

A (More) Formal Approach for Developing Agent-Based Social Simulation Models of Energy Users

Peer-Olaf Siebers, Meredith Susanty, and Graziela Figueredo
School of Computer Science, University of Nottingham, UK

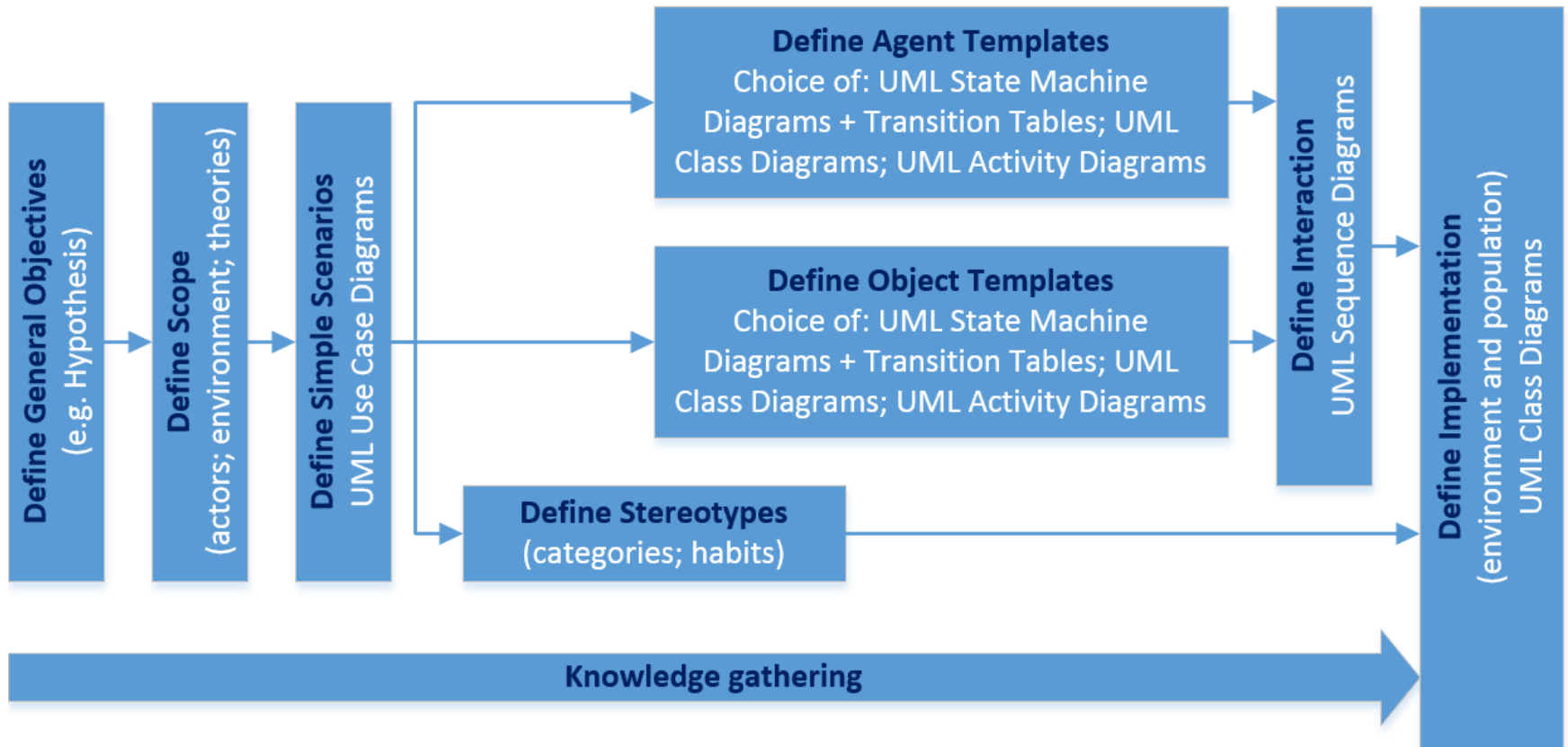
Conference on Social Science Research in Energy (27/04/2016)
Birmingham Energy Institute and Midlands Energy Consortium

The agent-based model used for the informative example is based on Zhang (2011)
The ideas regarding the modelling of normative behaviour are based on Bedwell (2014)

Project

- Problem
 - When building agent-based social simulation models one faces the question of how to build it and where to start
 - Challenging for novices in the field
 - Challenging to engage everyone in the modelling process in particular in bigger interdisciplinary projects
- Our solution
 - A novel framework that guides model development and besides supports reproducibility
 - It borrows ideas from many different disciplines

Framework



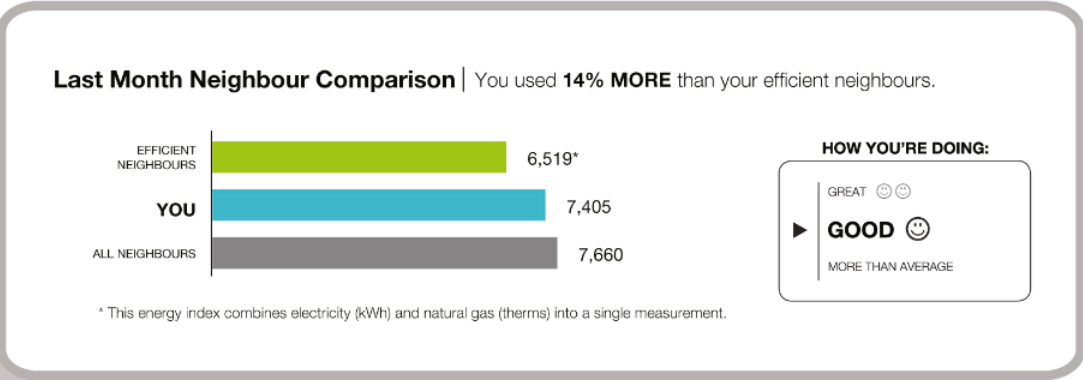
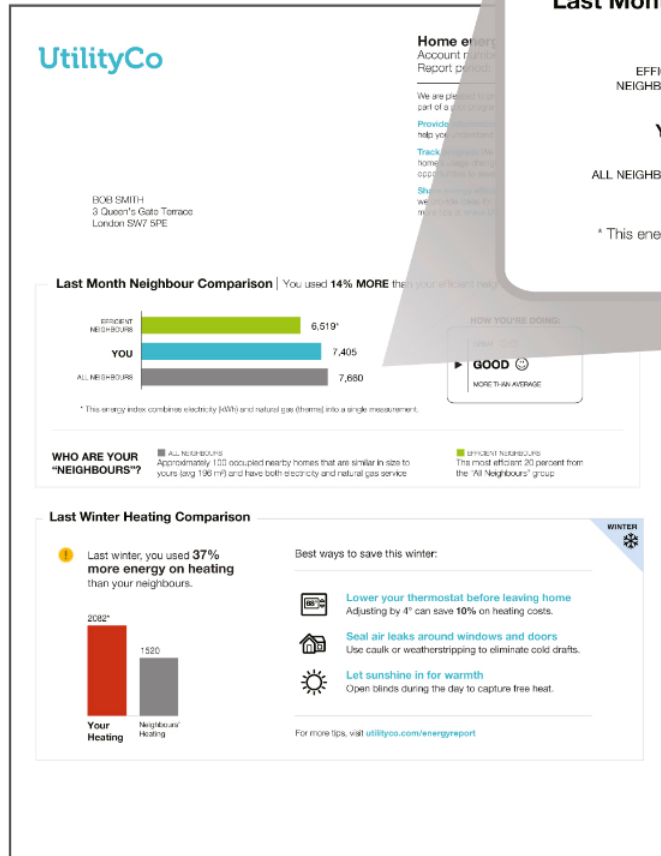
Framework

