Agent-based modelling of pedestrian behaviour: modelling for nano-simulations

Prof. Dr. Sabine Timpf
Department of Geography
University of Augsburg

University of Augsburg

- 7 faculties
- ~22'000 students
- ~4'000 staff, including scientific, technical and administrative personnel
- founded in 1970
- 8th faculty of medicine in planning
Faculty of Applied Computer Science

- founded 2003

Geography

Computer Science

Seven faculties

The University of Augsburg provides the ideal conditions for completing a degree programme successfully and within a reasonable time frame. Ever since its foundation, the university has been committed to reform. Seven faculties have been established, each with long-term strategies for development and using the most up-to-date facilities available:

- Faculty of Business Administration and Economics (founded 1970)
- Faculty of Law (founded 1971)
- Faculty of Theology (founded 1971)
- Faculty of Philosophy and Social Sciences (founded 1972)
- Faculty of Philology and History (founded 1972)
- Faculty of Mathematics and Natural Sciences (founded 1981)
- Faculty of Applied Computer Science (founded 2003).

Interdisciplinary, practice-oriented, responsible

There are many areas in which the faculties work together closely. Interdisciplinary cooperation is a daily feature of research and teaching at the university, and new forms of teaching to intensify and accelerate learning are developed in each of the faculties. Where appropriate, the degree programmes are designed to be as practice-oriented as possible. The courses on offer come from the three main fields of research and teaching that determine the university's profile: cultural and social sciences, innovative technologies and teacher training. The curricula are designed to meet the high standards of academic excellence on the one hand combined with the practical needs of society and the economy on the other. The University of Augsburg takes its responsibilities seriously with regard to the ethical issues and social responsibilities that come with education and research. This is reflected in the university's motto: "Scientia et conscientia".

The journey to Bologna is complete

Significant changes have come about in the range of subjects and degrees on offer at the University of Augsburg in the last few years as part of the internationalisation of university studies ("Bologna Process"). For the start of the 2008/9 winter semester, all courses were converted into new bachelor's and master's degree courses. Tuition fees at the university cost 480 euros per semester.

Strongly integrated in the Elite Network of Bavaria

With its participation in eleven master's and post-graduate programmes, the University of Augsburg is a strong presence in the "Elite Network of Bavaria" (ENB). This network, initiated by the Bavarian Ministry of Education and Science, offers the opportunity of first-class academic education aimed at particularly gifted, highly motivated and enthusiastic students. These unusual, attractive degree programmes are available in a variety of different subjects. All of the elite courses are distinguished by cooperations with partner universities in Germany and abroad, and by intensive support from the academic staff.

Bachelor in Geoinformatics

- 3 year program, i.e. 6 semesters
- 180 credit points in total, 30 per semester
- per semester 800-900 hours of work time, i.e. full-time work

- special: study program is a collaboration between geography and computer science
- only Bachelor program in Geoinformatics in Bavaria

- content:
  - in-depth studies in geoinformatics
  - basics in computer science and mathematics
  - basics in geography
  - electives and applied project work
**Master in Geoinformatics**

- 2 year program, i.e. 4 semesters
- 120 credit points in total, 30 per semester
- full-time study

- only Masters program in Geoinformatics in Bavaria

- content focus on:
  - agent-based modelling and simulation
  - geovisualisation
  - location-based applications, way finding and navigation
  - electives and applied project work

<table>
<thead>
<tr>
<th>Semester 1</th>
<th>Semester 2</th>
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</thead>
<tbody>
<tr>
<td>Scientific Writing &amp; Science Theory</td>
<td>Geodata Analysis</td>
</tr>
<tr>
<td>Modelling &amp; Simulation</td>
<td>Software Engineering</td>
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<tr>
<td>Databases &amp; Information Systems</td>
<td>Remote Sensing</td>
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<table>
<thead>
<tr>
<th>Year 2</th>
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<tr>
<td>Semester 1</td>
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<tr>
<td>GI Project</td>
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<tr>
<td>Research Module</td>
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</table>

**Master in Geoinformatics**

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  - Agent-based modelling and simulation
  - Geovisualisation
  - Location-based applications, way finding and navigation
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Overview of the talk

- Modelling of geo-spatial behaviour
- Agent-based modelling and nano-simulations
- Geo-savvy agents
  - needed concepts
  - walking behaviour
- Conclusions

Motivation: Using a public transport system

- What information do you need to carry out a specific navigation task?
- What information are you provided with by the designed environment?
- Hypothesis: These two types of information need to overlap in order for navigation to be successful

Information needs

Information provision

- Need: Understand (better) how humans navigate in a specific environment, especially in PTS, to derive information needs

