EABSS Workshop 2023

Co-Creation of Agent-Based Social Simulation Models

Engineering Agent-Based Social Simulations

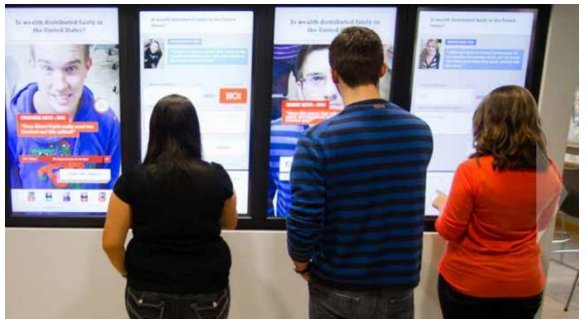
Example

The University of Nottingham
UNITED KINGDOM · CHINA · MALAYSIA

Warmup

Exploring Adaptive Architecture Design

- 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



Knowledge Gathering

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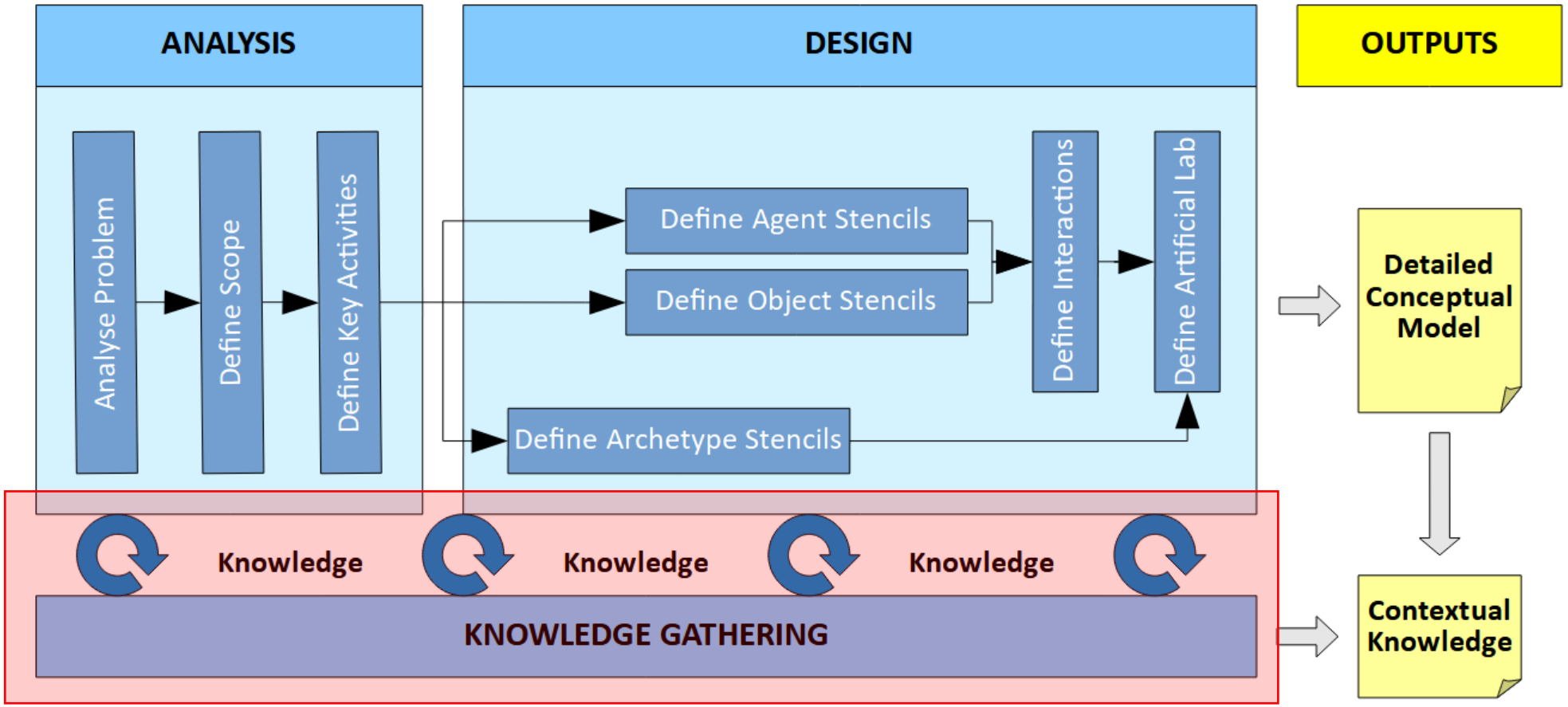

Knowledge Gathering

- Knowledge gathering happens throughout the structured modelling approach through
    - Literature review
    - Focus group discussions
    - Observations
    - Surveys
- Either a prerequisite for a task (e.g. a literature review) or embedded within a task (e.g. focus group discussions)

