(Cognitive) Agents for Social Simulation

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Virginia Dignum

Delft University of Technology

The Netherlands

TU Delft

Main issues

- ABM or MAS?
- Social simulation
- Approaches to simulation
- Rich Cognitive Models
- Examples
  - Smoking
  - Village economics

Firstly

- Many different interpretations of Agent Systems:
  - Disciplines: AI, Robotics, Complexity Science, Economics, Social Science
  - Each discipline has its own understanding of what constitutes an agent and a multi agent system
- Two main paradigms:
  - Multi-agent systems
    - Focus is on planning, coordination, action
    - MAS are operative (prescriptive); used to **develop** systems
  - Agent-based simulation systems
    - model to simulate some real-world domain and recreate some real world phenomena
    - MAS are descriptive; used to **analyze** systems

Social System:

- Complex interaction of
- a high number of
- complex actors.

Social systems and social policies

- Anti-smoking ban:
  - Aim: Healthy (work) environment
  - Result? Less bar revenues, civil disobedience
- VAT increases
  - Aim: More state revenues
  - Result? more black market, less revenues
- Higher fines on motorway speeding
  - Aim: Safer roads
  - Result? Massive violation, ‘jammed’ courts

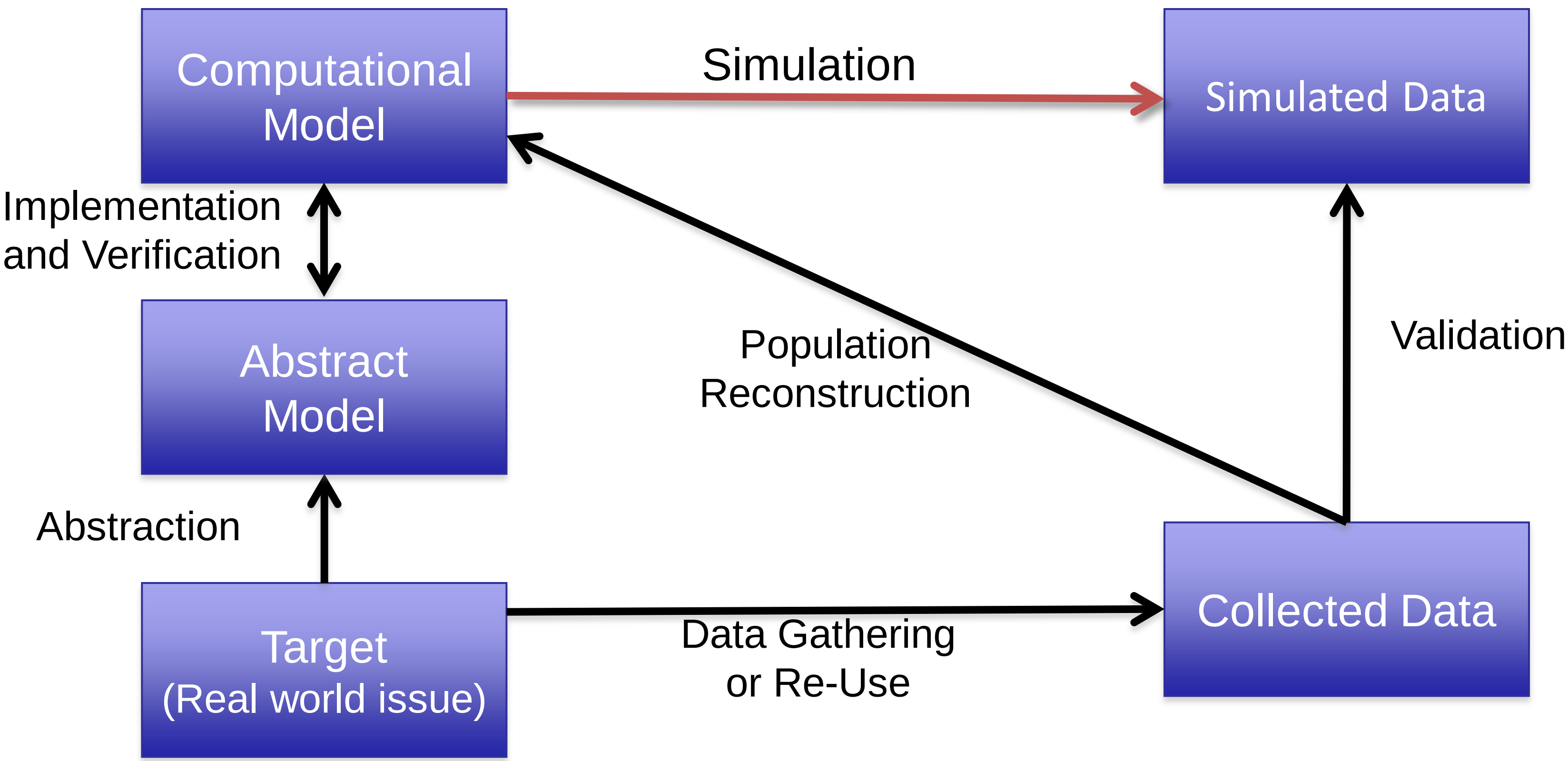
Why social simulation?

- Simulation can describe, predict, and explain (human) behaviour
- Complex
  - Behaviour of society depends on individual behaviour
  - Policy is planned at global / macro-level
  - Change is initiated at individual / micro-level
- Unpredictable
  - Ongoing dynamics of the environment
  - Context sensitive
  - Patterns of influence: macro influences micro influences macro influences…

Issues on social simulation

- Not all behaviour follows rational/economic rules
- Culture, context, social networks influences
- Models of human behaviour are needed for more realistic social interactions
  – Taking in individual differences
    - Follower vs. leader / Thinker vs. doer
    - Long term vs. short term / Individualism vs. collectivism
    - …
  – Taking in social context
    - What do my neighbours? Opinion makers…
    - You influence me, I influence you, you influence me…

Simulation as a Method



Adapted from Gilbert & Troitzsch

Classification of Simulation

- Static vs. Dynamic:
  - Static: No attempts to model a time sequence of changes.
  - Dynamic: Updating each entity at each occurring event.
- Deterministic vs. Stochastic:
  - Deterministic: Rule based.
  - Stochastic: Based on conditional probabilities.
- Discrete vs. Continuous:
  - Discrete: Changes in the state of the system occur instantaneously at random points in time as a result of the occurrence of discrete events.
  - Continuous: Changes of the state of the system occur continuously over time.