- The framework is particularly well suited for models that will be implemented using IDEs that support automated UML state machine translation
- The two most commonly used environments that support this
 - Repast Simphony
 - Open source agent-based modeling toolkit
 - AnyLogic
 - Commercial multimethod simulation modeling tool

Example

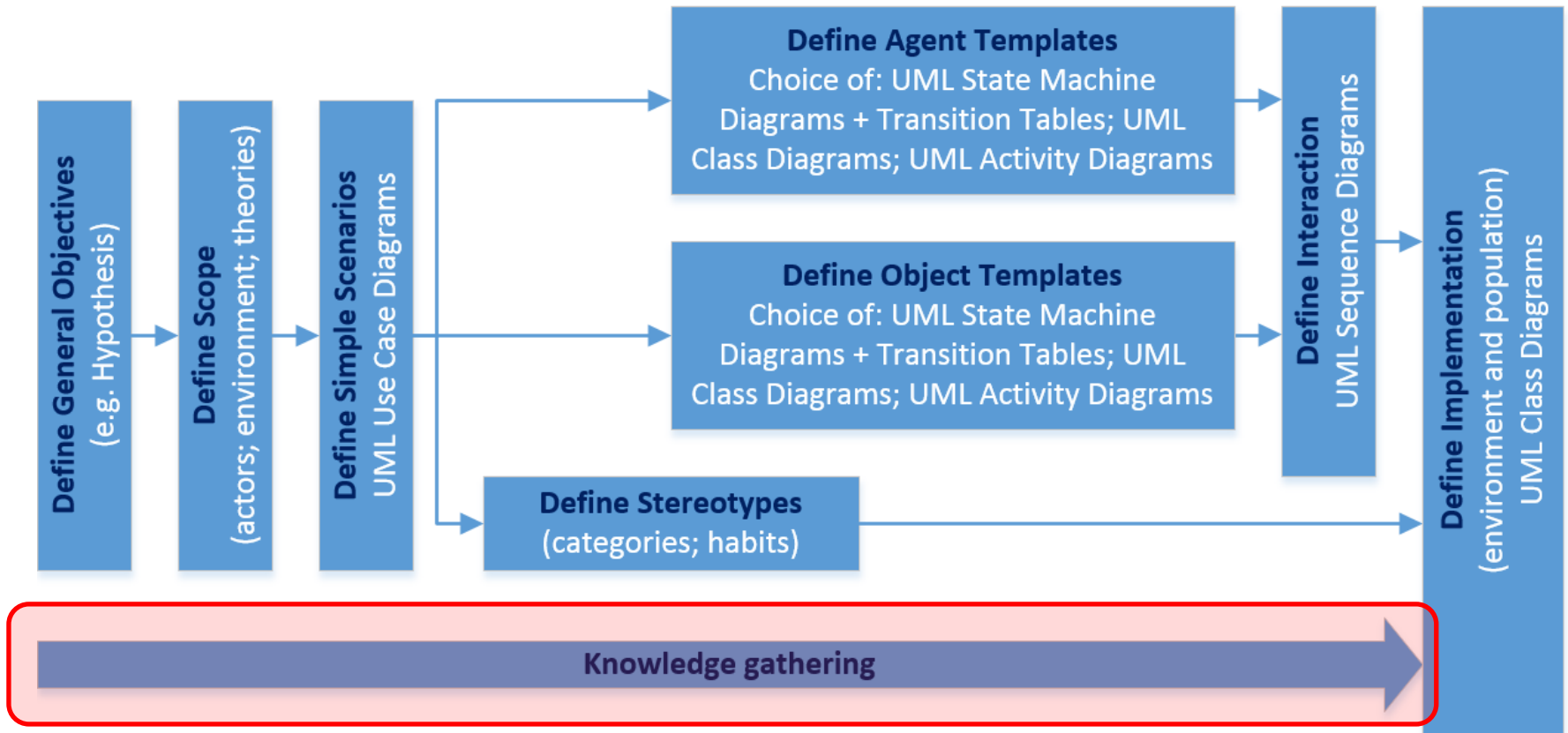
- Informative example for demonstrating the framework
 - Normative comparison amongst colleagues with regards to energy consumption in an office environment
 - Strategies to test:
 - Individual apportionment of energy consumption information
 - Group apportionment of energy consumption information
- Normative energy consumption comparison
 - Giving people clear regular personalised insight into their own energy consumption (e.g. "you used 11% more energy than usual for this month") and allow them to compare it to that of their neighbours (e.g. "that is a lot more for this month than your neighbours used")