Analysis

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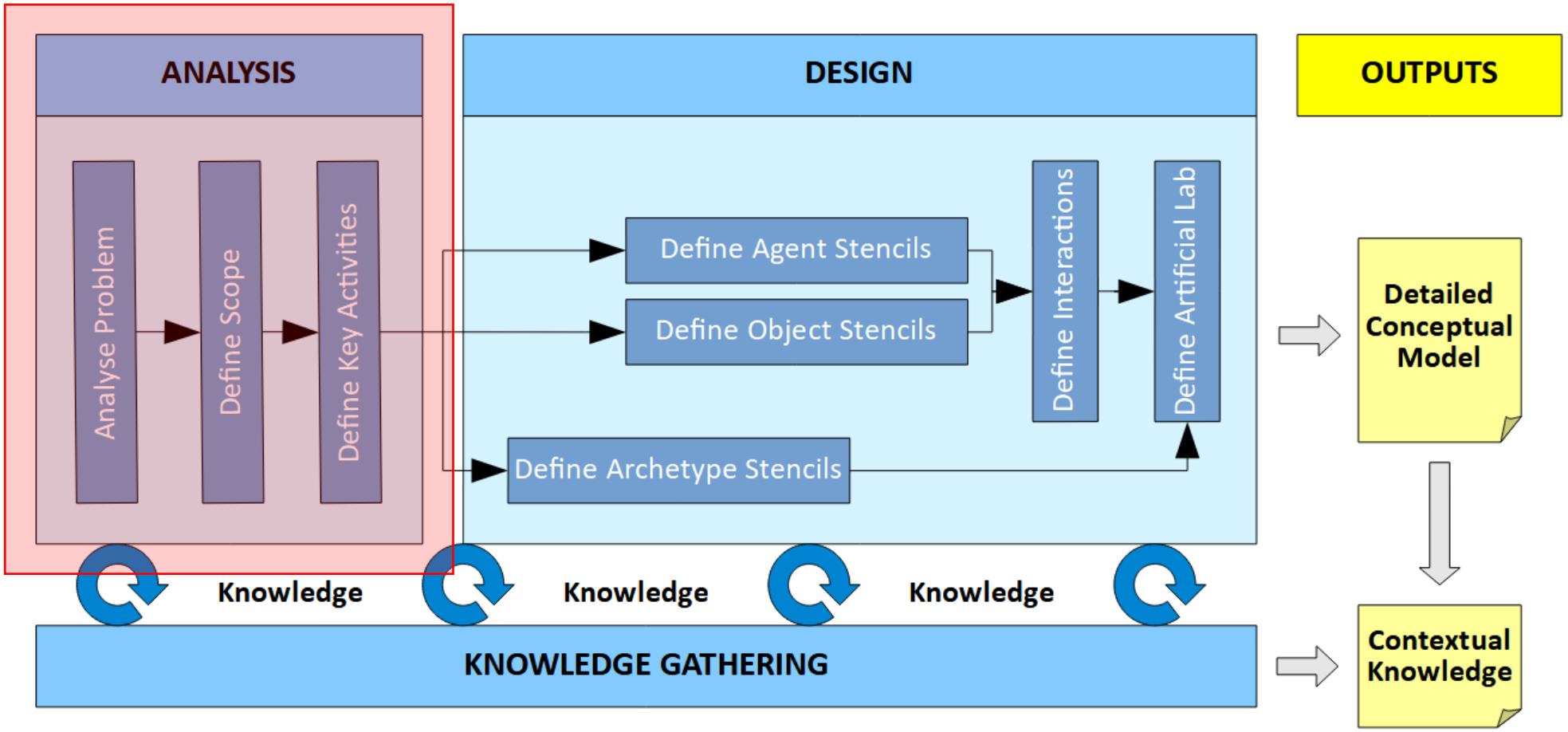


Analyse Problem

- 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

Analyse Problem

- Experimental factors (look at objectives/hypotheses to work these out)
  - Visitors arrival rate
  - Initial number of windows
  - 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)
  - Average time of visitors spend in the museum
  - Visual representation of the system and its dynamics

Define Scope (Design Details)

- 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 Environment	Service	Projector	PE01	Exclude	Considered by the windows
		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 Psychological Aspects / Phenomena	Visitor behaviour	Movement	SPAP01	Include	Required to trigger the window AI
		Vision area	SPAP02	Include	Will affect visitor movement behaviour
	Window behaviour	Movement	SPAP03	Include	Part of the AI to be tested
		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

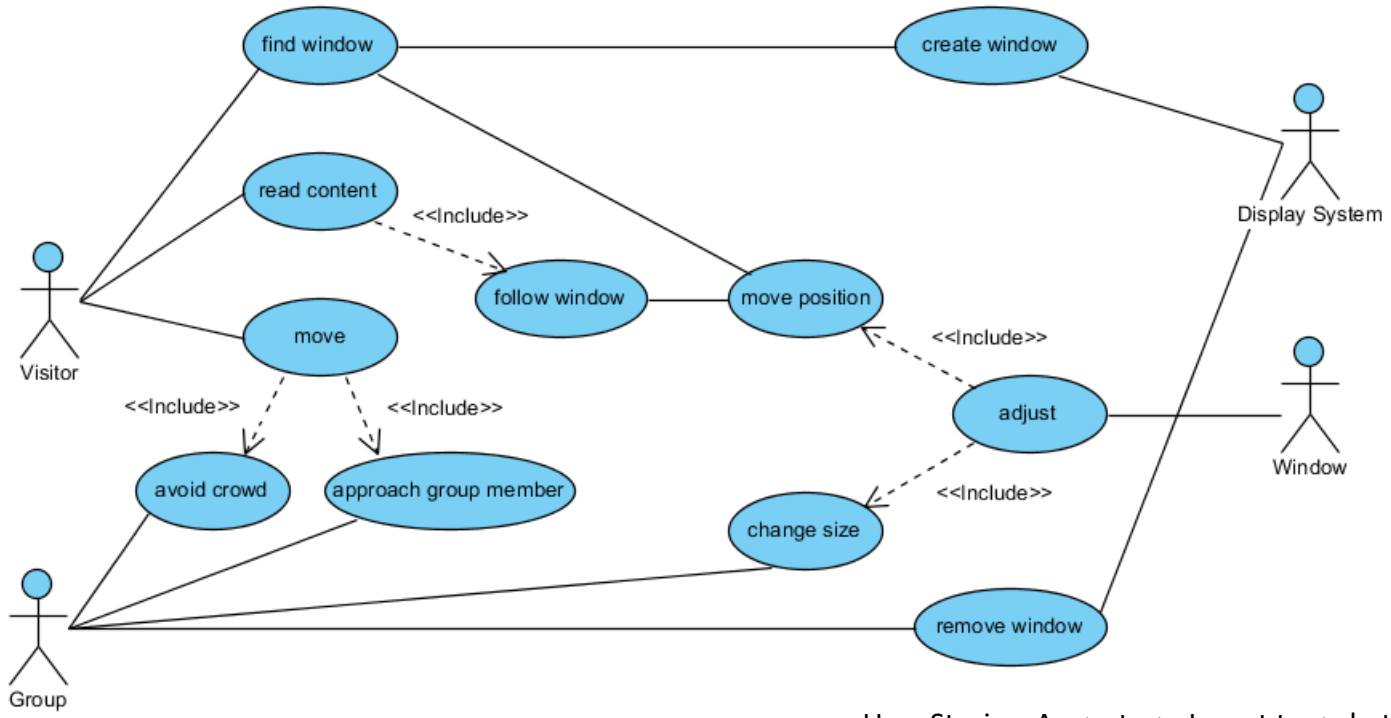
Define Scope (Implementation Details)

