Co-Creating Artificial Labs for Studying Human-Centric Systems

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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.

- Example from the Gaming World (https://www.youtube.com/watch?v=dcDy1CCd-F8)

Engineering Agent-Based Social Simulations

- Agent-Based Modelling:
  - A complex system is represented by a collection of agents that are programmed to follow some behaviour rules
  - System properties emerge from its constituent agent interactions

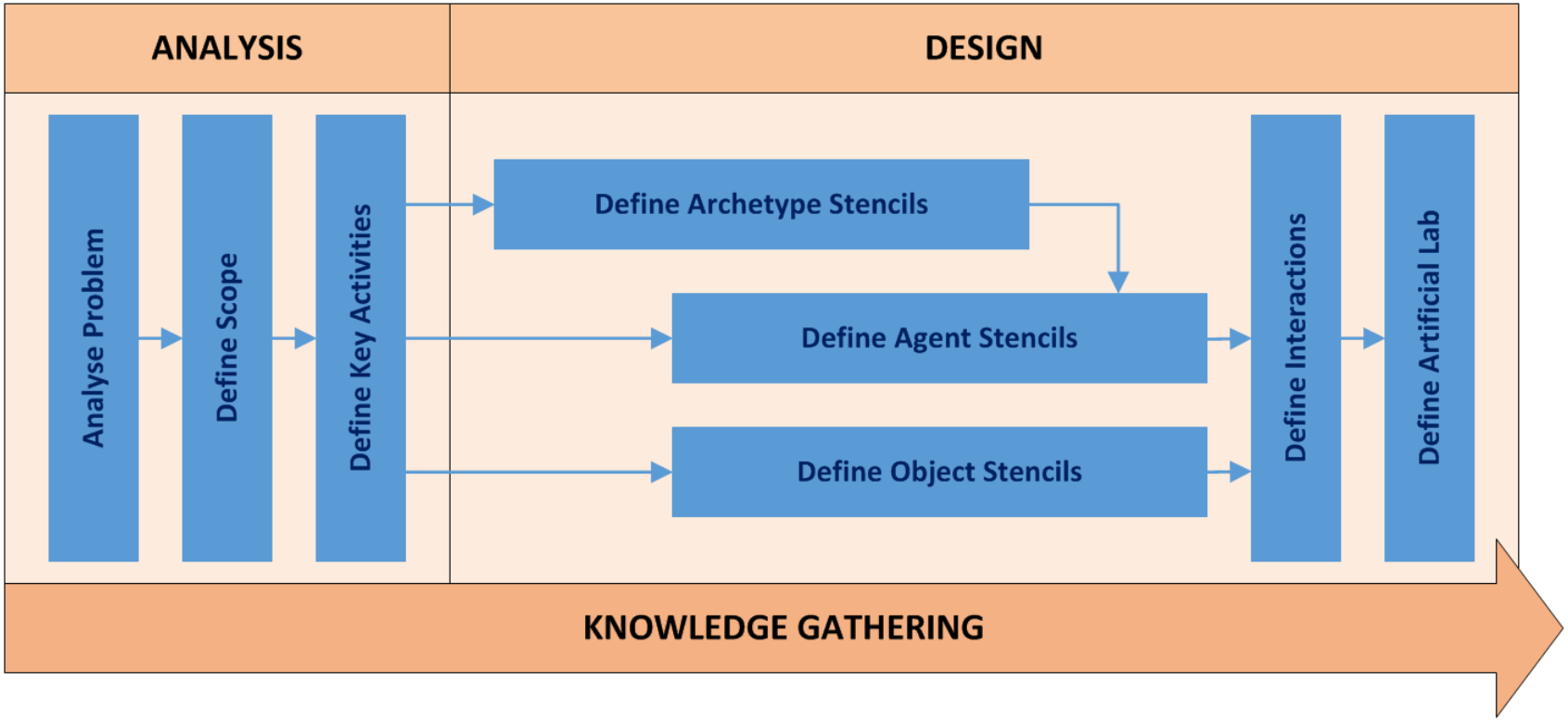
- How do we develop such Agent-Based Models (ABMs)?
  - There is a need for an ABM development framework
    - To support multi disciplinary collaboration
    - To work with all kinds of stakeholders (academics / non academics)
    - For exploratory and explanatory studies
    - For communication; conceptual modelling; reverse engineering

Engineering ABSS

- What do we mean by "agents"?
  - Agents are "objects with attitude" (Bradshaw 1997)
  - Similar to non-player characters in computer games
- Properties (borrowing from AI):
  - Discrete entities
    - Have a memory
    - Have their own goals (missions)
    - Have their own thread of control
  - Autonomous decisions
    - Capable to adapt and to modify their behaviour
  - Proactive behaviour
    - Actions depending on motivations generated from their internal state