Paradigms

- System Dynamics
  - Modelling: Causal loop diagrams
  - Simulation: Deterministic continuous (differential equations)
- Discrete Event Modelling and Simulation
  - Modelling: Flow charts
  - Simulation: Stochastic discrete (flow oriented approach)
- Agent Based Modelling and Simulation
  - Modelling: Agent behaviors
  - Simulation: Stochastic discrete
- Mixed Methods

Classification of paradigms

- System Dynamics Simulation
  – (continuous, deterministic)
  – Aggregate view; differential equations
- Discrete Event Simulation
  – (discrete, stochastic)
  – Process oriented (top down); one thread of control; passive objects
- Agent Based Simulation
  – (discrete, stochastic)
  – Individual centric (bottom up); each agent has its own thread of control; active objects
- Mixed Methods

Agent-Based Modelling

- 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 pro-active actors, such as human-centred systems.

When use Agent-Based Modelling?

- Simulating interactions between dynamic populations in changing environments
- Heterogeneous populations – each individual has specific attributes such as age, gender, socio-economic status, health, etc.
- Stochastic process – each run can differ from previous
- Notion of emergence – larger-scale phenomena produced through many small interactions / events
- Sets of simple rules produce complex behaviour – sets can be large…
- Can help model and analyse phenomena too complex for closed form, can be used in absence of knowledge about causality

Agents in ABM

- The agents can represent individuals, households, organisations, companies, nations, … depending on the application.
- 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.

emergence

Emergence

- Emergence
  - Emergent phenomena result from the interactions of individual entities. The whole is more than the sum of its parts because of the interactions between the parts.
- An emergent phenomenon can have properties that are decoupled from the properties of the part.
  - Example: Traffic Jam Dynamics

Agent-Based Model of Decision Making

- Each individual decision maker is represented through a set of behavior rules that link its interpretation of environment to a decision
- Decisions depend on the agent's physical environment (the landscape), on its past, on its 'personality', on its background and social network,…
- Decisions also depend on what other agents do as well

ABM Engineering

- Building an ABS model
  - Identify active entities (agents)
  - Define their states and behaviour
  - Put them in an environment
  - Establish connections
  - Test the model
- Validating an ABS model
  - System behaviour is an emergent property
  - Validation on a micro level
  - How to validate on macro level ?

When to use ABM?

- When the problem has a natural representation as agents – when the goal is modelling the behaviours of individuals in a diverse population
- When agents have relationships with other agents, especially dynamic relationships - agent relationships form and dissipate, e.g., structured contact, social networks
- When it is important that individual agents have spatial or geo-spatial aspects to their behaviours (e.g., agents move over a landscape)
- When it is important that agents learn or adapt, or populations adapt
- When agents engage in strategic behaviour, and anticipate other agents' reactions when making their decisions
- ...

But also ....

Explanation and Feedback!

[Siebers et al. 2010]

ABM examples

- NetLogo (Biology): Flocking
  - http://ccl.northwestern.edu/netlogo/models/Flocking
- NetLogo (Social Science): Party
  - http://ccl.northwestern.edu/netlogo/models/Party
- NetLogo (Social Science): Traffic Basic
  - http://ccl.northwestern.edu/netlogo/models/TrafficBasic
- Netlogo (Social Science): Urban Dynamics
  - http://ccl.northwestern.edu/netlogo/models/UrbanSuite-EconomicDisparity

ABM software

- Rapid growth over last 10 years
- Free:
  - Swarm, NetLogo, Repast, SeSAm, Mason, ...
- Commercial
  - AgentSheets, AnyLogic, ...
- For a comprehensive list see
  - http://www.swarm.org/wiki/Tools_for_Agent-Based_Modelling

Levels of simulation / models

- Macro-level
  - Shows the global result of agents’ behavior
  - Used to measure policy effect
  - Averages over behaviour of individuals
- Micro-level
  - Allows variation in behaviours
  - Represents personal circumstances
  - Analysis of behavior require rich cognitive models
    - Personality
    - Cultural differences
    - Social circles

Macro models: societies

- Model interactions
- Focus on economical models
- Assumes (one only) rational agent type with low complexity
- Benchmark macro model: to check validity of average agent behaviour

- But…
  - Not all behaviour follows rational/economic rules
  - Models of human behaviour are needed for more realistic social interactions

Micro models: Agents

- Model individual decision making
- Represent the impact of the social on the individuals and what impacts on the social level
- Human behaviour as a conjunction of
  - Reasoning (decision-making)
  - Emotions
  - Personality
  - Personal values (cultural background, ethical or moral beliefs etc.)

- But…
  - Scalability!
  - Global behaviour is more than ‘sum’ of individual behaviours

Where to start

- The dual problem of the micro-macro relation:

a) FROM MICRO TO MACRO: Find the aggregate implications of given individual behaviors

b) FROM MACRO TO MICRO: Find the conditions at the micro level that give raise to some observed macro phenomena

Elements of rich agent models

- Rational: Goal-directed
- Social: Culture, organisation and norms
- Personality: Individual differences/reasoning models
- Physiological: Hierarchy of needs/urges
- Emotional: reaction to a perceived situation

- Resulting behaviour
  - Perceived social environment
  - Possible worlds foreseen
  - Emotions and goals drive decision making and perception of current state

The agent's mind

- Integration of the different aspects
- Altruistic vs. egoistic agents
  - Social goals and expectations before individual goals
- Law abiding agents
  - Always follow the norm or deal with violation
- Functional vs. emotional
  - Consider achievement, failure, motives…
- …

Personality (MBTI)

1. Introvert vs. Extravert
2. Intuition vs. Sensing (perception)
3. Thinking vs. Feeling (judgement)
4. Judging vs. Perceiving

- Intuitive → "do what is right"
- Sensing → "do what others do"
- Thinking → "follow norm if important for society"
- Feeling → "follow norm if group profits"

Culture (Hofstede)

1. Uncertainty Avoidance Index (UAI)
2. Individualism (IDV)
3. Power Distance Index (PDI)
4. Masculinity
5. Long term vs. Short term directed

- Collective $\rightarrow$ “follow norm”
- Individualistic $\rightarrow$ “depend on personality”
- Long term $\rightarrow$ “follow norm”
- Short term $\rightarrow$ “follow interest”