Example



Opower's Home Energy Reporting Program

Framework

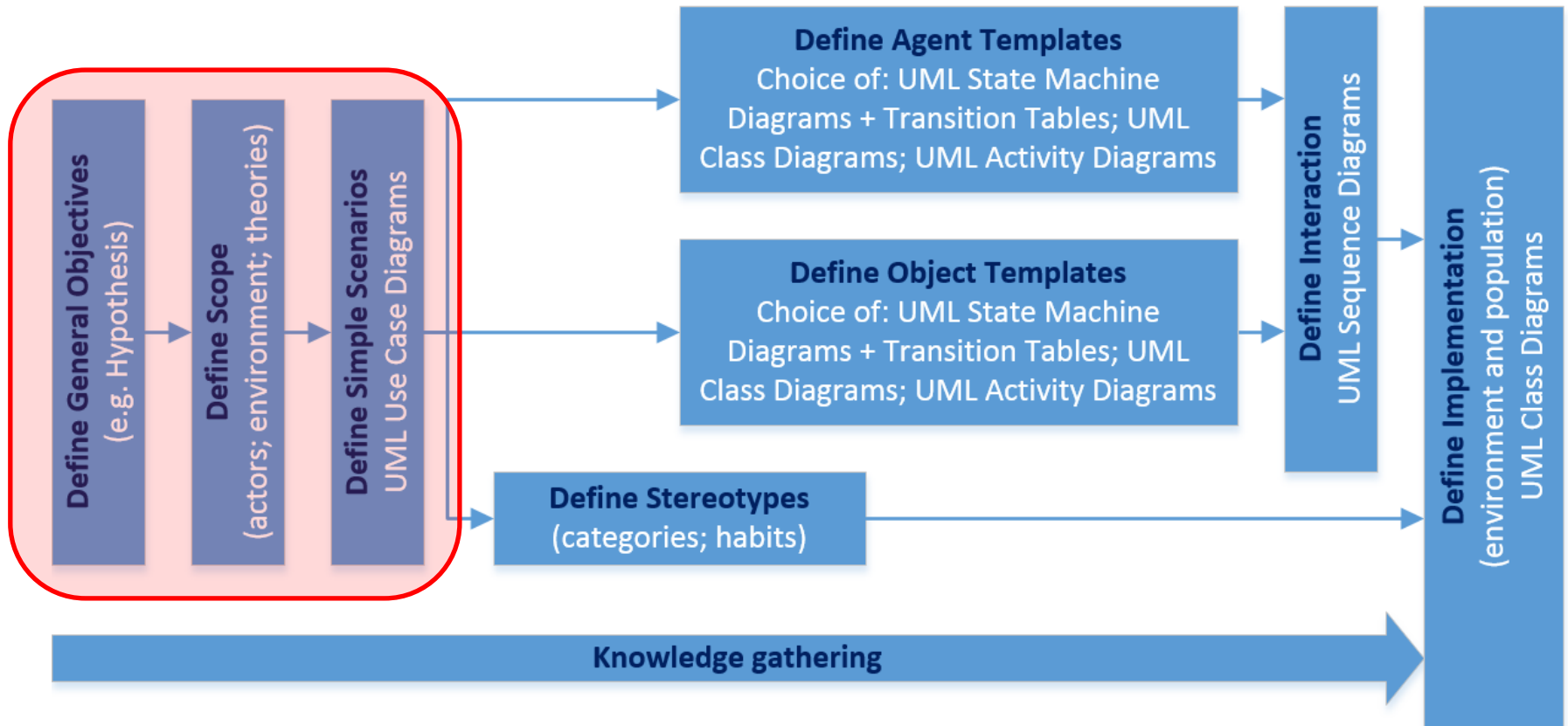


Knowledge Gathering

- Knowledge gathering happens throughout the project
 - We need general knowledge to enable us to set the objectives
 - We need knowledge that supports us with defining the model scope
 - We need knowledge to fully define the stereotypes
 - ...
- Knowledge gathering happens in many different forms



Framework



Knowledge Gathering (1)

- At this stage we gathered some general knowledge to enable us to set the objectives for the study
 - Internal focus group discussions and a literature review

Define General Objectives

(defined through internal focus group discussions)

- General Objectives
 - We are interested in studying normative comparison in an office environment
 - We aim to answer the following questions:
 - What are the effects of having the community influencing the individual?
 - What is the extent of impact (significant or not)?
 - Can we optimise it using certain interventions?
- Our hypothesis:
 - Peer pressure leads to greener behaviour
 - Peer pressure has a positive effect on energy saving

Knowledge Gathering (2)

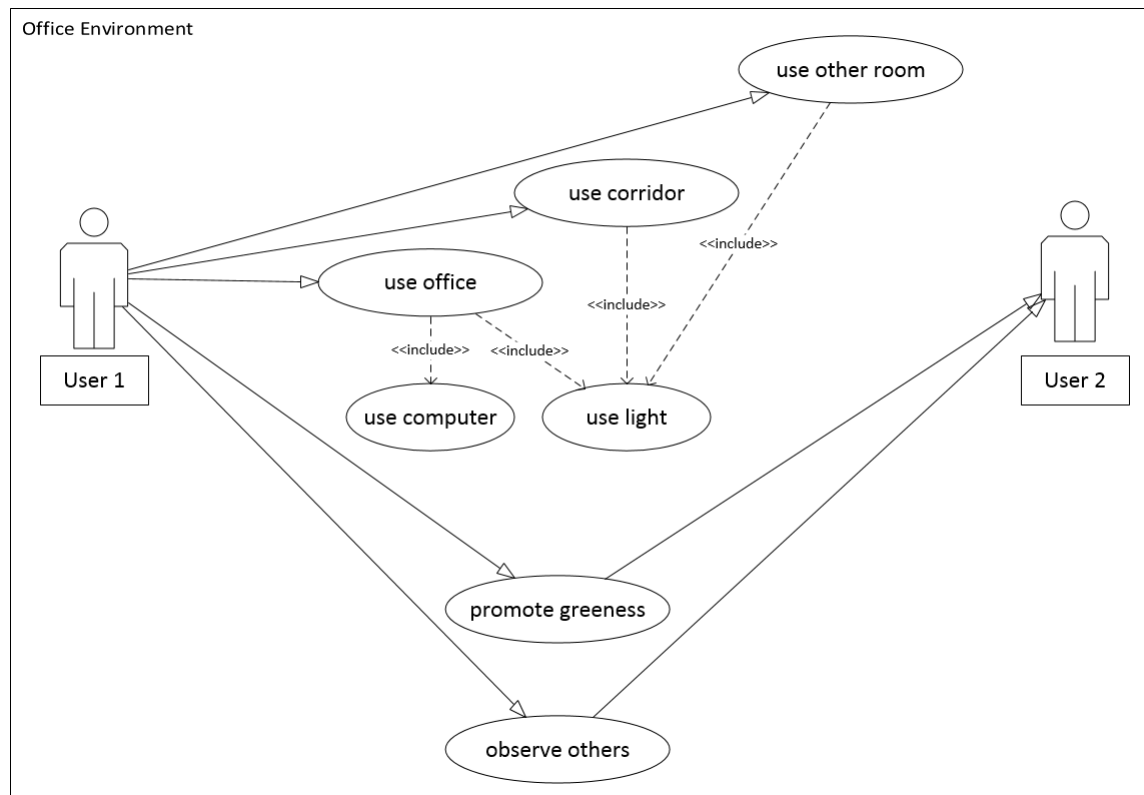
- At this stage we were interested in gathering knowledge that can support us with defining the model scope
 - Literature review and observation of the existing system