Engineering ABSS

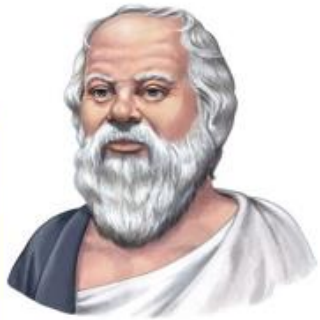
- Model development process



Inspired by Siebers and Klügl (2017)

Engineering ABSS

- Using a focus group approach (group sizes of 4-5 work best)
  - Socrates vs Confucius
    - Collaborative brainstorming
    - Information capturing
    - Debates only when needed
  - Moderators
    - Will guide
    - Will act as stakeholder (modeller)
  - Iterative process
    - Reuse of information (small printed remarks are meant to guide the moderator)
    - Important to go forward and backwards



Illustrative Example

Adaptive Architecture

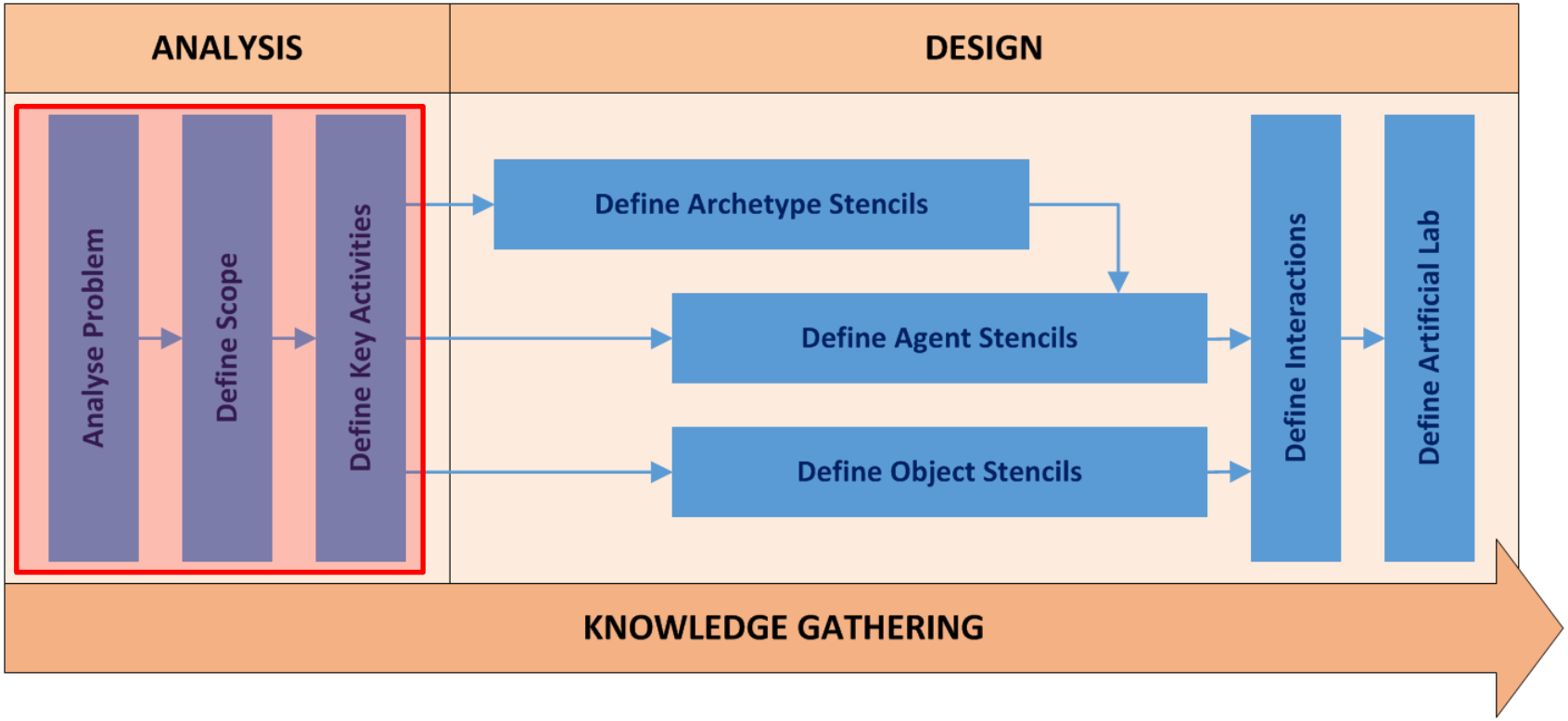
Illustrative Example: Context

- 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.