- Level of Detail: How and Why?

ID	Implementation Detail	Decision	Justification
SPA01	Movement algorithm: Social Force Model	Include	Well established in Social Simulation
SPA03	Movement algorithm: Social Force Model	Include	Well established in Social Simulation
SPA03	Movement algorithm: Hammer Algorithm	Exclude	Alternative to SFM but to be ignored due to time constraints

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?>)

Design

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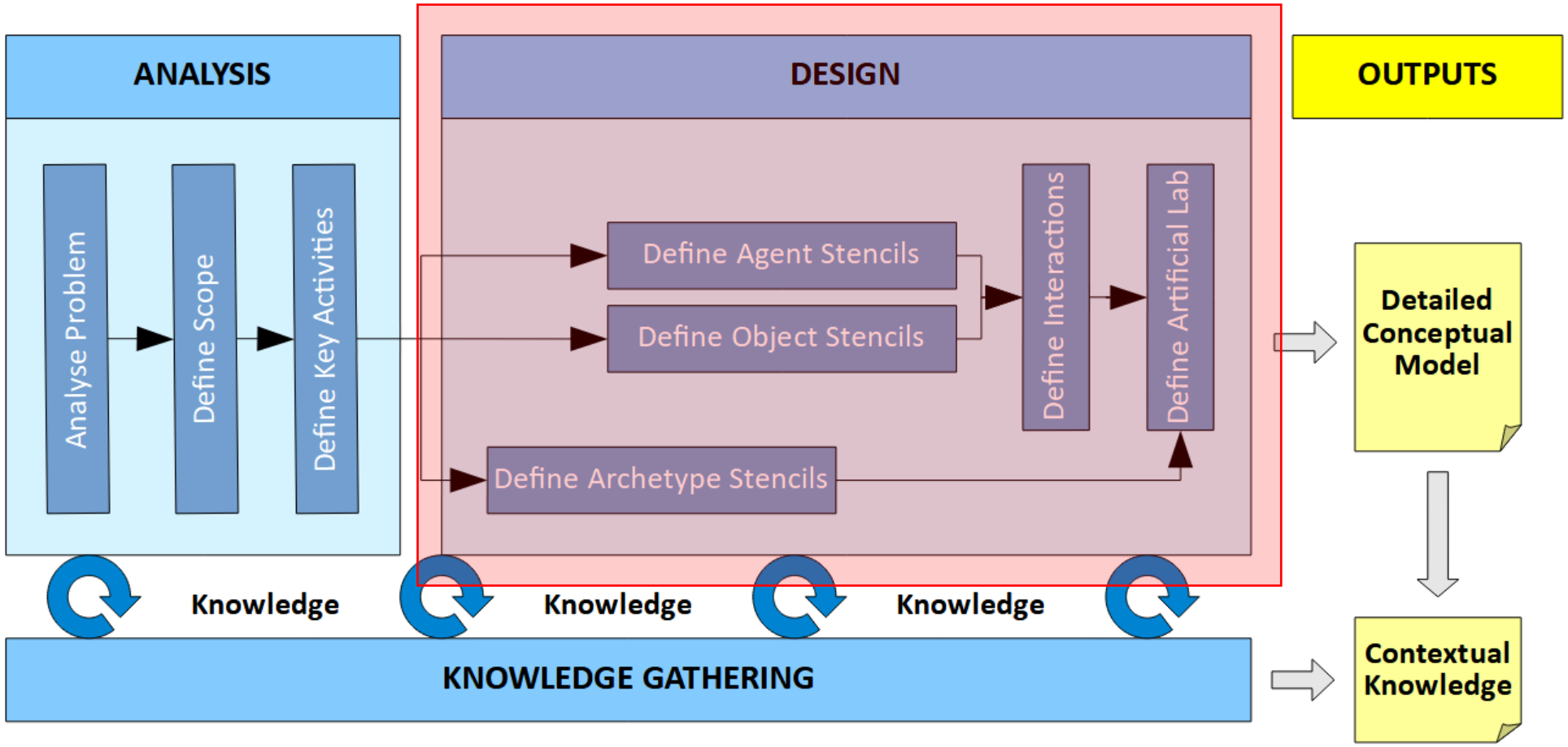