Influence of culture

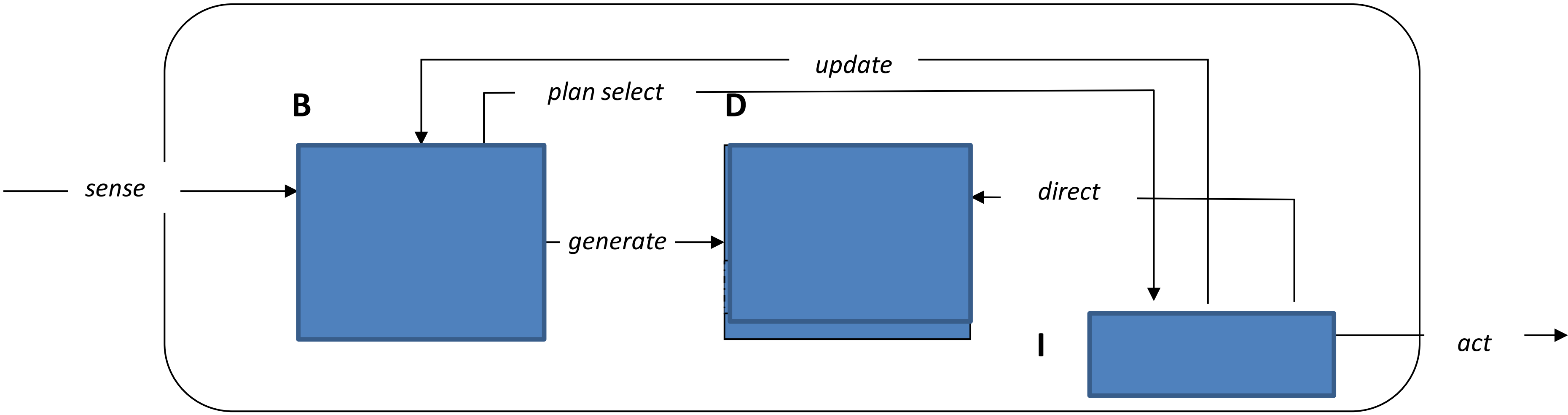
- Culture modifies parameter values in the decision functions
- Describe culture based on Hofstede's five dimensions of national cultures
- Relational attributes have different significance in different cultures:
  - Group distance
  - Status difference
  - Interpersonal trust

Organisation/Norm-aware agents

- Level of normative reasoning
  - Low:
    - Take norms as constraints
    - Social archetype / Role is blueprint for agent
  - High:
    - Able to decide on norm adoption based on goals, culture, personality
    - Rich cognitive model enrich role enactment