- Note about the difference between "actors" and "agents"
  - Actors represent specific roles individuals play
  - Agents represent individuals or groups of individuals
  - Throughout the modelling process we will convert actors to agents
    - Some differences can be embedded into archetypes

Engineering ABSS

- Model development process



Inspired by Siebers and Klügl (2017)

Illustrative Example: Analysis

- Aim
  - Study the impact of an adaptive screen (including several display windows) in a museum exhibition room
- 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

Illustrative Example: Analysis

- Simulation Setup Opportunities (look at objectives/hypotheses to work these out)
  - A subset of parameters of the underlying theoretical movement model
  - Visitors arrival rate
  - Initial number of windows
- Simulation Outputs (look at objectives/hypotheses to work these out)
  - Number of groups of visitors
  - Average time spend in the museum
  - Visual representation of the system and its dynamics

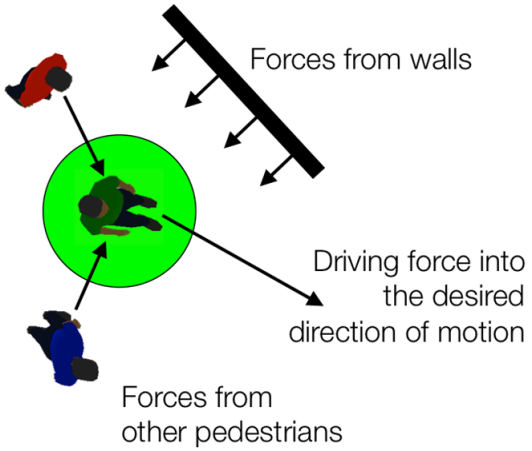
Illustrative Example: Analysis

- Scope (what elements do we need to fulfil the aim) (look for nouns in previous text to find elements)

Category		Element	Decision	Justification
Actor	Human	Visitor	Include	Main research subject
		Group	Include	Important for capturing group behaviour
		Staff	Exclude	Have no impact on the dynamics
	Intelligent Object	Window	Include	Intelligent display unit that can make proactive decisions
		Display system	Include	Controls the life cycle of each window
Physical Environment	Service	Projector	Exclude	Considered by the windows
		Screen	Include	Home of the windows
	Structure	Wall	Include	Used by social force model
		Door	Include	Used by social force model
		Lighting	Exclude	Not necessary for testing hypotheses
		Furniture	Exclude	Not necessary for testing hypotheses
	Weather	Temperature	Exclude	Not necessary for testing hypotheses
		Natural light	Exclude	Indoor environment
	Building	Exhibition room	Include	Location where visitors move around
		Corridor	Exclude	Not necessary for testing hypotheses
		Toilet	Exclude	Not necessary for testing hypotheses
Social and Psychological Aspects	Visitor behaviour	Social force model	Include	Modelling visitor movement
		Vision area	Include	Will affect visitor movement behaviour
	Window behaviour	Social force model	Include	Part of the AI to be tested
		Vision area	Include	Area that visitors are able to read clearly
		Hammer algorithm	Exclude	Alternative to SFM but to be ignored due to time constraints
Other		N/A	N/A	N/A

Illustrative Example: Analysis

- The "social force model" (Helbing and Molnar 1995) assumes that the acceleration, deceleration and directional changes of pedestrians can be approximated by a sum of different forces, each capturing a different desire or interaction effect.



$$m_i \frac{d\boldsymbol{v}_i}{dt} = m_i \frac{v_i^0(t)\boldsymbol{e}_i^0(t) - \boldsymbol{v}_i(t)}{\tau_i} + \sum_{j(\neq i)} \boldsymbol{f}_{ij} + \sum_W \boldsymbol{f}_{iW}$$

