Report of the Session:

The Role of Spatial Cognition for Robotics

Chair: Ben Kuipers
Rapporteurs: Till Mossakowski & Reinhard Moratz

Human spatial knowledge has distortions

- Is this a bug or a feature?
- Is it due to limitations in the “hardware”?
- Or unavoidable side-effects of optimal strategy?

For robots with human-level spatial cognition

- What should we follow in the human model?
- What should we avoid?

Ben Kuipers’ Talk

- See slides
- Questions/Answers:
  - Map building tree → rectangular world necessary? No, axioms are topological only
  - What about boundary relations in a U-shaped road? Boundary relations need to be defeasible
  - Comment (Ian Pratt-Hartmann) -> How do you know your axioms are right? Spatial calculi could be applied? BK: I agree
  - Do you prune your map building tree? Because of hierarchy/topological abstraction not a practical problem, otherwise possibilities grow too fast

Gerhard Lakemeyer’s Talk

- See slides
- Questions/Answers:
  - What is the reason for segmentation into equal-size rectangles? This segmentation comes from soccer books

Cyrill Stachniss’ Talk

- See slides
- Questions/Answers:
  - Comment (Diedrich Wolter): When using heuristics, you loose properties! CS: Some problems are too complex to compute the optimal solution an there are fast heuristics important.

Dagstuhl Seminar Proceedings 05491
Spatial Cognition: Specialization and Integration
http://drops.dagstuhl.de/opus/volltexte/2007/981

Diedrich Wolter's Talk

- See slides

Christoph Flores' Talk

- See slides

Joint Discussion

What do we need from spatial cognition for a robot to have human-level (at least) spatial reasoning capabilities?

1. To build a robot, what aspects of human spatial cognition
   - should we emulate?
   - should we avoid?

   (including preferences, emotions, attitudes)
2. To build a robot, what new research would you like from the spatial cognition community?
3. What is the relationship between
   - human conceptual level?
   - robot computational level?
4. what human capabilities should a robot have?

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Should the robot be allowed to say: "I don't feel like going there"?
Yes, if there is a dialogue and the robot explains why.

Are we trying to build a human-like robot? Yes (appears to be the answer).

If a human has a mobility limitation, and has a relationship
with semi-intelligent robot, where should the robot's autonomy lie?

It has to have some autonomy, e.g. it should be able to follow a map,
but if the robot carries the patient at wrong places, or refuses
to carry the patient, this gets problematic
However: the robot might prevent the patient from danger - but it
should explain this, and be open to negotiation

Driver assistance systems in cars: should they prevent accidents?
We want an assistant offering services, that we however may reject.

We need dynamic adaptivity to the situation, and want to mirror
human faculties.
E.g. if fire breaks out, and there are soft obstacles in front of door,
that robot normally would refuse to go into, the robot nevertheless
should go across these obstacles.
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Advantage of robots/computers:

Programs never get bored - can do routine work
but entertainment robot should entertain

If I am human, I am driver, not a passenger: the human has the autonomy. Any autonomy of the robot is by human delegation.
The human should be able to change the mode of the robot and force it to ignore obstacles, or to drive downstairs (to escape fire, or to commit suicide).

Three different tasks:

A. robot in interaction with human being (as servant)

A robot should be able to detect human mistakes
and therefore needs to understand spatial cognition
and human limitations, peculiarities.
A topological map may be a human strategy that scales up,
and hence is not a limitation when compared with a metrical map.

Human and robot should be able to communicate, share human concepts, although this does not prejudge the implementation model of robot.

The problem is not the type of map, but the mapping from robot representation to presentation to human.

How to model small errors in human communication?
A speaker has to have a really good model of hearer if he wants to use a wrong input to achieve the right things.

If walking to a kiosk, I want the robot to be a tool, giving me a map, and instructing me about spatial conecpts.

For humans, language is a good sparse description. As long as we do not equip robot with environmental knowlegde, we have to communicate

What if a reference is ambiguous? The robot should force us to disambiguate. It has to take the past into account.

Cognition is always relative to perception, and human and robot perception differ. They could be complementary, via dialogue.
Even if human is the master, the robot could contribute in this way.

B. Robot doing task on its own (as autonomous agent)

Autonomous robots can act in dangerous areas.
To what extent do they have to have cognitive faculties?

Service robots, e.g. clinic robots, should behave predictably (even if we do not know their structure).
The robot should even behave similar to a human?
No, predictability is more important: like with your personal computer.

A dog or a cat are autonomous and behave predictably enough

The ABIO has an interesting balance between predictability and unpredictability.
It has a certain predictable scope of behaviour, but within this scope, it has unpredictabilities. It is more a creature than a machine.

It takes its own decisions, but does nothing that is destructive or annoying. It makes some noises that are more utterances to itself. It is well designed. It shows bounded unpredictability. In Japan, these robots are companions for elderly people, or care about houses.
On the other hand, unlike a dog, the machine can just left behind, there is no moral responsibility.

AIBOs are on the one hand autonomous, on the other hand interacting with people.
What types of human spatial cognition are relevant for an autonomous agent? what types of sensors?

An autonomous agent that learns about places, can have two general strategies for orientation:
1. try do what you know, and only if forced, check for consistency.
2. try do as many actions as you can in order to find out inconsistencies.
An experiment showed: those (humans?) that had an overview map were worse than those that just could move!
Can we try to impose our common sense approach to the robot?

There are strong functional reasons that human strategies are optimal for their resources. What for robots?

As I am exploring a city and building a map, there is the problem of a tree of possibilites. But there are strategies to prune the tree down.
If I do not circulate, there are many possbilities.
If I start by going around the same block a few times, I gain confidence => A more compact strategy may be optimal.
Piaget: a babay has circular = repetitive strategies.

It would be easy to implement system that reasons about the tree of possible ways and potential actions (the number is not too high).
In a histogram of likelihoods, those options near to zero possibility can be pruned, peaks should be followed.

C. Robot as implemented cognitive model

What if we came up with an experimentation system: lots of tools, certain filters, arrows linking them, inputs, outputs...
if we could do this with a robot...
and do translations between representations

Use of robots for spatial cognition?!
Is robotics just an application?

If you want to implement spatial cognition, you might recognize what information is missing (in spatial cognition).

Distortion of human knowledge could be unavoidable side effect of optimal human strategies.
No robot has acted in an environment of complexity comparable to that handled by humans.
Hence, if robot does not succeed, that does not tell us anything about cognitive theories, but rather about limitations of robots.

Robots could get too much information. Humans are very good in focussing, changing attention (not only wrt. perceptual information), abstracting away from information.
But this is missing in research.

Before speaking, babies develop a lot of sense for space.
This also holds for robots. (David Pierce's work on maps...)
Topology is used in human cognition, metric is thrown out.
This is a good model for robots as well.

In heuristics, it was interesting to look at disorders
of spatial cognition, e.g. route descriptions that presuppose
too much local knowledge, that are imprecise about landmarks.
For example, "left" and "right" might be confused because
a route drawn on a blackboard is going from the top to the bottom.