(Cognitive) Agents for Social Simulation

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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 a 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 geospatial 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
- ...

[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 → “follow norm”
• Individualistic → “depend on personality”
• Long term → “follow norm”
• Short term → “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
Extending BDI

Beliefs
Desires
Intentions

sense

B

plan select

generate

D

update

direct

I

act
The BRIDGE architecture

Beliefs
Response
Intentions
Desires
Goals
Ego

Beliefs
Response
Intentions
Desires
Goals
Ego

stimuli

explicit

implicit

sense

act

plan select

update

direct

overrule

urges, stress

deficiency needs

select

select

interpret

filter

plan

generate

B
Normative beliefs
Cultural beliefs

D
Growth needs

G
deficiency needs

personal ordering Preference
Inference method

E

I

R

The BRIDGE architecture
Emotional Architecture used in Lirec

Level 3
(Memory, Reasoning and Action Selection)

Level 2
(competencies)

Local Emotional/Affective system

Actuation
Speech Visual Movement Obj. Manipulation

Sensing
Identification Vision Sounds Positioning Distance Internal state

Memory
Reasoning & Action Selection

Forgetting
Perm-sf
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/)

• **ABM:**
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?

<table>
<thead>
<tr>
<th></th>
<th>PDI</th>
<th>IDV</th>
<th>MAS</th>
<th>UAI</th>
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<tr>
<td>IRL</td>
<td>22</td>
<td>65</td>
<td>62</td>
<td>30</td>
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<tr>
<td>NL</td>
<td>38</td>
<td>80</td>
<td>14</td>
<td>53</td>
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</table>
Simulation results

![Graph showing simulation results with population composition and accept smoking clients.]

- Bar chart with two sets of bars: clients and accept smoking clients.
- Composition population data:
  - 50 30 60 30 70 20 0 100 0 20 60 50
  - 30 50 30 60 20 70 0 0 100 60 20 50
  - 20 20 10 10 10 10 100 0 0 20 20 0
- Legends: clients, accept smoking clients.
- Notes: % deontic agents, % social agents, % private 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
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)

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<tr>
<td>17</td>
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<td>0</td>
<td>Gatherers survive with 100% of health.</td>
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<td>6</td>
<td>11</td>
<td>0</td>
<td>All creatures die because amount of food is not sufficient to keep a good health level.</td>
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<tr>
<td>0</td>
<td>9</td>
<td>8</td>
<td>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)</td>
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<tr>
<td>0</td>
<td>17</td>
<td>0</td>
<td>All creatures survive more than 100 TICs. However, food stack must be 900 to allow Hunters to get together within 500 ticks.</td>
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<tr>
<td>9</td>
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<td>Very good society but depends on the probability of Hunters to get together.</td>
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<td>Stable society with health 80%. However some Others will die.</td>
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<td>Stable society with health 80%. However some Others will die.</td>
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<td>Good and stable society with health greater than 80%</td>
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<td>Very good society with health 95% but instable if Hunters are isolated.</td>
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<td>Very good society with health in 95% but instable if Hunters are isolated.</td>
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<td>5</td>
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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