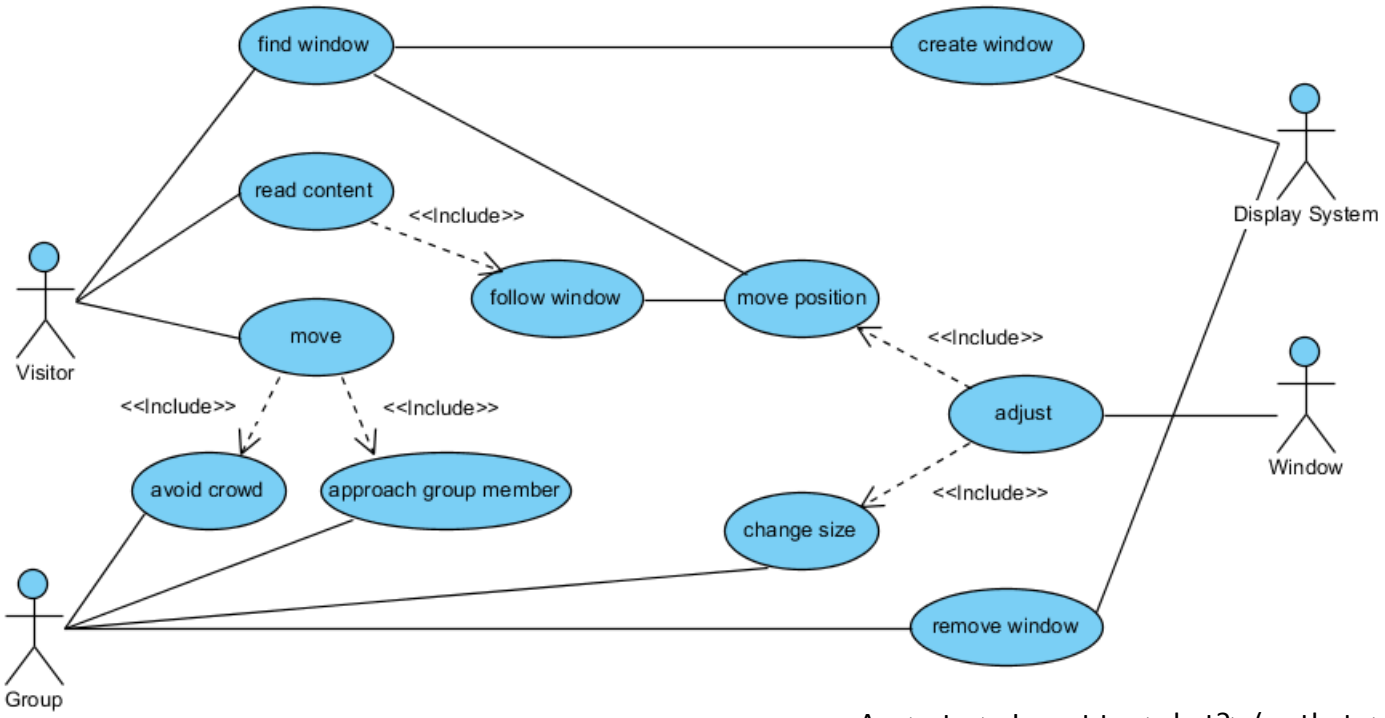
$$\boldsymbol{f}_{ij} = \boldsymbol{f}_{ij}^{psy} + \boldsymbol{f}_{ij}^{phy}, \quad \boldsymbol{f}_{ij}^{psy} = A_i \exp\left(\frac{r_{ij} - d_{ij}}{B_i}\right)\boldsymbol{n}_{ij}$$

$$\boldsymbol{f}_{ij}^{phy} = kg\left(r_{ij} - d_{ij}\right)\boldsymbol{n}_{ij} + \kappa g(r_{ij} - d_{ij})\Delta v_{ji}^t \boldsymbol{t}_{ij}$$

- The "extended social force model" (Xie et al 2010) adds vision

Illustrative Example: Analysis

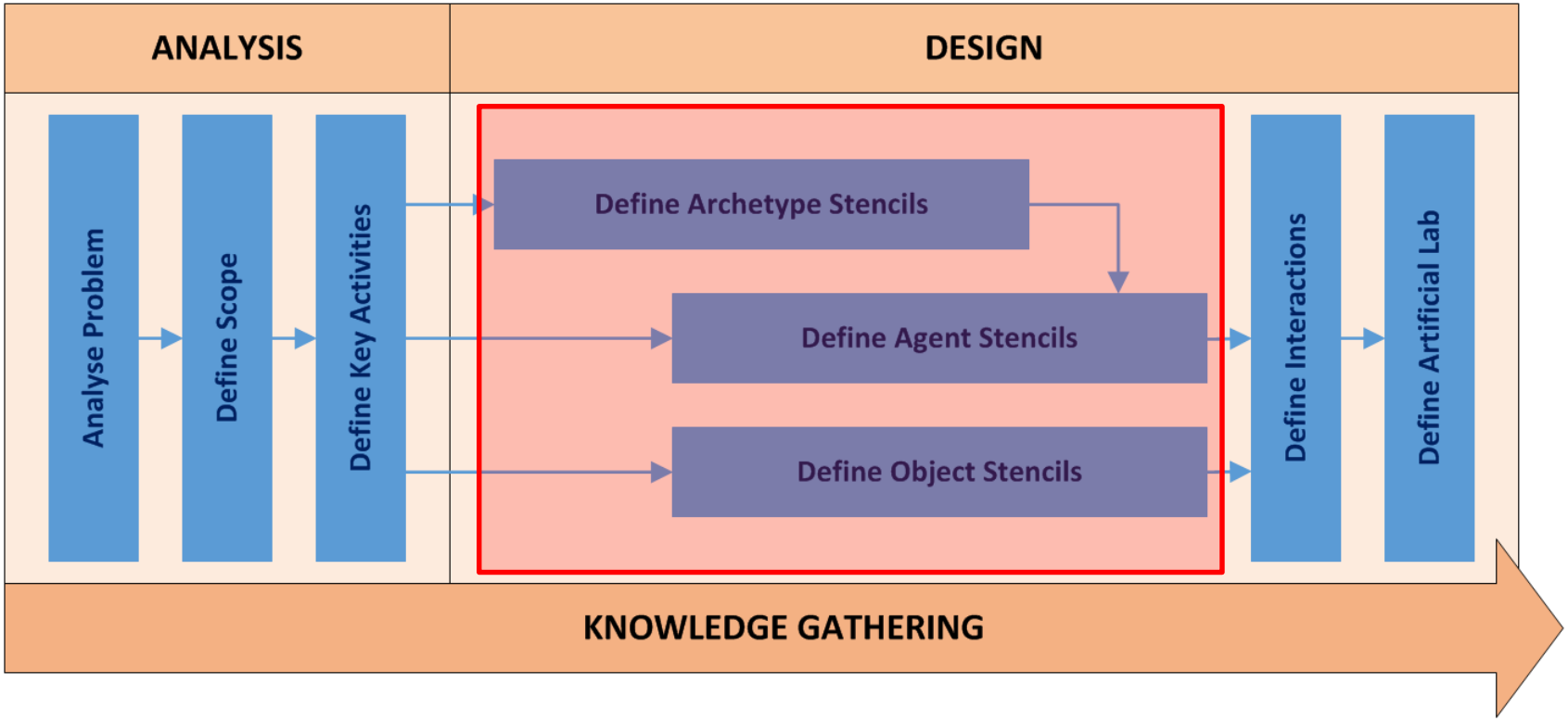
- Key activities (actors come from scope table; use cases come from hypotheses and by creating user stories)



