []
- administrator
- decisionMethod : int
- debug : boolean
- socialFeed : collection
- personTrust : double
- sessionCompetence : double
- + writeExperiment1() : event
- + writeExperiment2() : event
- + clearNewsFeed() : event
- + checkInputs() : void



Implementation





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Small Groups: Develop modelling ideas for your own problems (45 min)

Joint Activity: Summarise outcome of previous activity (15 min)





What Did You Discuss?





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Wrap-Up

General discussion and Q&A (15 min)





Resources



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)ay 3			
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Any Questions?



Screenshot taken from Marie-Louise Gay's book "Any Questions?"



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