Define Archetype Stencils

- 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

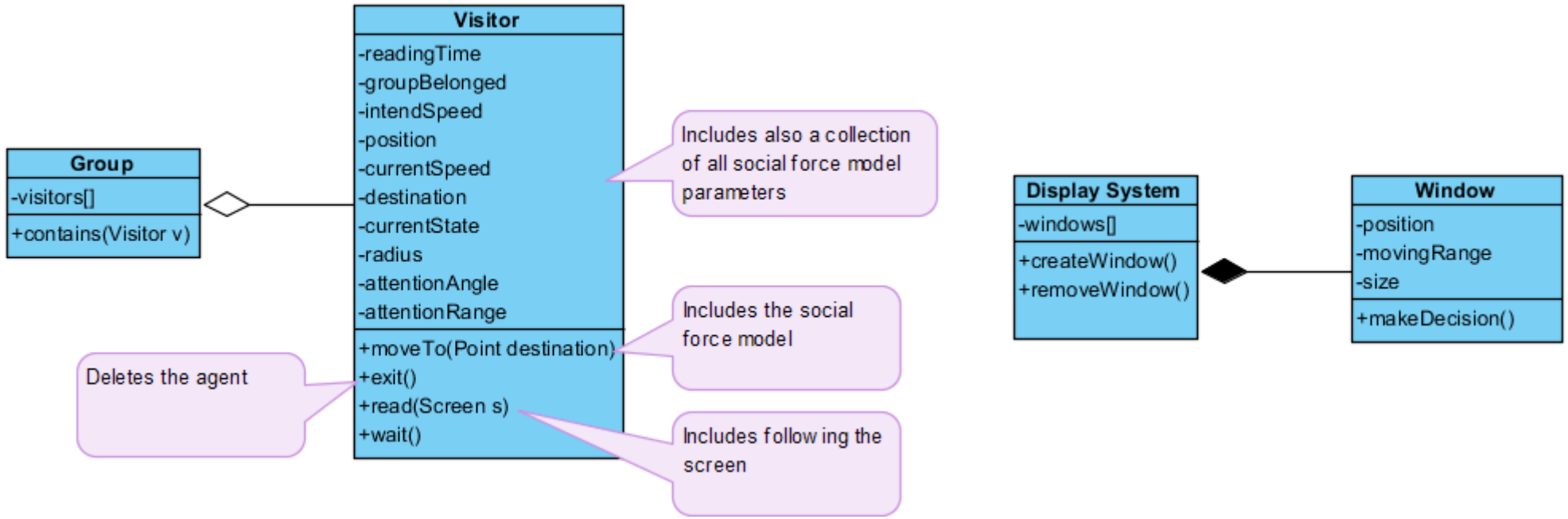
Note: The values are not really required at this stage, but you should capture them if they emerge from the discussion

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

Agent and Object Stencils

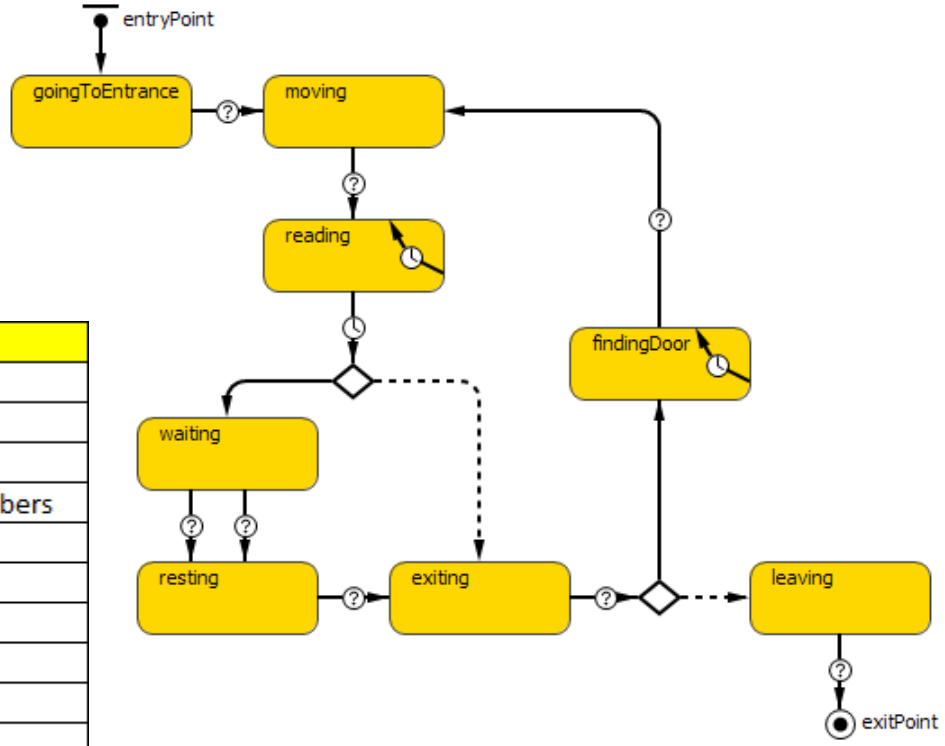
- Agent and object classes (attributes can be derived from archetype criteria and by looking at the scope table; operations can be derived from the states in the related state charts)



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)