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

Engineering ABSS

- Model development process



Inspired by Siebers and Klügl (2017)

Illustrative Example: Design

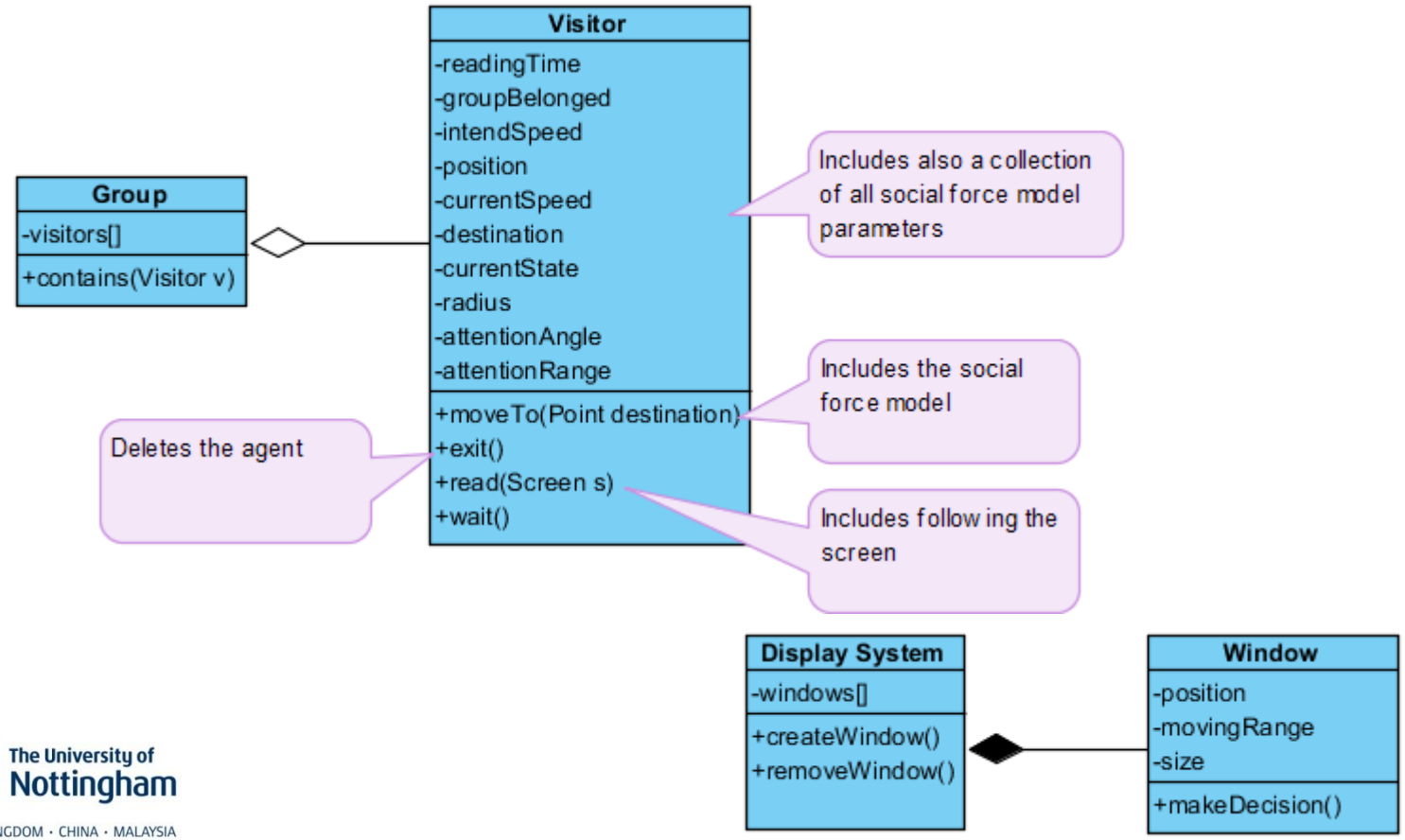
- Archetype stencils
  - Allowing to define behaviour of actors