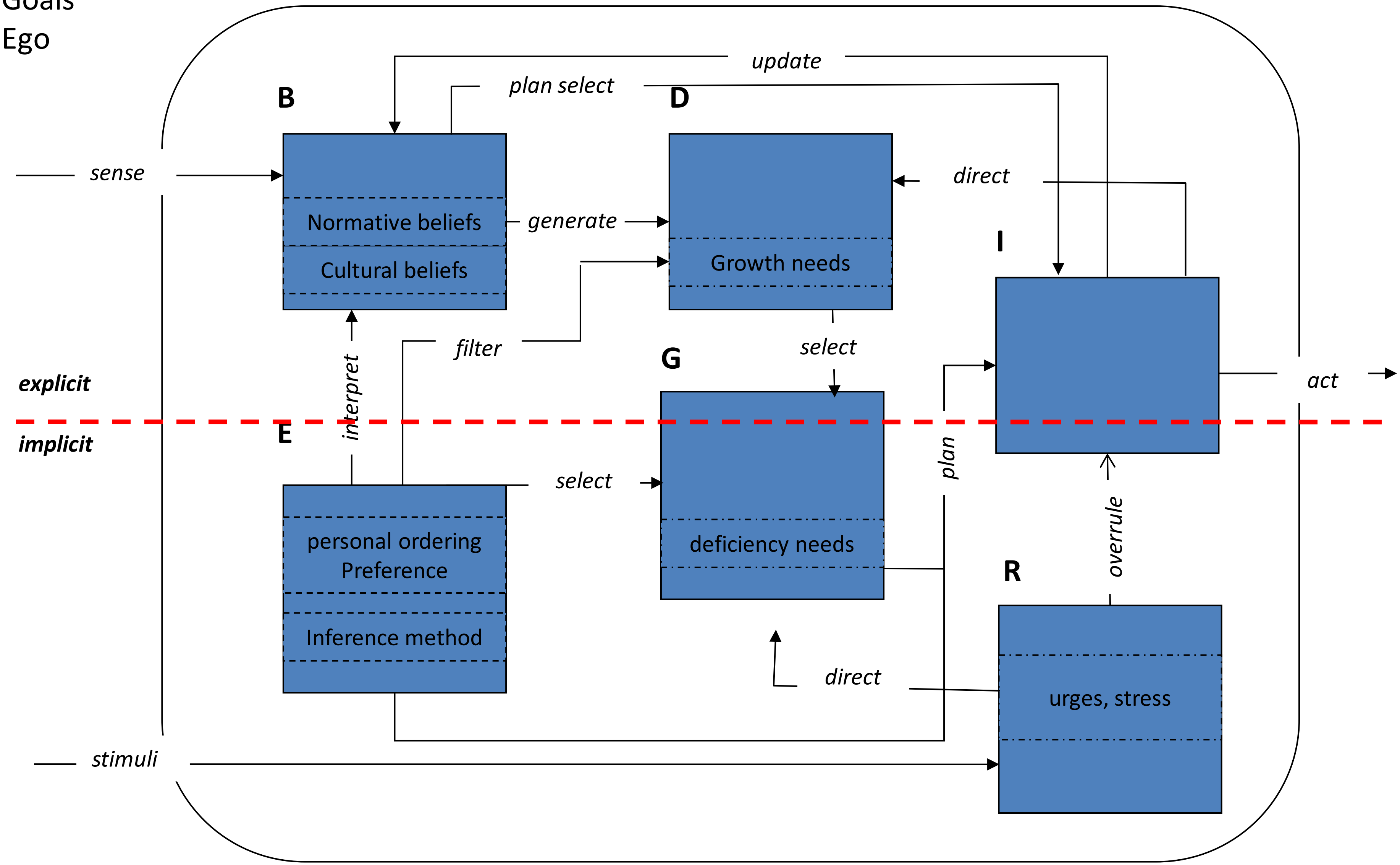
Beliefs
Desires
Intentions

Extending BDI

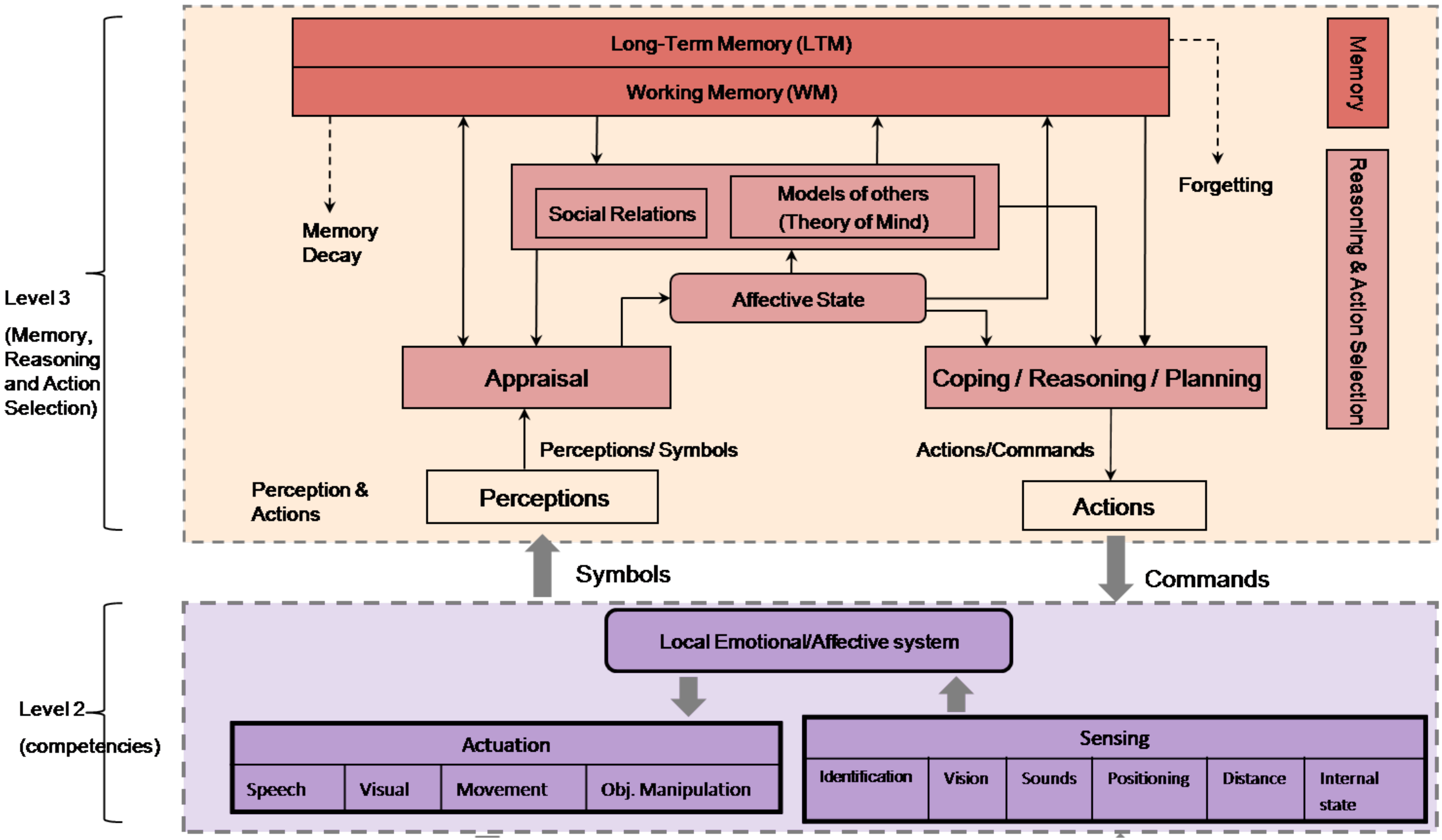


Beliefs
Response
Intentions
Desires
Goals
Ego

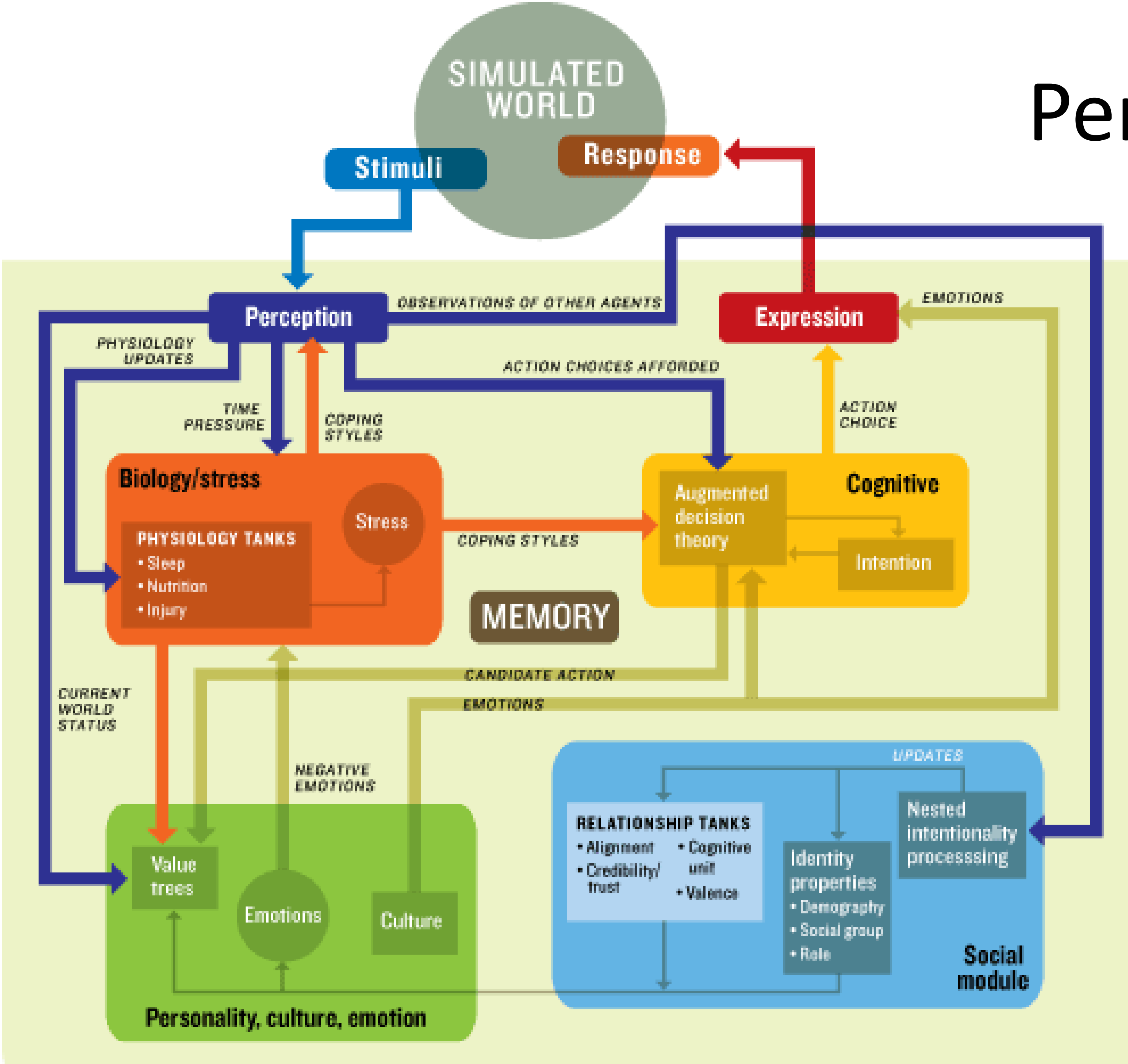
The BRIDGE architecture



Emotional Architecture used in Lirec



Perm-sf

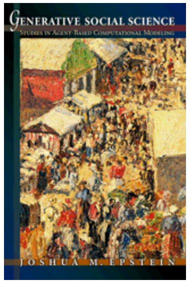

SIMULATED WORLD
Stimuli
Response
Perception
OBSERVATIONS OF OTHER AGENTS
Expression
EMOTIONS
PHYSIOLOGY UPDATES
ACTION CHOICES AFFORDED
TIME PRESSURE
COPING STYLES
ACTION CHOICE
Biology/stress
Stress
PHYSIOLOGY TANKS
• Sleep
• Nutrition
• Injury
COPING STYLES
Augmented decision theory
Cognitive
Intention
MEMORY
CANDIDATE ACTION
EMOTIONS
CURRENT WORLD STATUS
NEGATIVE EMOTIONS
UPDATES
RELATIONSHIP TANKS
• Alignment
• Credibility/ trust
• Cognitive unit
• Valence
Identity properties
• Demography
• Social group
• Role
Nested intentionality processing
Social module
Value trees
Emotions
Culture
Personality, culture, emotion

Main issues

- ABM or MAS?
- Approaches to simulation
- Social simulation
- Rich Cognitive Models

Further reading

- Social Simulation:
  - Nigel Gilbert and Klaus G. Troitzsch:
    Simulation for the Social Scientist
    (cress.soc.surrey.ac.uk/s4ss/)
  - Joshua M. Epstein
    Generative Social Science:
    Studies in Agent-Based Computational Modeling
    (http://press.princeton.edu/titles/8277.html)



- ABM:
  - Bonabeau (2002). Agent-based modeling: Methods and techniques for simulating human systems. In: Proceedings of the National Academy of Science of the USA. 99:7280-7287.
  - Macal and North (2007). Agent-based modeling and simulation: Desktop ABMS. In: Henderson et al. (Eds.). Proceedings of the 2007 Winter Simulation Conference. Washington DC.