<table>
<thead>
<tr>
<th>Traveler</th>
<th>Designer</th>
</tr>
</thead>
<tbody>
<tr>
<td>Path</td>
<td>Network</td>
</tr>
<tr>
<td>Start/goal</td>
<td>Route with temporal information</td>
</tr>
<tr>
<td>Bus stop (name)</td>
<td>Bus stop (name)</td>
</tr>
<tr>
<td>Subway station (name)</td>
<td>Station (name), right-hand/left-hand</td>
</tr>
<tr>
<td>Connection</td>
<td>Connecting station</td>
</tr>
<tr>
<td>Transportation modes (name)</td>
<td>Transportation modes</td>
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<tr>
<td>Subway name, bus name</td>
<td>Subway lines, bus lines</td>
</tr>
<tr>
<td>Train type</td>
<td>Train type</td>
</tr>
<tr>
<td>Regular user</td>
<td>Regular user</td>
</tr>
<tr>
<td>Map</td>
<td>Map</td>
</tr>
<tr>
<td>Sign</td>
<td>Dynamic sign, sign</td>
</tr>
<tr>
<td>Street</td>
<td>Street</td>
</tr>
<tr>
<td>Direction</td>
<td>Direction/destination</td>
</tr>
<tr>
<td>Distance</td>
<td>Distance</td>
</tr>
<tr>
<td>Time</td>
<td>Time</td>
</tr>
<tr>
<td>Ticket</td>
<td>Ticket</td>
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</tbody>
</table>

Table 5: Comparison of concepts
Modelling geo-spatial behaviour

- as a means of verifying that we understand geo-spatial behaviour
- to derive spatio-temporal information needs
- to inform geo-design (e.g. signage, floor plans, ...)

For modelling we need knowledge about

- actions of humans
- interactions of humans with space
- interactions with each other
- in a rich (urban) environment
- a tool to provide us with the personal perspective

Agent-based modelling

- agents are representations of decision-makers with individual properties, action capabilities and environmental knowledge
- agent-based modelling is useful when
  - the whole situation to be modelled is made up of individual components (agents) that may change and learn over time
  - the underlying environment has its own set of changes
  - the patterns to detect depend on the interaction between (potentially changing) agents and (potentially changing) environments
- an agent-based model (ABM) is one of a class of computational models for simulating the actions and interactions of autonomous agents (both individual or collective entities such as organizations or groups) with a view to assessing their effects on the system as a whole
Nano-simulation

- Microsimulation relies on random numbers to generate vehicles/pedestrians, select routing decisions, and determine behaviour
  - it is heavily influenced by statistics
  - the moving objects/subjects do not engage in “thinking” and cannot be distinguished by personal preferences and abilities
  - behaviour is rational

- Nano-simulation
  - implements individual behaviour that may also be irrational
  - models individual agents with different spatial and cognitive abilities
  - incorporates reasoning about spatial objects, configurations and actions

Research goals

- analyse, model and simulate movement behaviour of
  - single persons,
  - groups of persons,
  - crowds
  - in planned spaces
  - with the minimal number of cognitive concepts
  - identify a small set of simple behaviours that are needed for interacting with the environment

geo-savvy agents
Geo-savvy agents

- agents immersed in geographic space, spaces, places (spatially explicit simulation)
- able to perceive surrounding (geo-)environment and reason about it
- able to move around in space and behave according to common sense
- able to carry out the intended activity
- able to interact with other agents
- able to communicate about space
- able to follow rules about spaces and people
- personal preferences and abilities

Geo-savvy agents: personal spaces

- E.T.Hall postulated at least four spaces around the human body:
  - intimate
  - personal
  - social
  - public

- Activity Footprints
  no implementation yet
Geo-savvy agents: Image schemata

- An image schema is a recurring structure within our cognitive processes which establishes patterns of understanding and reasoning.
- partitions space into different types of image schemata (Johnson 1987)
- produces a stratified part-of hierarchy of partitions of space
- represents general knowledge about an environment as well as functional specifics

**Description of Scene space using a schematic geometry**
Geo-savvy agents: Image schemata

- interpretation of a specific railway station (Enge, ZH)

- wayfinding means going from gateway to gateway (or from view to view)

- if the next gateway is determined, then the next action can also be chosen

**ODEON: a stage for schematic geometry**
Geo-savvy agents: Mental Maps

- Kevin Lynch: five perceptual structures of an urban environment used in mental maps
  - PATH
  - EDGE
  - DISTRICT
  - NODE
  - LANDMARK

- first step: storing information in a mental map
- second step: interpreting what is stored and tag the stored information
Fig. 3 Steps of the viewing process, from left to right: The first three images show how the seekers (blue: hatching, black: moving) move and the fourth one illustrates the footprints of the different seekers and the resulting field of vision.

Fig. 4 Placement of building turtles and links between the agent and the building turtles.