Archetype	Reading time(second)
Not-interested	
General-visitor	
Researcher	

Archetype	Speed(meter per second)	Collision radius(meter)
Child		
Adult		

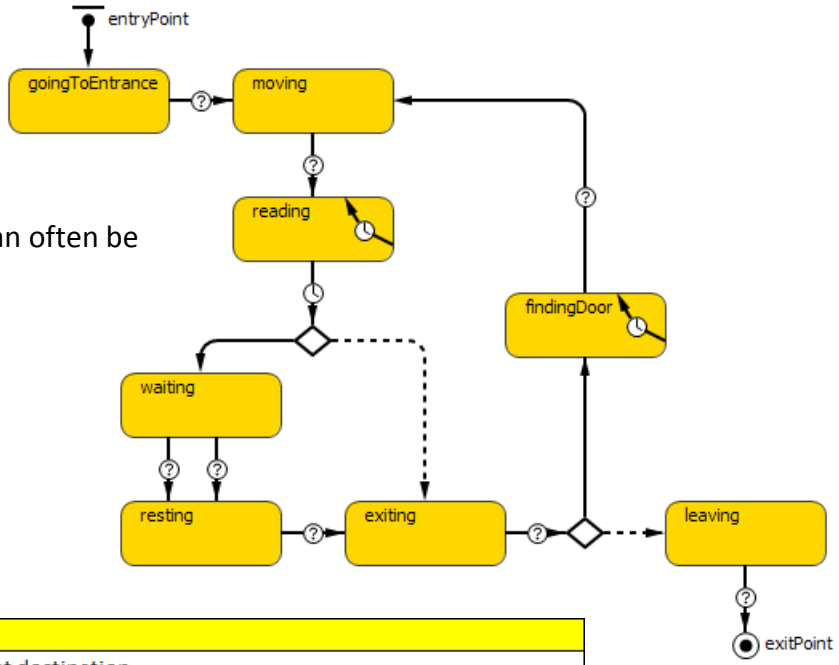
Illustrative Example: Design

- Agent and object stencils (attributes can be derived from archetype criteria, theory parameters, methods can be derived from the states in the related state charts)