Agent and Object Stencils

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



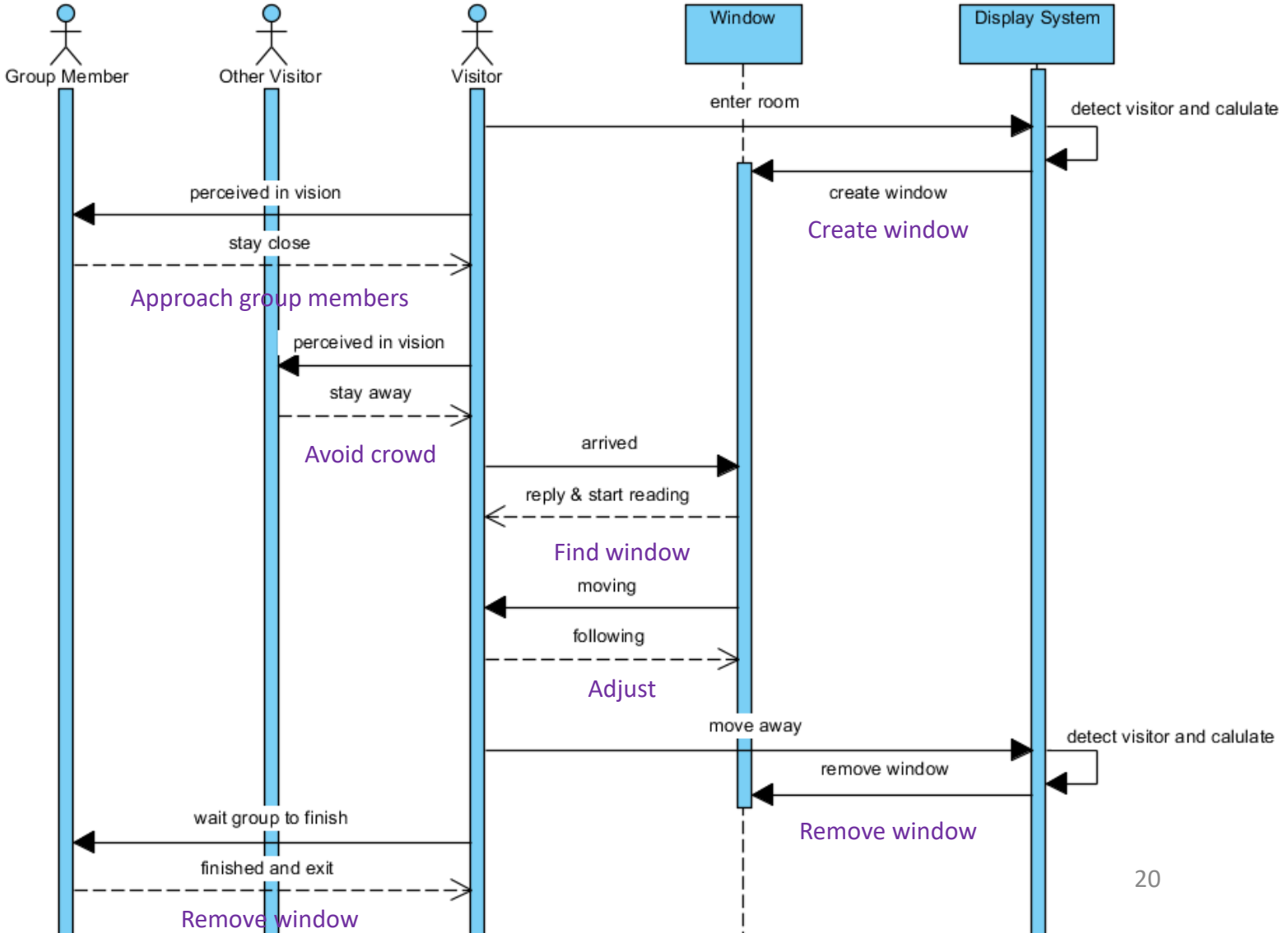
- Transition table of **visitor agent**

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

Define Interactions

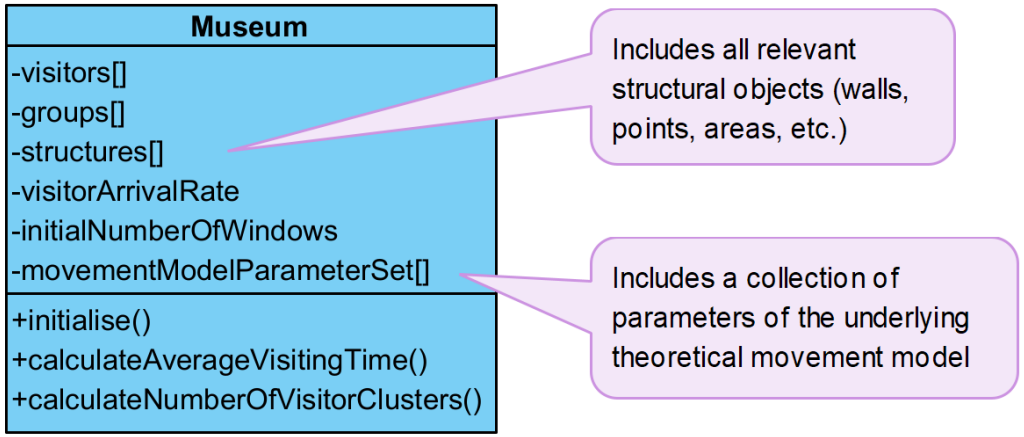
- Interaction (all elements defined in the Agent and Object Stencils step need to be listed on the horizontal axis; use cases could be listed on the vertical axis; alternatively, a separate diagram could be created for each individual use case)

Note: We should also consider the "Other Visitor" actor earlier in the Scope Table and the Key Activities Diagram. Whenever we consider interaction rules between actors of the same type we require an additional actor group "Other actor" to be able to define the interactions.