Scope

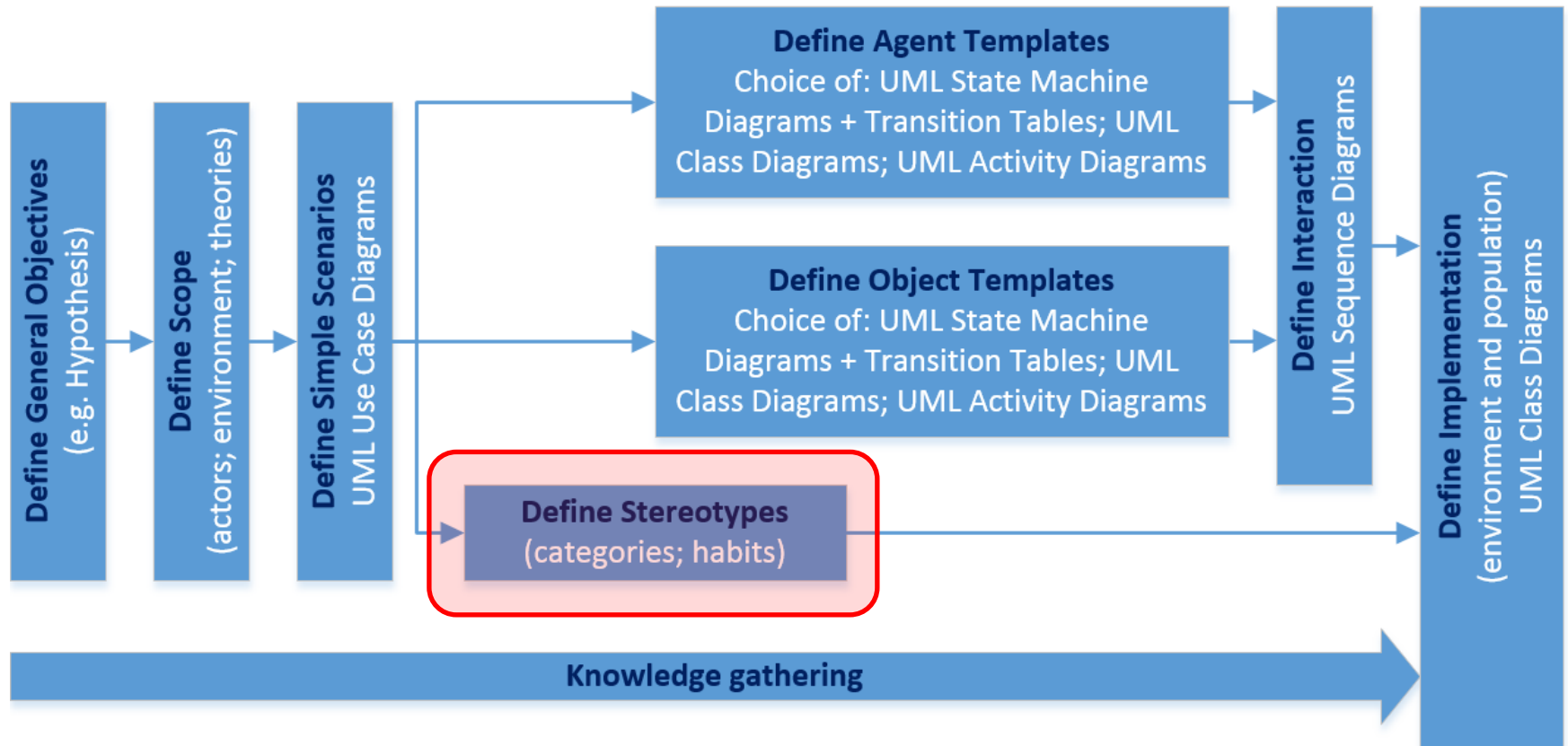
Element	Detail	Decision	Justification
Actor	Staff	Include as group (User)	Regularly occupy the office building
	Research fellows		
	PhD students		
	UG+MSc students	Exclude	Do not have control over their work environment
	Visitors	Exclude	Insignificant energy use
Appliance	HVAC (Heating + Ventilation + Aircon) system	Exclude	We only need one major energy consumer to test the theory; we decided to go for electricity
	Lighting	Include	Interacts with users on a daily basis; controlled by user
	Computer	Include	Interacts with users on a daily basis; controlled by user
	Monitor	Exclude	Modelled as part of the computer
	Continuously running appliances	Exclude	Constant consumption of electricity; not controllable by individuals
	Personal appliances	Exclude	No way to measure consumption
Weather	Temperature	Exclude	Not necessary for proof-of-principle
	Natural light level	Exclude	Not necessary for proof-of-principle
Room	Office	Include	Location where electronic appliances are installed
	Lab	Exclude	Mainly used by UG+MSc
	Kitchen	Include as group (Other Room)	Common areas frequently used by "users"
	Toilet		
	Corridor	Include	Commonly used when "users" move around
Psychology factors	Comparative feedback	Include	Effective strategy to reduce energy consumption in residential building
	Informative Feedback	Include	Effective strategy to remove barriers in performing specific behaviour
	Apportionment level	Include	Potential strategy to reduce energy consumption in office building
	Freeriding	Include	Behaviour that differentiate two apportionment strategy
	Sanction	Include	Factor to encounter freeriding behaviour
	Anonymity	Include	Factor to encounter freeriding behaviour

Simple Scenarios

- Specialised UML Use Case Diagram



Framework



Stereotypes

- Process
 - Define categories of stereotypes
 - Come up with the habits that describe these stereotypes
- Result
 - Work Time stereotype
 - Arrival time at office; leaving time from office
 - Energy Saving Awareness stereotype
 - Energy saving awareness; likelihood of switching off unused electric appliances; likelihood of promoting greenness

Knowledge gathering (3)

- To get the information we needed to fully define the stereotypes we conducted a survey amongst our academics, researchers, and PhD students, anonymously asking them questions about their habits towards work time and energy saving awareness

Stereotypes

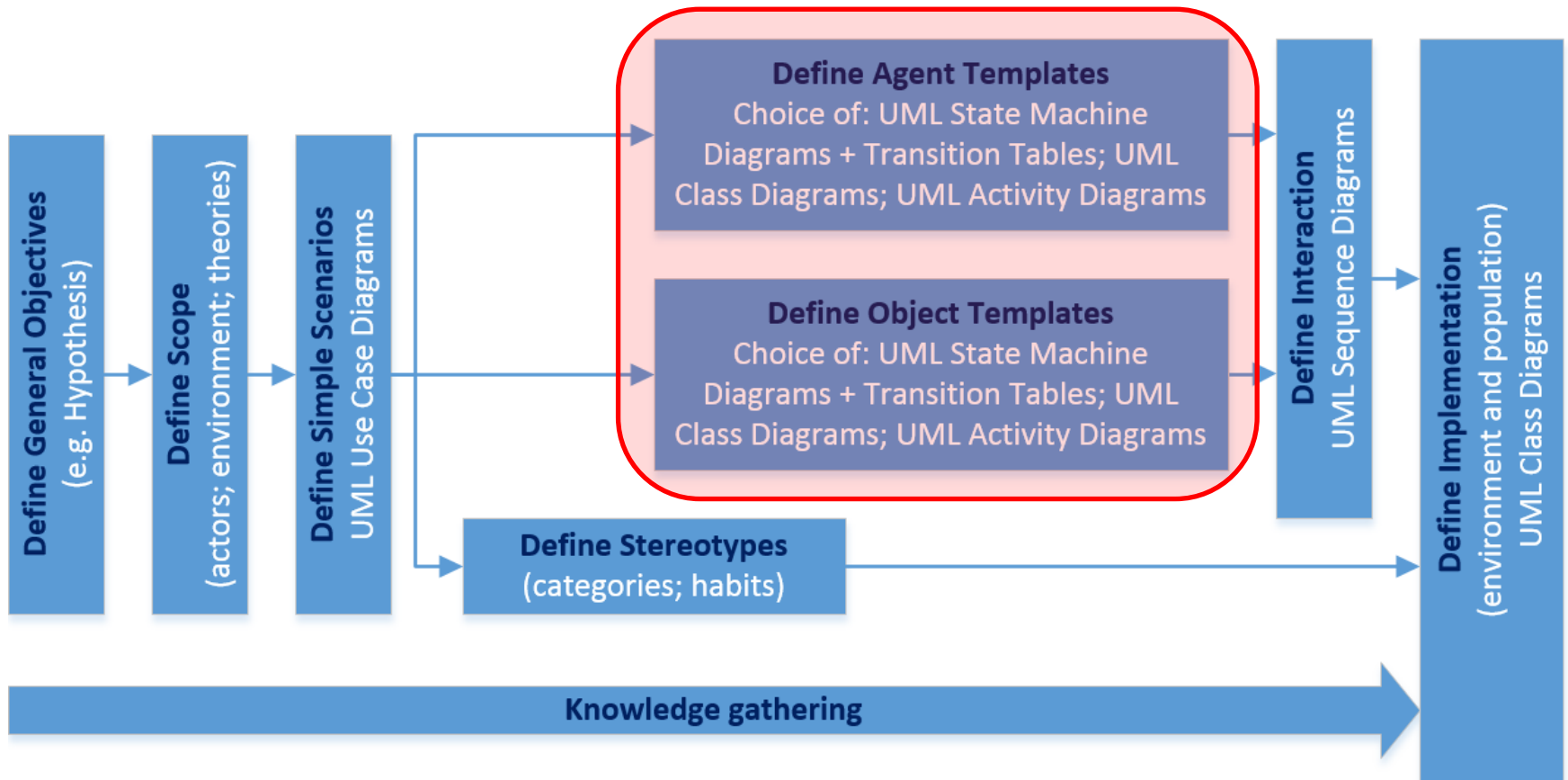
- User stereotypes defining work time habits