Illustrative Example: Design

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

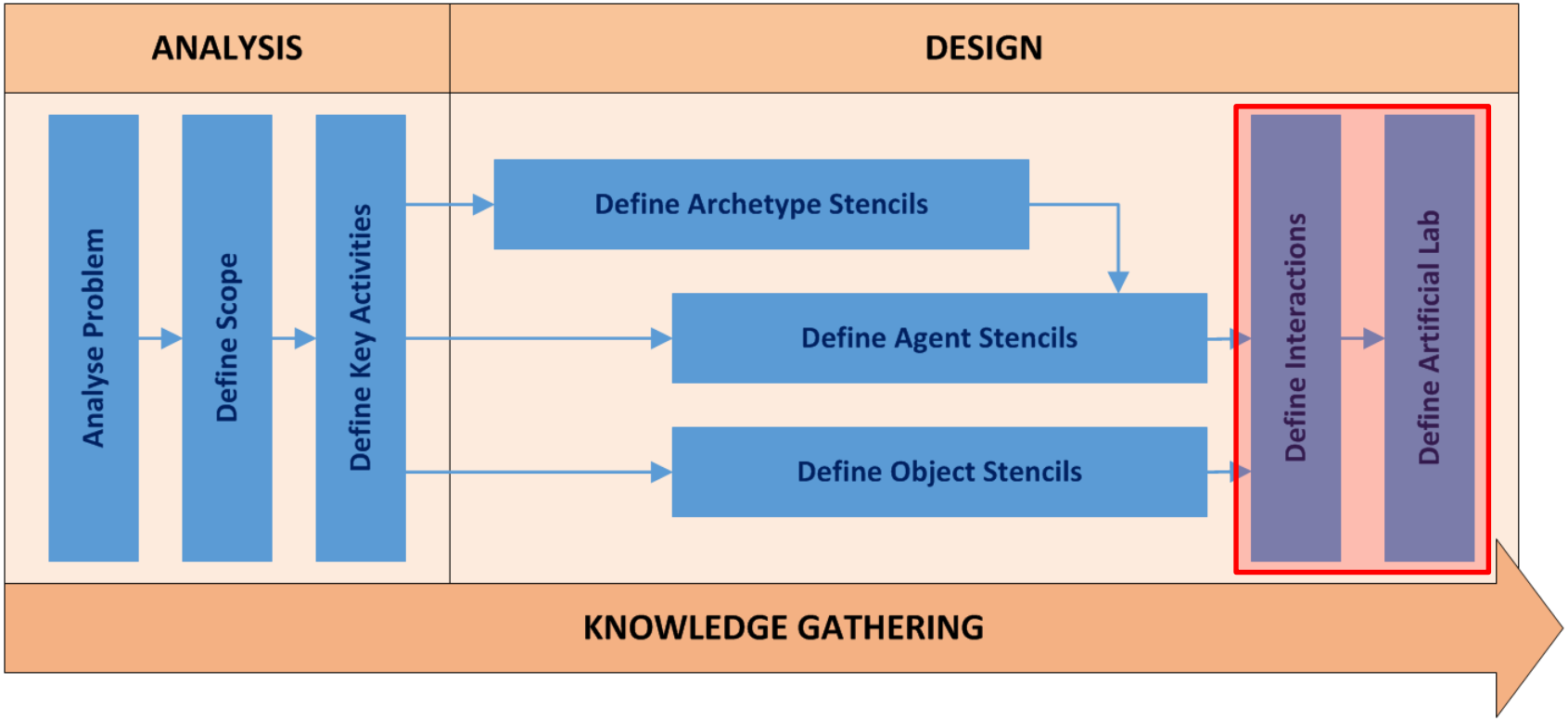


- Transition table of visitor agent

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

Engineering ABSS

- Model development process



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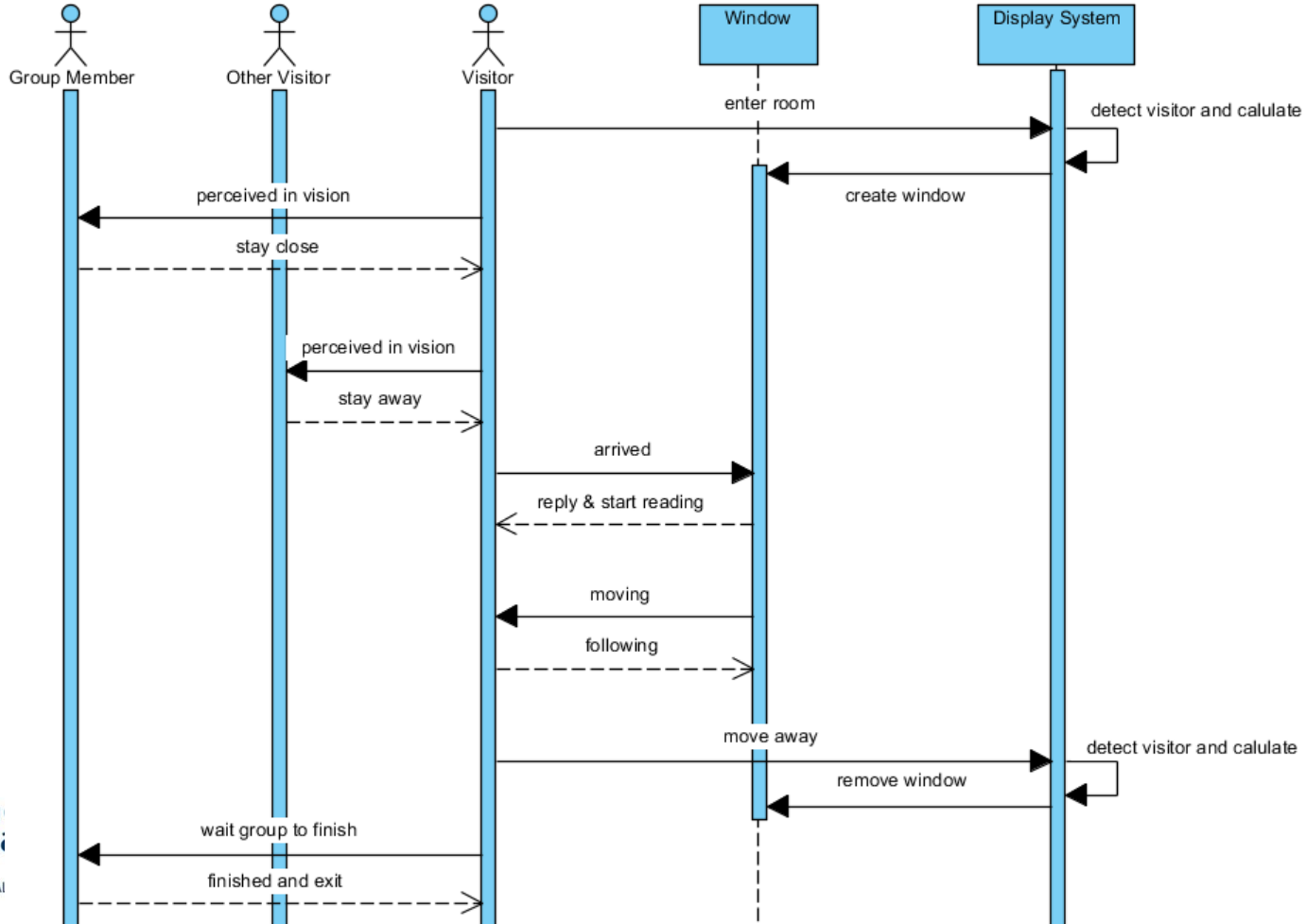
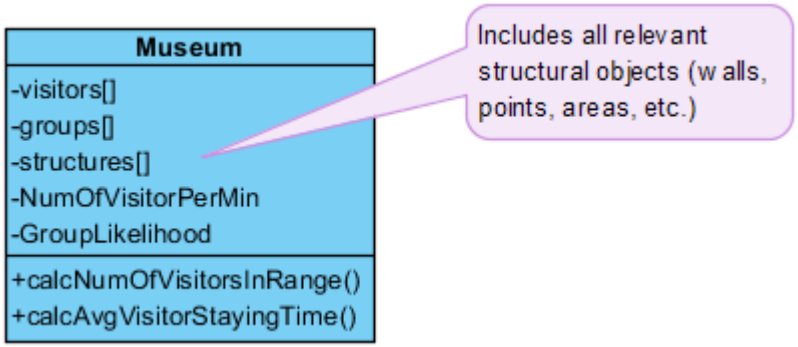
Illustrative Example: Design