  - Shannon (1975). Systems simulation: The art and science. Prentice-Hall: Englewood Cliffs, NJ.
  - Siebers and Aickelin (2008) Introduction to multi-agent simulation. In: Adam and Humphreys (Eds.). Encyclopedia of Decision Making and Decision Support Technologies, Pennsylvania: Idea Group Publishing, pp 554-564.
  - Siebers et al. (2010). Discrete-event simulation is dead, long live agent-based simulation! Journal of Simulation, 4(3) pp. 204-210.

APPLICATIONS

Case study: smoking ban

- Formal smoking prohibitions for cafes and restaurants.
- Underlying values: freedom, autonomy, health, care for others.

- Introduced a.o. in Ireland (2004), Netherlands (2008)

- Empirical results of introduction smoking ban in IRL and NL:
  - compliance in Ireland drastically higher than in NL.
  - Vastly violated after introduction in some countries (like NL!)

- Can we explain violation in terms of different cultures / individual preferences ?

Simulation setup

- Agents:
  - Have a fixed private preference towards whether smoking should be allowed in bar
  - a preference for
    - Following the law (deontic norm)
    - Being social (social norm)
    - Keeping own values (private norm)

- Environment:
  - Variable bar population (people come and leave)
  - Majority present in bar determines current social norm
  - Half way law is introduced:
    - lawful agents change with law introduction

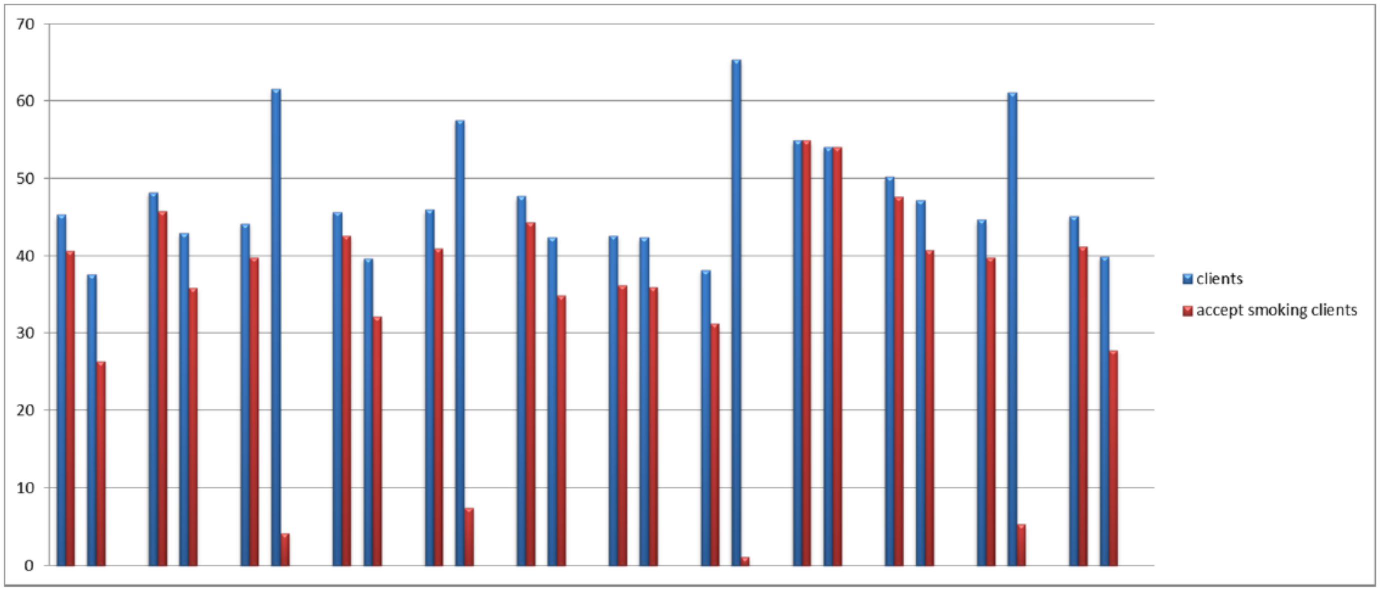
- Hofstede's four cultural dimensions
  - Power Distance Index (PDI) ~ ↑ legal ↓ social, private
  - Individualism (IDV) ~ ↑ private ↓ social
  - Masculinity Index (MAS) ~ ↑ private ↓ social
  - Uncertainty Avoidance Index (UAI) ~ ↑ legal ↓ private

- (Disclaimer: connection speculative, to be researched!)