Stereotype	Working days	Arrival time	Leave time
Early bird	Mon-Fri	5am-9am	4pm-7pm
Time table complier	Mon-Fri	9am-10am	5pm-6pm
Flexible worker	Mon-Fri	10am-1pm	5pm-11pm
Hardcore worker	Mon-Fri + Sat	8am-10am	5pm-11pm

- User stereotypes defining energy saving habits









Stereotype	Energy saving awareness [0-100]	Probability of switching off unnecessary appliances	Probability of sending emails about energy issues to others
Environmental champion	95-100	0.95	0.9
Energy saver	70-94	0.7	0.6
Regular user	30-69	0.4	0.2
Big user	0-29	0.2	0.05

Framework



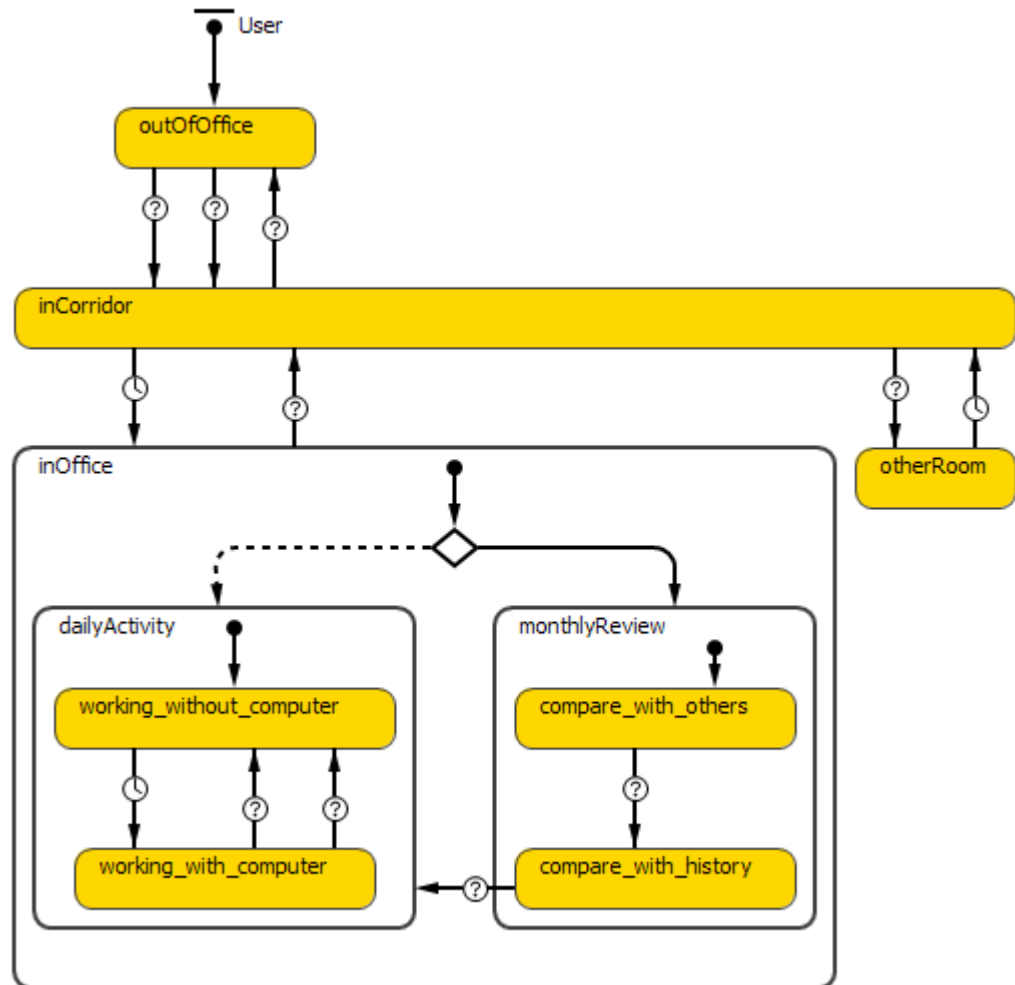
Agent & Object Templates

- State machine diagram symbols

Component	Symbol	Description
Entry pointer		Indicates the initial state after an object is created
State		Represents a locus of control with a particular set of reactions to conditions and/or events
Initial state pointer		Points to the initial state within a composite state
Final state		Termination point of a state chart
Transition		Movement between states, triggered by a specific event
Branch		Transition branching and/or connection point
Shallow history		The state chart remembers the most recent active sub state (but not the lower level sub-states)
Deep history		The state chart remembers the most recent active sub state (including the lower level sub states)

Agent Templates

- User state machine



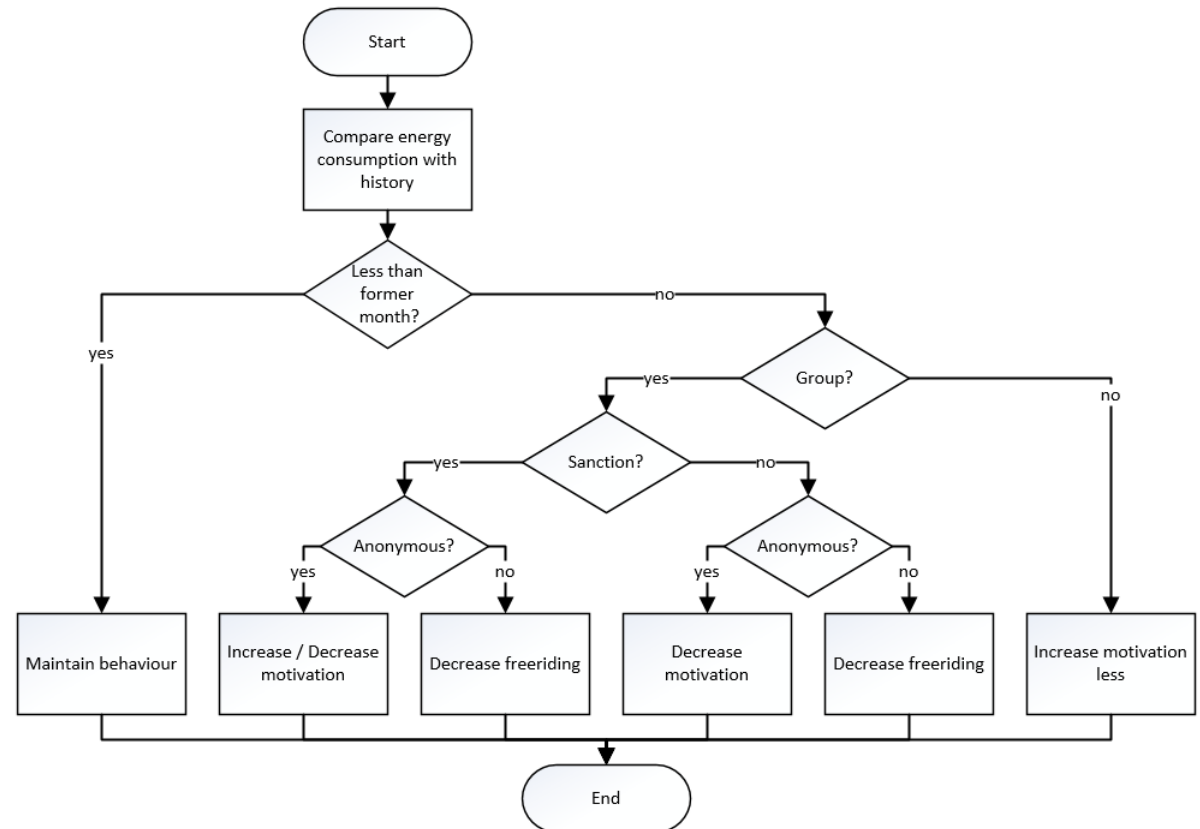
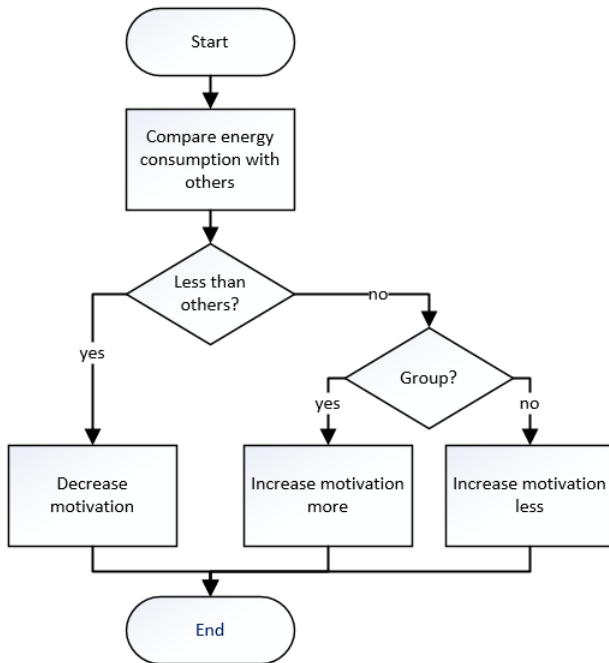
Agent Templates