Define Artificial Lab

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



Outputs

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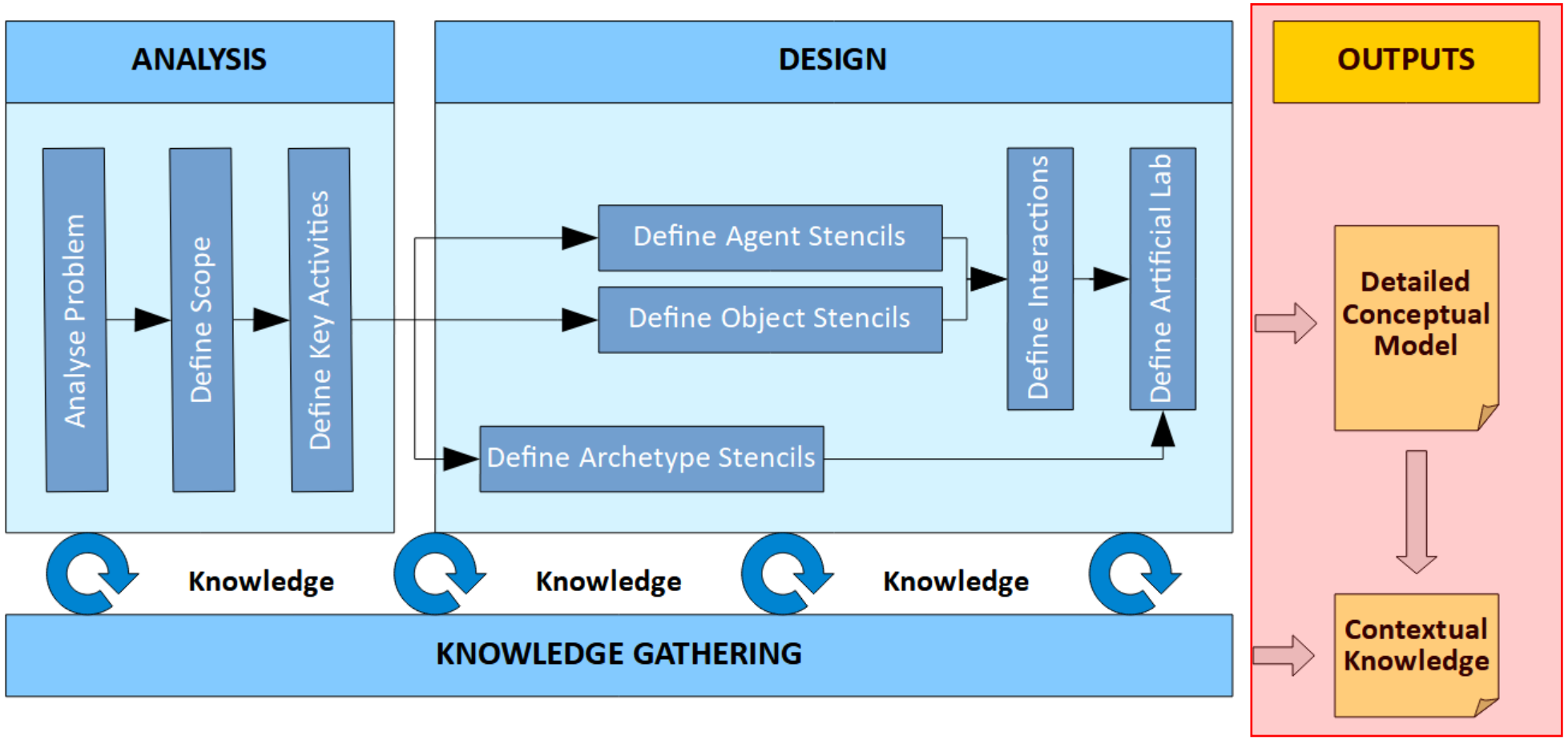


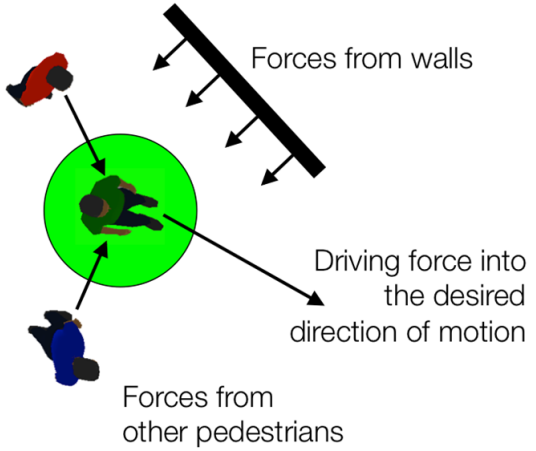
Outputs

- Detailed Conceptual Model
  - Ready for implementation by software engineer or modeller
- Contextual Knowledge
  - Qualitative data generated could be used for inductive research or used for further analysis

Implementation

Choice of Movement Model

- The Social Force Model (SFM) 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.



(Helbing and Molnar 1995)