- Compliance in Ireland higher than in NL: can we explain?

	PDI	IDV	MAS	UAI
IRL	22	65	62	30
NL	38	80	14	53

Simulation results



Population Composition	B A	B A	B A	B A	B A	B A	B A	B A	B A	B A	B A	B A	
	50	30	60	30	70	20	0	100	0	20	60	50	% deontic agents
	30	50	30	60	20	70	0	0	100	60	20	50	% social agents
	20	20	10	10	10	10	100	0	0	20	20	0	% provate agents

Example 2: Reorganisation

1. Identify match of organization structure to environment characteristics
2. Adaptation to (drastic) changes
   - Structural vs. behavioral
   - Role-directed vs. collaborative
3. Communication requirements to reason about change
   - Also, reasoning with limited knowledge

Simulation Aims - 1

- Agent behavior depends on
  - Own state and environment state
  - But also on the organizational structure
  - Organizational structure is thus not just a component of the environment
- Organizational elements considered:
  - Type of goal (simple to complex)
  - Roles (many agents, one agent)
  - Interactions (communication protocols, dole dependencies)

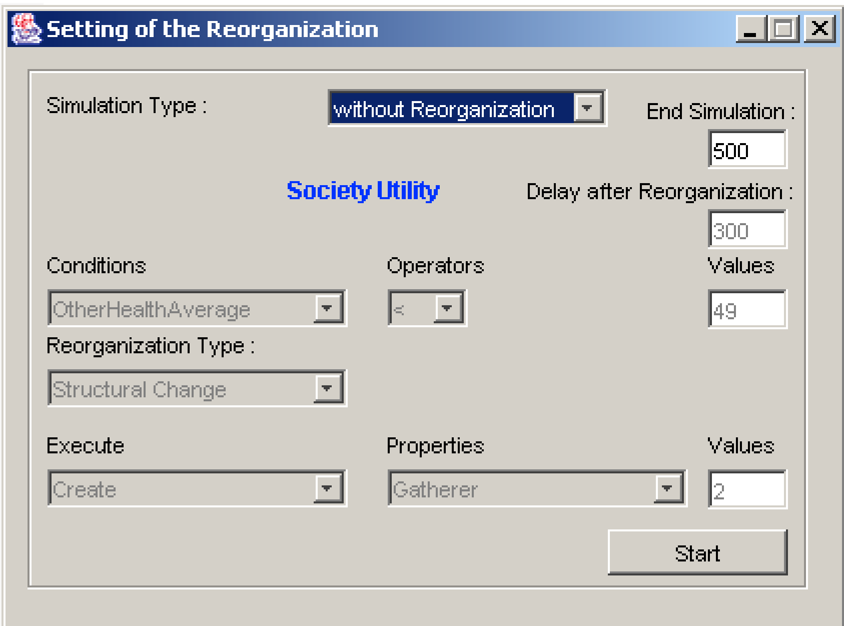
The VILLA environment

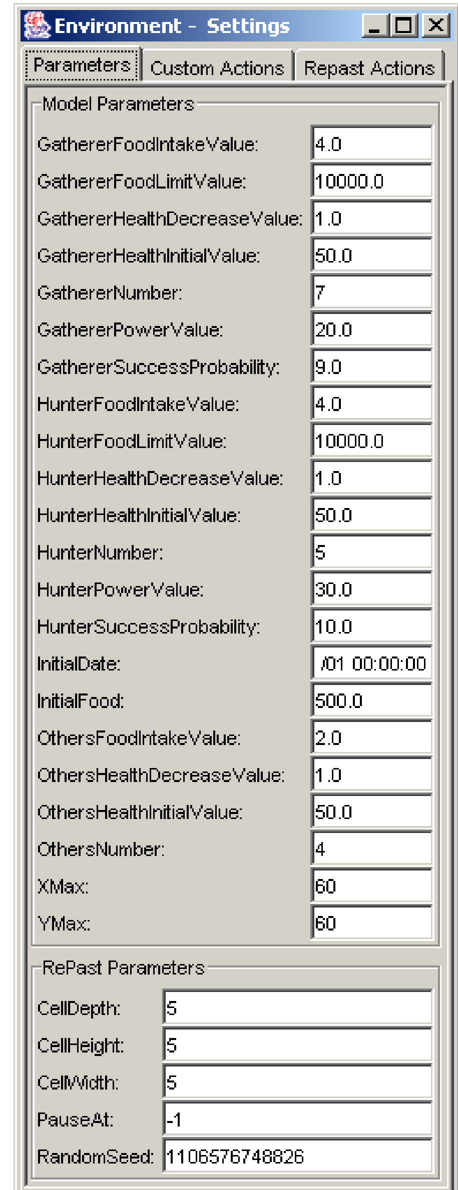
- Aim: community survival
- Creatures
  - Gatherers: can collect (limited) food individually
  - Hunters: can hunt (large amounts of) food in groups
  - Others: consume food, can grow to become Gatherers or Hunters
  - *Chief: observe and change society*

VILLA: Activities

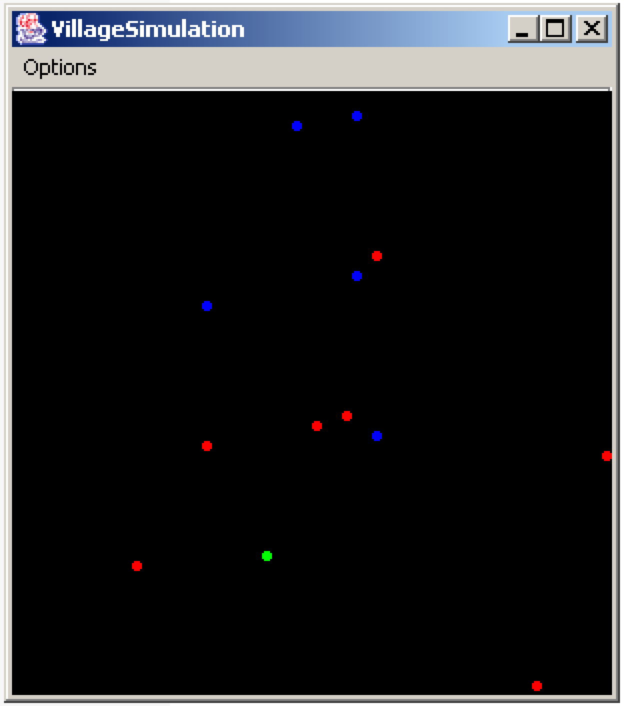
- Simulation takes a number of runs (days)
- In each run:
  - Eat
    - If food available
    - Collectors eat more than others
    - If not eat, health decreases
    - If health = 0, then creature dies
  - Collect
    - Gatherers: individual function on health
    - Hunters: groups’ function on health and size
  - Move
    - Hunters must move to form group