- User transition definition table (excerpt)
 - Should perhaps also include laymen definition

From state	To state	Triggered by	Definition
outOfOffice	inCorridor	Condition	<code>arrivalTime==hourOfDay&&day!=1&&day!=7</code>
outOfOffice	inCorridor	Condition	<code>(day==1 day==7)&&(uniform_discr(1,50)==1)&&(arrivalTime==hourOfDay)</code>
inCorridor	outOfOffice	Condition	<code>hourOfDay>=leaveTime</code>
inCorridor	inOffice	Timeout	<code>5*Math.random()</code> [minutes]
inOffice	inCorridor	Condition	<code>hourOfDay==uniform_discr(arrivalTime,leaveTime) hourOfDay>=leaveTime</code>
inCorridor	otherRoom	Condition	<code>hourOfDay==uniform_discr(arrivalTime,leaveTime)</code>
otherRoom	inCorridor	Timeout	<code>10*Math.random()</code> [minutes]
...

Agent Templates

- Normative behaviour logic flow (UML Activity Diagrams)
 - Requires rationale for changes to motivation and freeriding

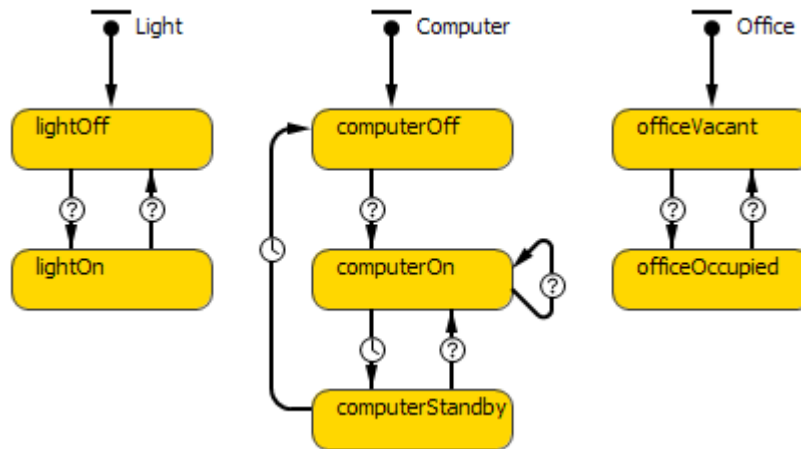


Agent Templates

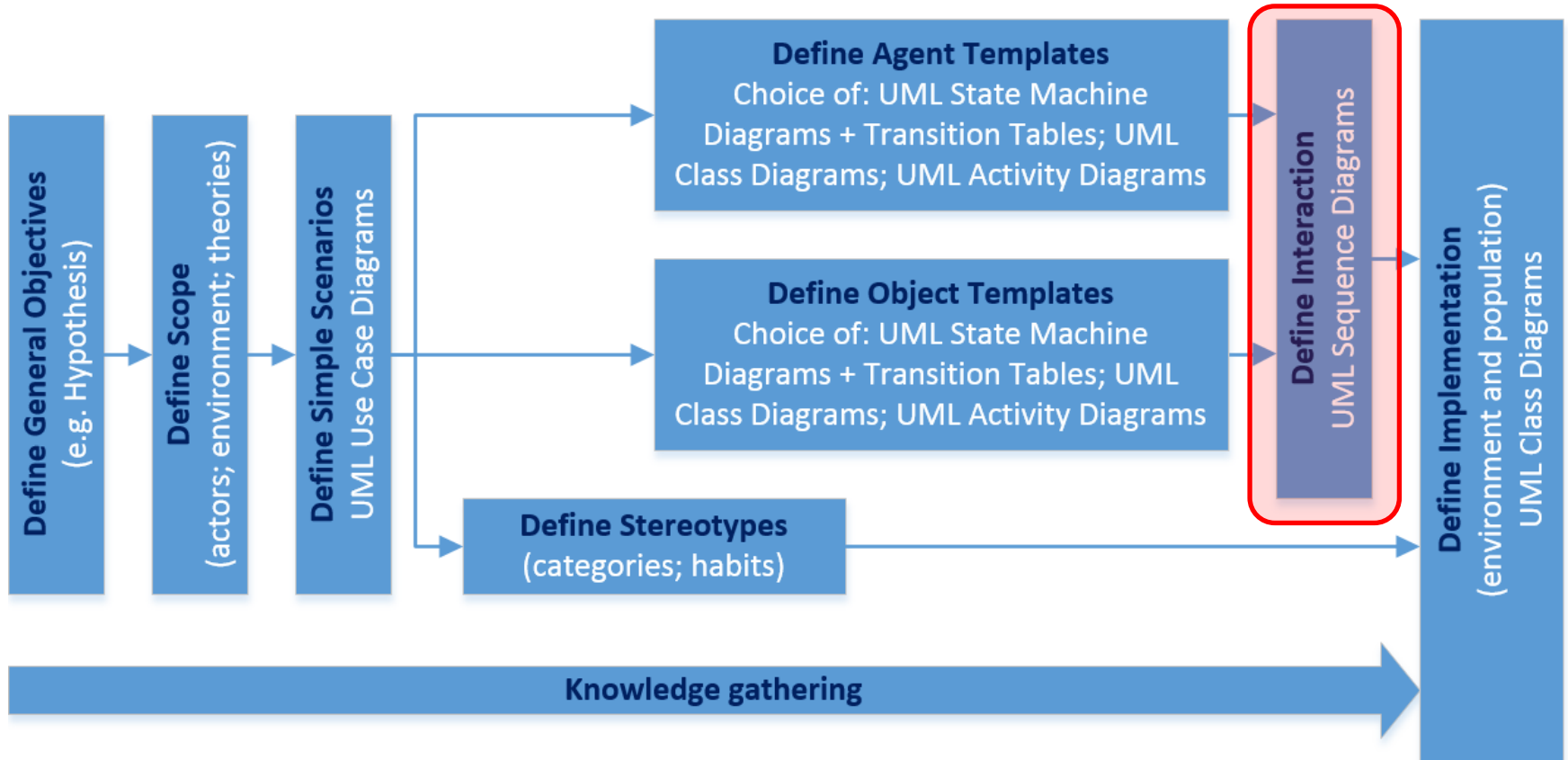
- Sometimes it is useful to have class definitions and diagrams
 - Individual classes
 - Represent key variables
 - State variables: e.g. Greenness of behaviour
 - Data collection variables: e.g. Energy consumption
 - ...
 - Define function signatures
 - Hierarchical structure
 - To represent inheritance (generalisation)
 - We could use this if we consider different types of users