Geo-savvy agents: Affordances

- J.J. Gibson: affordances are what an object affords an animal, what it allows it to do
- depending on purpose (activity), affordances of an object can be quite different: e.g., a chair also affords standing on it
- different types of affordances:
  - social affordances
  - physical affordances
- Objects in a park afford specific activities:
Geo-savvy agents: Planning, instructing, moving

- goal directed locomotion
- exploratory locomotion
- wayfinding <-> locomotion

<table>
<thead>
<tr>
<th>Activity</th>
<th>get from A to B</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tasks</td>
<td>Plan, make survey</td>
</tr>
<tr>
<td>Operations</td>
<td>Find routes, determine constraints</td>
</tr>
</tbody>
</table>

Process
Geo-savvy agents: Planning, instructing, moving

- Different strategies for planning a route or path:
  - shortest path
  - least time path
  - simplest path
  - most scenic route
  - longest leg first
  - least angle

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<tr>
<th></th>
<th>mittl. Distanz in m</th>
<th>Abweichung in %</th>
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</thead>
<tbody>
<tr>
<td>Shortest Path</td>
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<td>-</td>
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<tr>
<td>Least Time Path</td>
<td>23919,40</td>
<td>5,5</td>
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<tr>
<td>Simplest Path</td>
<td>30108,86</td>
<td>32,8</td>
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<tr>
<td>Most Scenic Routes</td>
<td>24767,46</td>
<td>9,2</td>
</tr>
<tr>
<td>Longest Leg First Strategy</td>
<td>31695,35</td>
<td>39,8</td>
</tr>
<tr>
<td>Many Turns Strategy</td>
<td>33083,04</td>
<td>45,9</td>
</tr>
<tr>
<td>Least Angel Strategy</td>
<td>23869,40</td>
<td>5,3</td>
</tr>
</tbody>
</table>

Geo-savvy agents: Walking behaviour

- investigation of popular algorithms for walking behaviour of crowds (Torrens 2012)
  - results indicate that none of these are suited for agent-based modelling of individuals
    - hopping and simple random walk are not suited at all
    - path-planning appropriate for global but not for local movement
    - Brownian motion performs well against real-world data at a global scale
    - social force works well for high density crowds in confined spaces
    - Levy flight performs well across scales down to population level, but not for individuals
Geo-savvy agents: Walking behaviour

- more investigations needed on
  - the basic movement for a single individual in cluttered spaces
  - how movement behaviours interact
  - how they scale in different spaces
  - how they relate to the social, built and technical environment
- potential types of movement:
  - walking while avoiding stationary obstacles
  - walking while avoiding dynamic obstacles
  - walking in a group or in pairs (social context)
  - climbing stairs, using the elevator or escalator
  - crossing the street or a park
  - jogging, running (following a path)

Geo-savvy agents: Walking around an obstacle

- humans often automatically walk around an obstacle (part of locomotion)
- the moment when the evasion process starts is difficult to determine
- there are also very different avoidance processes: sidestepping, swerving, dodging
- dependent on speed of agent
Geo-savvy agents: Walking around an obstacle

- accommodate walking according to
  - type of obstacle
  - size of obstacle (extension in several dimensions)
  - speed of agent
  - relative size of agent with respect to obstacle (comfort zone)
  - relative size of obstacle with respect to neighbourhood
  - planned path relative to the obstacle
  - shape of obstacle
Geo-savvy agents: movement in pairs

- e.g., parent and child, man and dog
- invisible elastic band?

Geo-savvy agents: movement in groups

- process emerging from the dyadic interaction rules governing the spatial distances between the members of the group (Beltran’s dissatisfaction minimizer)
- boids, i.e. human groups as flocks (Reynolds)
- following a leader: schoolchildren
Conclusions

• Goal: Understand (better) how humans navigate in a specific environment by taking the personal perspective and use agent-based modelling

• in nano-simulations we model geo-savvy agents, i.e. agents
  • that are imbued with cognitive capabilities for perceiving and reasoning about geographic space and
  • that exhibit common-sense walking behaviour

• different models in environmental cognition can be brought together: geo-savvy agents' concepts
  • personal space
  • image schemata
  • mental maps
  • affordances

Conclusions (cont.)

• modelling walking behaviour: walking style depends strongly on
  • who is doing the walking and
  • if they are alone or walking together with others and
  • for what purpose they are walking

• Next steps
  • find an expression of walking (e.g. a function) that encompasses all necessary parameters for the different styles we found, i.e. including activity context
  • expand the styles (large obstacles require different strategies than small ones, moving obstacles etc.)
  • look at interactions between walking styles
  • carry out real-world studies, i.e. observe people walking
  • incorporate all different models in a single model for geo-savvy agents
Thank you for your attention!

Questions ? Comments ?

or

send an email to sabine.timpf@geo.uni-augsburg.de