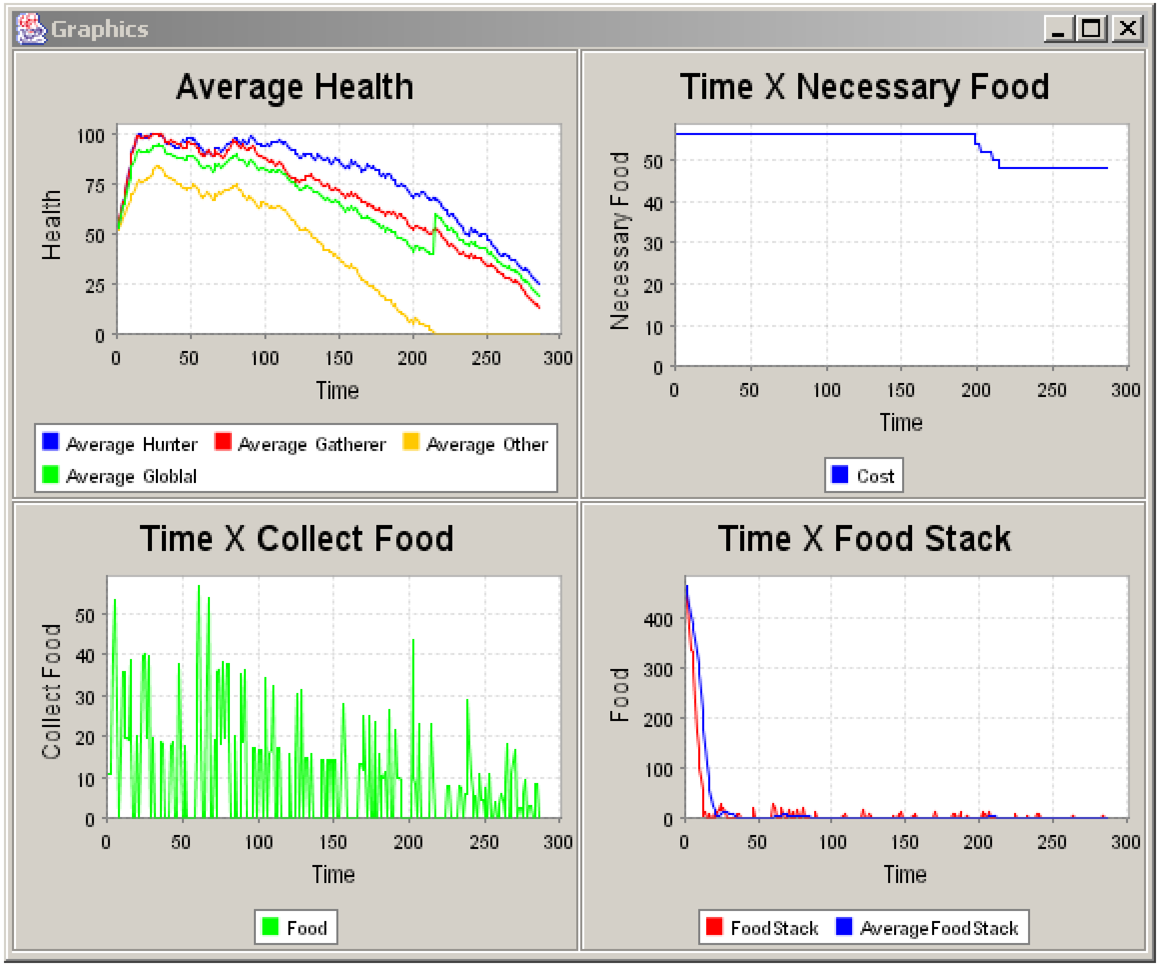
VILLA setup


Setting of the Reorganization
Simulation Type :
without Reorganization
End Simulation :
500
Society Utility
Delay after Reorganization :
300
Conditions
Operators
Values
OtherHealthAverage
<
49
Reorganization Type :
Structural Change
Execute
Properties
Values
Create
Gatherer
2
Start


Environment - Settings
Parameters
Custom Actions
Repast Actions
Model Parameters
GathererFoodIntakeValue:
4.0
GathererFoodLimitValue:
10000.0
GathererHealthDecreaseValue:
1.0
GathererHealthInitialValue:
50.0
GathererNumber:
7
GathererPowerValue:
20.0
GathererSuccessProbability:
9.0
HunterFoodIntakeValue:
4.0
HunterFoodLimitValue:
10000.0
HunterHealthDecreaseValue:
1.0
HunterHealthInitialValue:
50.0
HunterNumber:
5
HunterPowerValue:
30.0
HunterSuccessProbability:
10.0
InitialDate:
/01 00:00:00
InitialFood:
500.0
OthersFoodIntakeValue:
2.0
OthersHealthDecreaseValue:
1.0
OthersHealthInitialValue:
50.0
OthersNumber:
4
XMax:
60
YMax:
60
RePast Parameters
CellDepth:
5
CellHeight:
5
CellWidth:
5
PauseAt:
-1
RandomSeed:
1106576748826

VILLA without reorganization





Evaluation of VILLA

- Influences on health:
  - Role typology
  - Role capabilities
- Results from evaluation of non reorganization situation:
  - Food stack decreases a lot at beginning
  - Need to introduce delay in adaptation
  - Others average health seems to be good indicator for reorganization
  - Need to evaluate time interval, not time point

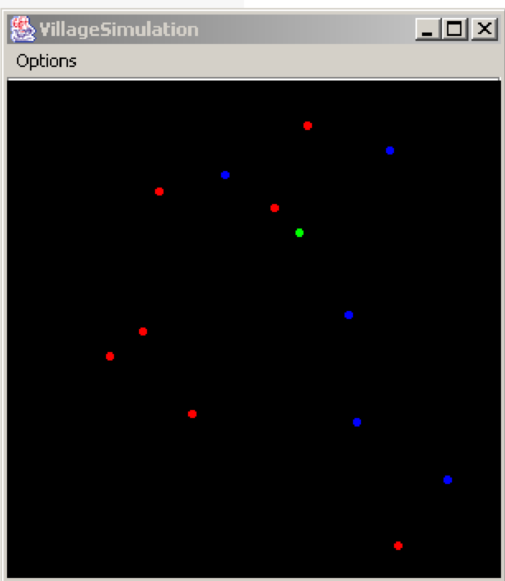
Evaluation of VILLA (parameter space)