Object Templates

- Light and Computer and Room state machines
 - These also require transition definition tables
 - It might also be useful to add class definitions and class diagrams here

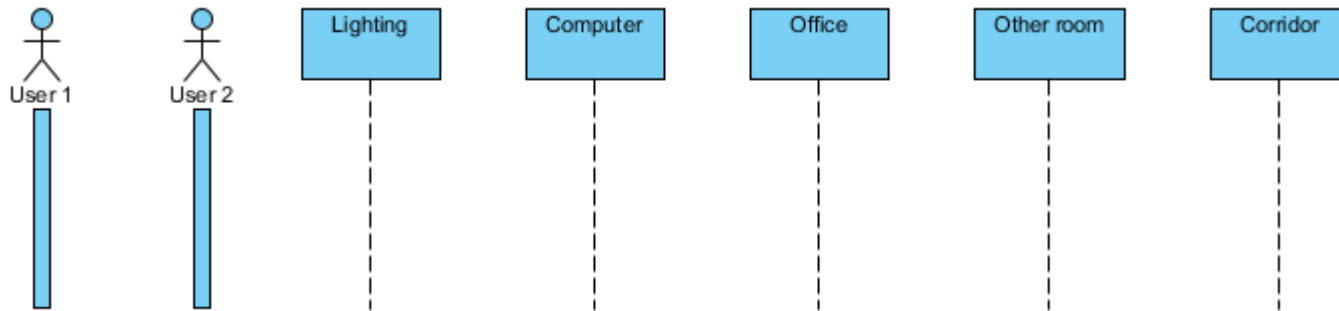


Framework



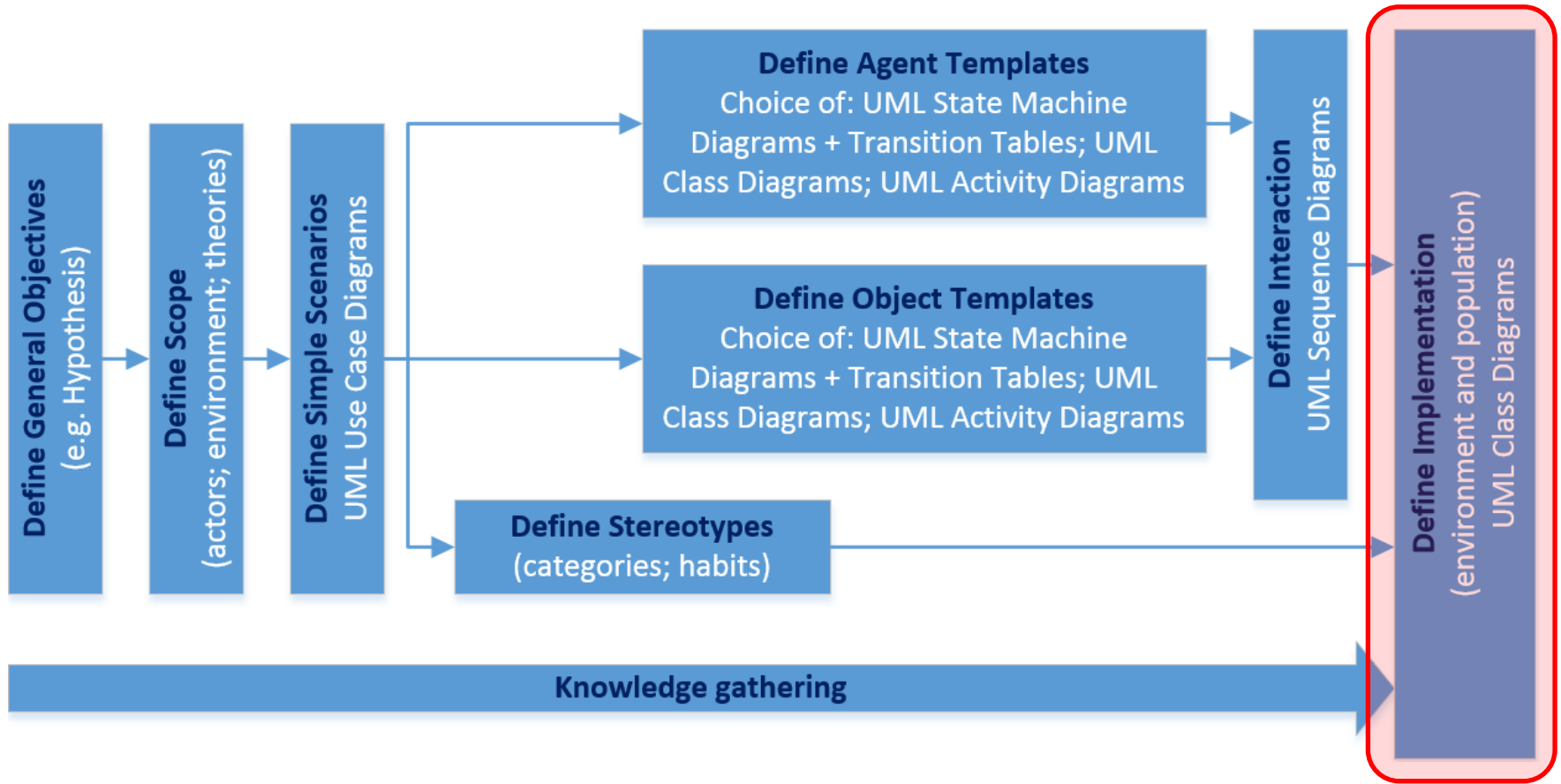
Interaction

- Consider communication between elements
 - Sequence diagram describes an interaction by focusing on the sequence of messages that are exchanged



This is still work in progress!
Your suggestions are welcome!