- Interaction (all elements defined in the agent/object stencil step need to be listed on the horizontal axis) (use cases could be listed on the vertical axis)



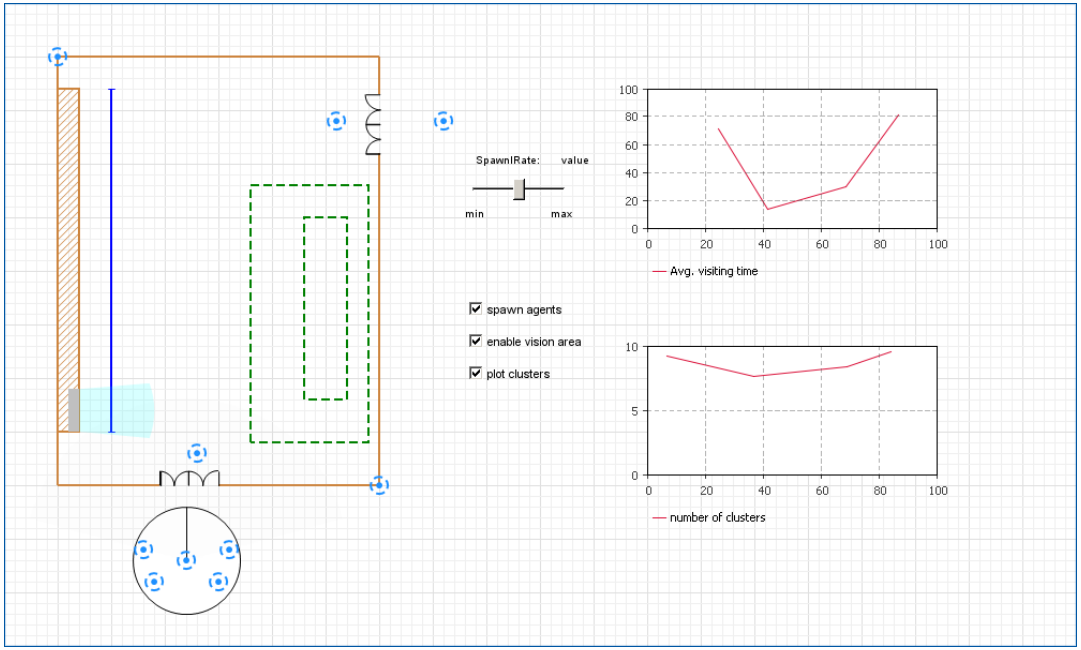
Illustrative Example: Design

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



Illustrative Example: Outcome

- The resulting model



References

- Bradshaw (1997). Software Agents. MIT Press.
- Siebers and Klügl (2017). What Software Engineering has to offer to Agent-Based Social Simulation. In: Edmonds and Meyer (eds). Simulating social complexity: A handbook - 2e, Springer.

Socrates vs Confucius

- Remember ...