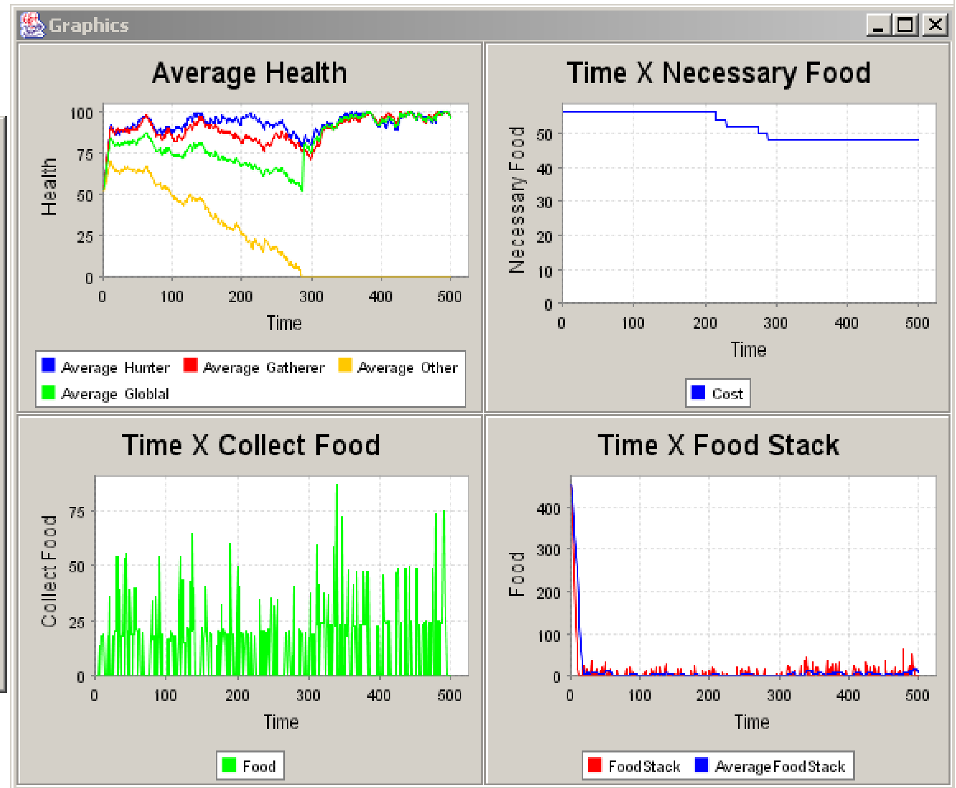
G	H	O	Comments
17	0	0	Gatherers survive with 100% of health.
6	11	0	All creatures die because amount of food is not sufficient to keep a good health level.
0	9	8	All creatures die. Only in cases when the hunters get together very early some creatures survive. Hunters keep others alive if food stack is very high (more than 10000)
0	17	0	All creatures survive more than 100 TICs. However, food stack must be 900 to allow Hunters to get together within 500 ticks.
9	8	0	Very good society but depends on the probability of Hunters to get together.
8	5	4	Stable society with health 80%. However some Others will die.
8	6	3	Stable society with health 80%. However some Others will die.
8	6	2	Good and stable society with health greater than 80%
7	5	4	All creatures die
7	7	3	All creatures die
7	3	7	All creatures die
9	5	3	Very good society
9	6	2	Good society
9	7	1	Very good society with health 95% but instable if Hunters are isolated.
6	10	1	Very good society with health in 95% but instable if Hunters are isolated.
5	11	1	Very good society with health in 95% but instable if Hunters are isolated.
4	11	2	Good society but very instable if Hunters are isolated.
3	11	3	Good society but very instable if Hunters are isolated.

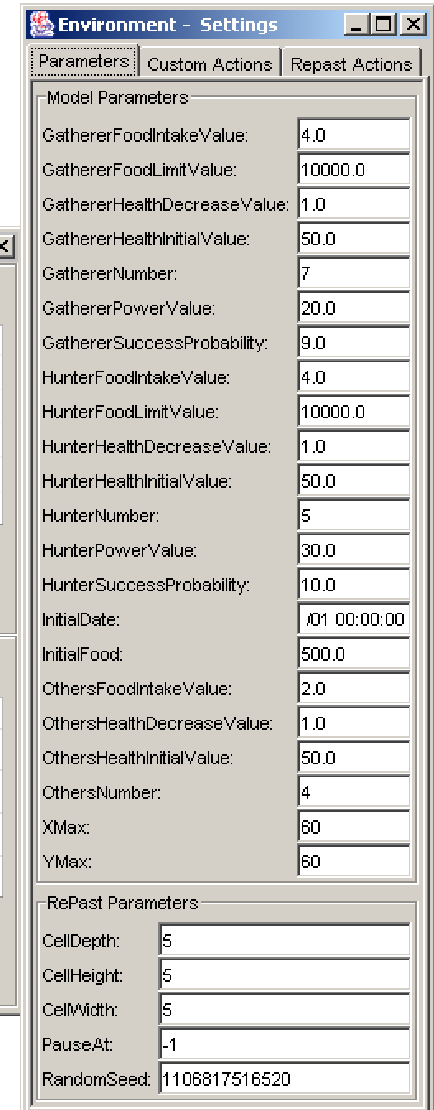
G	H	O	Prob. Gather	Prob. Hunter	Comments
9	5	3	9	10	Instable Society, depending on hunters' aggregation.
9	6	2	9	10	Instable Society, depending on hunters' aggregation.
9	5	3	15	18	Stable society independent of hunters aggregation. Reach 100% and food stack increase.
9	6	2	15	18	Stable society independent of hunters aggregation. Reach 100% and food stack increase.
9	0	8	15	18	Stable society independent of hunters aggregation. Reach 100% and food stack increase.
5	0	12	15	18	Minimum number of gatherers for supporting other life.
0	17	0	15	18	With the increasing of prob. Hunters always still alive and keep society good
8	5	4	15	18	Health society before was 80% now 100%.
7	7	3	15	18	Stable society independent of hunters aggregation. Reach 100% and food stack increase.
7	6	4	15	18	100% “
7	5	5	15	18	100% ”
7	5	5	18	20	100%

Reorganizing Societies

- Behavioral change:
  - If food stack < 250, increase gather power by 1
  - Reorganization delay is 100







Reorganizing Societies

- Structural change:
  - If food stack < 250, create 1 gatherer (from Others)
  - Reorganization delay is 100