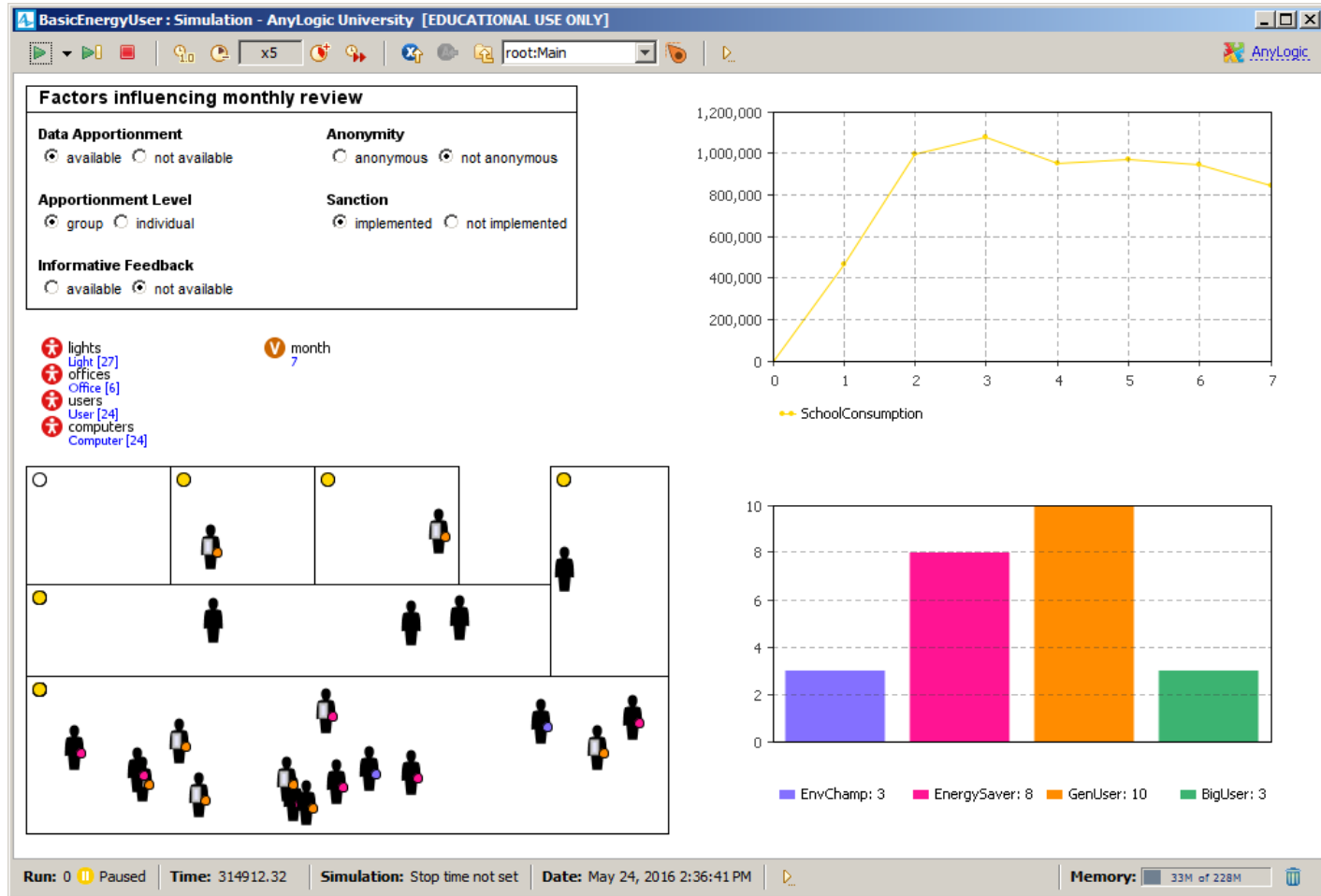
Framework



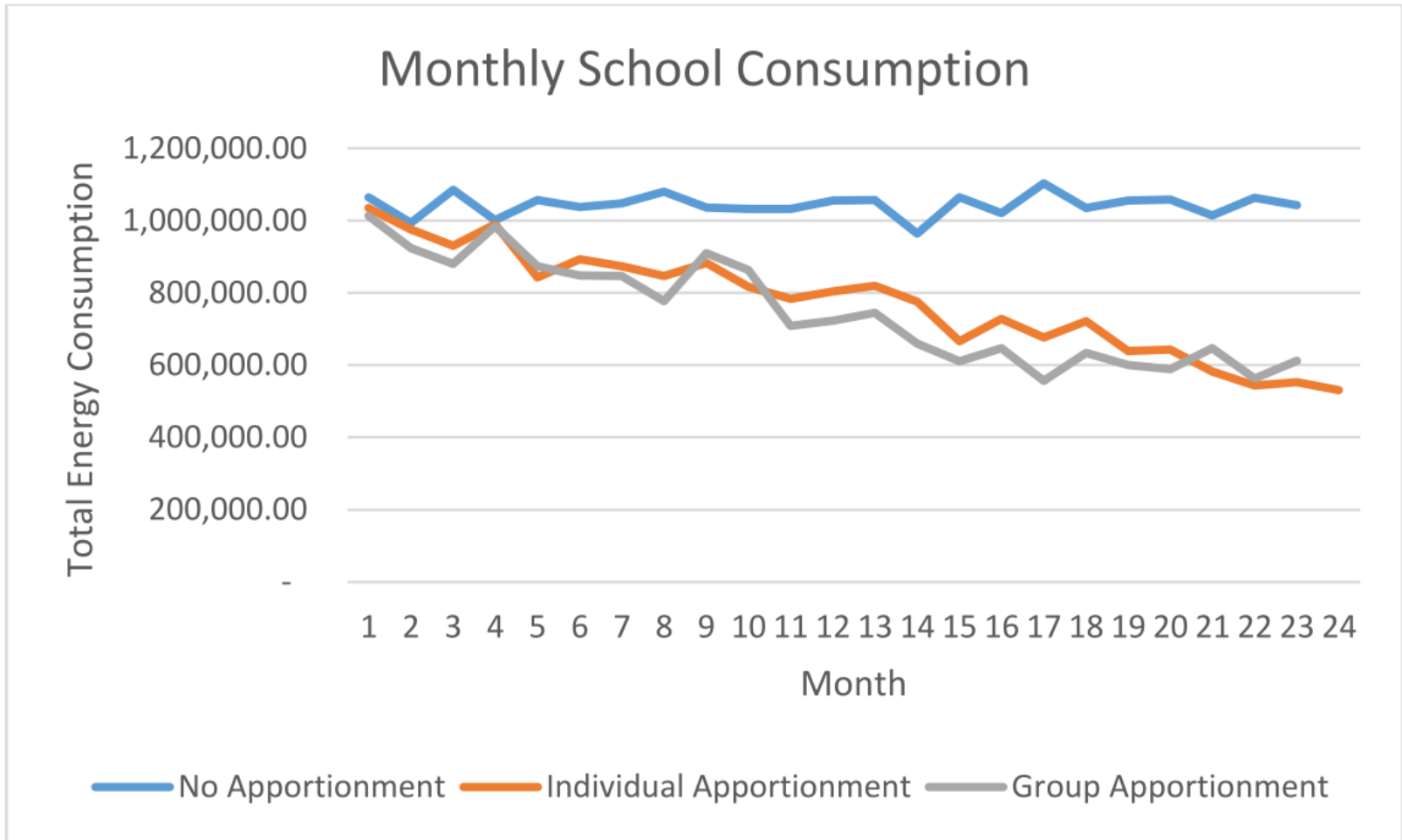
Implementation

- Using a class definition (equivalent to main class) for defining the environment and population
- Consider
 - Global variables (e.g. to collect statistics)
 - Compound variables that store agents and objects
 - General functions (signatures)

Simulation Model



Simulation Study



References

- Zhang, T., Siebers, P. O., & Aickelin, U. (2011). Modelling electricity consumption in office buildings: An agent based approach. *Energy and Buildings*, 43(10), 2882-2892., 43(10) pp. 2882-2892.
- Bedwell, B., Leygue, C., Goulden, M., McAuley, D., Colley, J., Ferguson, E., ... & Spence, A. (2014). Apportioning energy consumption in the workplace: a review of issues in using metering data to motivate staff to save energy. *Technology Analysis & Strategic Management*, 26(10), 1196-1211.