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

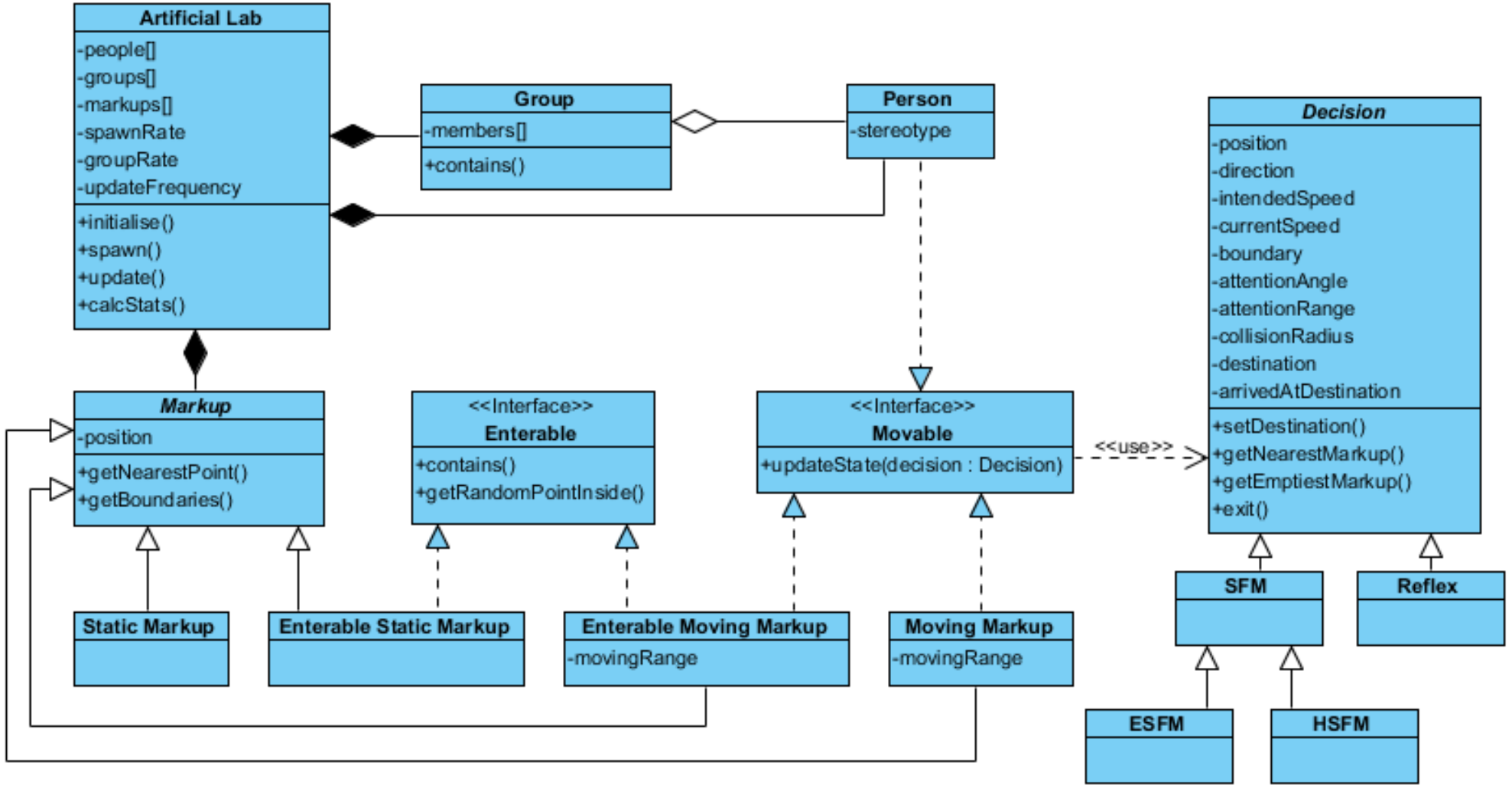
$$\boldsymbol{f}_{ij} = \boldsymbol{f}_{ij}^{psy} + \boldsymbol{f}_{ij}^{phy}, \quad \boldsymbol{f}_{ij}^{psy} = A_i \exp\left(\frac{r_{ij} - d_{ij}}{B_i}\right)\boldsymbol{n}_{ij}$$

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

- The Extended Social Force Model (ESFM) adds more realistic vision

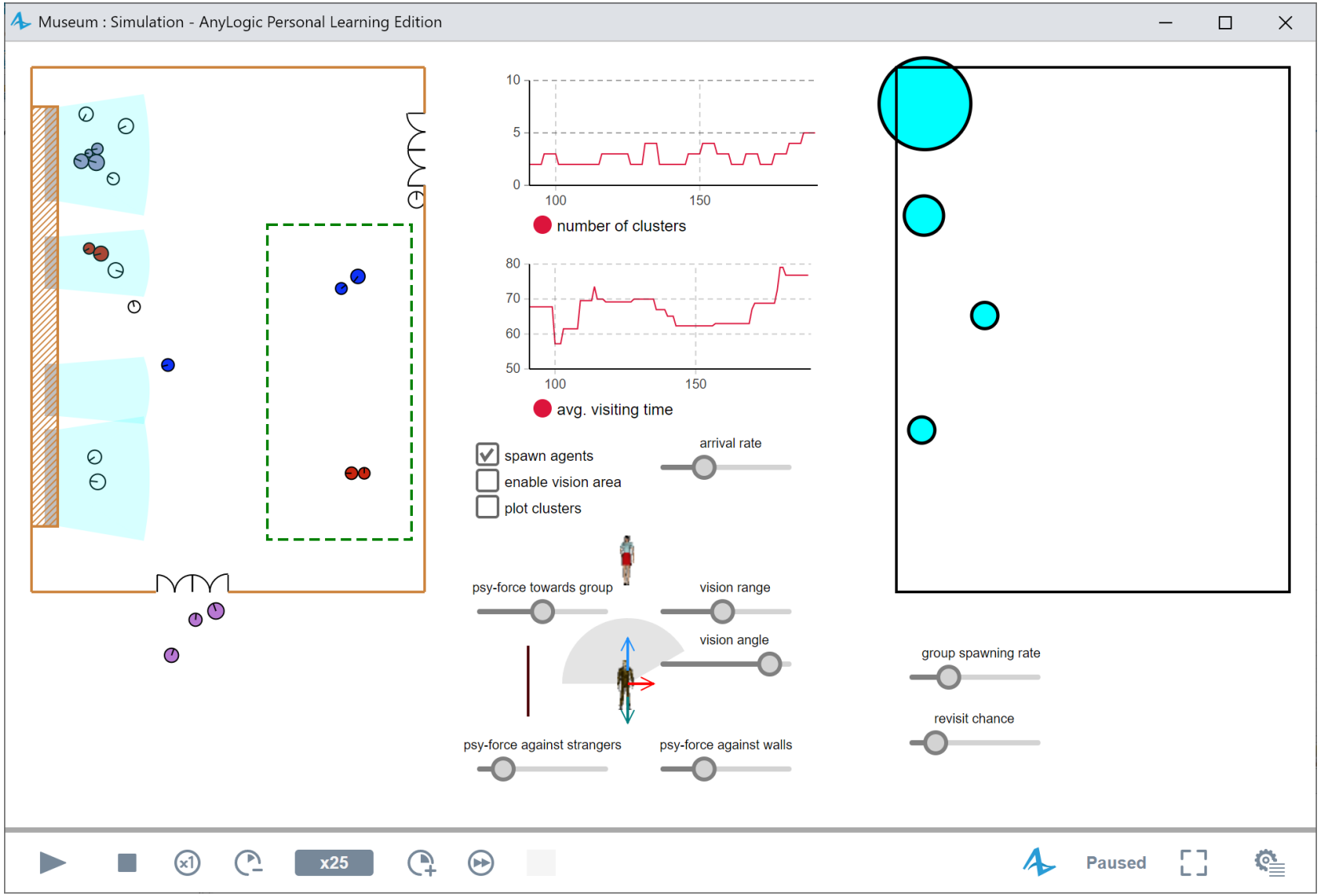
(Xie et al 2010)

Design Pattern for ESFM Implementation

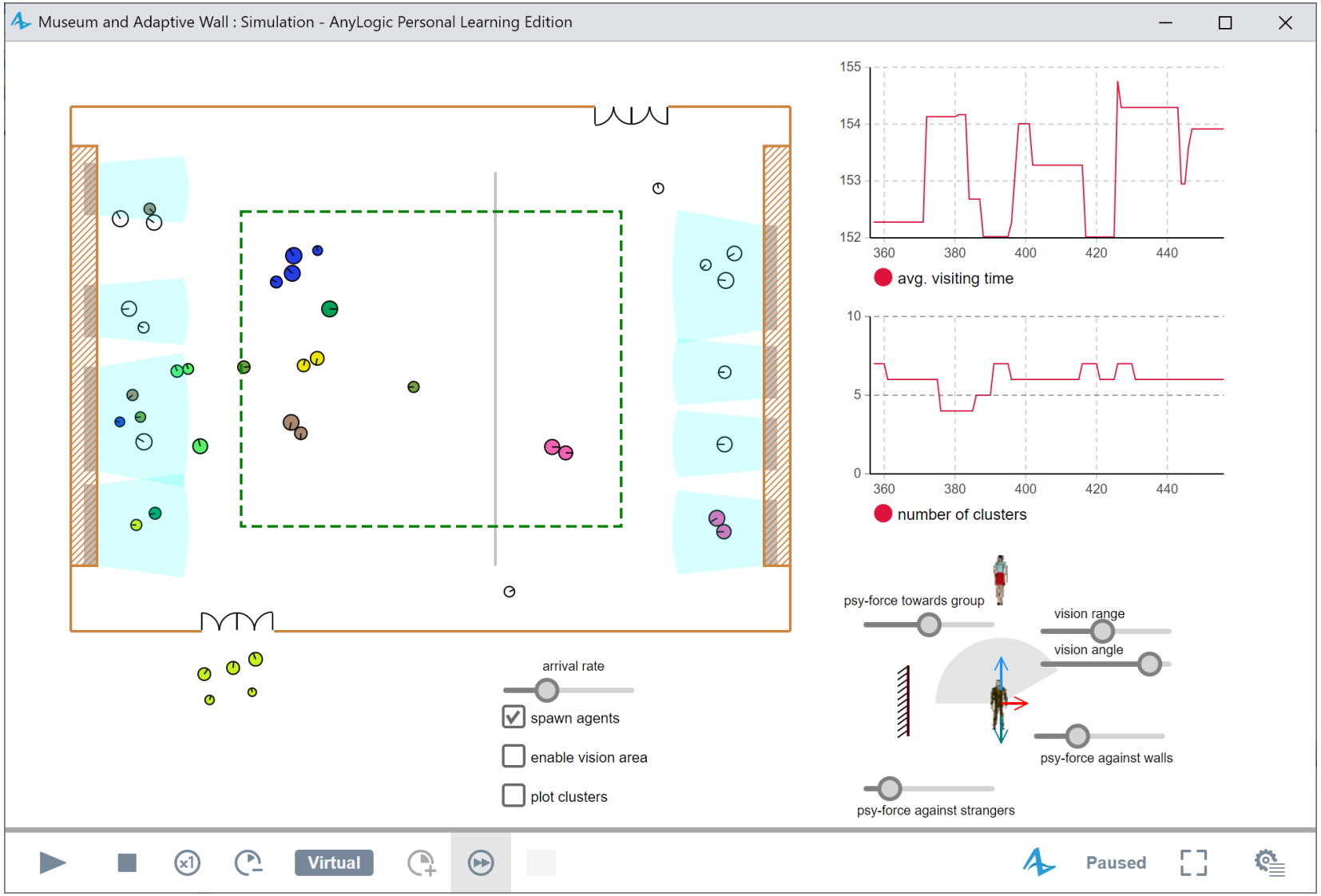


Siebers et al (2018)

The Implemented Model



An Extended Version of the Implemented Model



Any Questions?

References

- Helbing D and Molnar P (1995). Social Force Model for Pedestrian Dynamics. Physical Review E, 51(5).
- Siebers et al (2018). Proposal of a Design Pattern for Embedding the Concept of Social Forces in Human Centric Simulation Models. In: Proceedings of the 9th Simulation Workshop (SW2018), 19-21 Mar, Stratford, Worcestershire, UK.
- Xi H, Lee S, and Son YJ (2011) An Integrated Pedestrian Behavior Model Based on Extended Decision Field Theory and Social Force Model. In: Rothrock L and Narayanan S (eds.) Human-In-The-Loop Simulations: Methods and Practice, London, UK: Springer, pp.69-95.