Sandbox Geography

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Abstract — *The present work investigates formal models of spatial conceptualizations. Algebraic specifications are derived from recent findings in developmental psychology. The proposed models consider adaptation as a crucial element and are of specific interest for raising the usability of geographic information systems. Interoperability of geographic information often fails due to different conceptualizations. The work aims to overcome these differences by finding transition mechanisms between spatial conceptualizations.*

I. INTRODUCTION

“Hard sciences” like physics and geometry define how to build models of spatial reality into a geographical information system. This results in systems lacking user friendliness and suffering from low acceptance because humans conceptualize spatial reality differently. There is a need for conceptualizations of the world that are not based on physical or geometrical principles but on common sense respectively naïve conceptualizations [1].

In order to model these conceptualizations, studies of the human mind should be considered. The psychologists Andrew Meltzoff and Alison Gopnik introduce the theory theory, a theory about how children build conceptualizations (theories) of reality [2]. Conceptualizations in their sense are very small and underlie frequent change when counterevidence is observed. Children build theories of the world that are based on testing hypothesis in a way scientists do. In the present work formal models of these theories are proposed.

Theories are often considered to be something big like Einstein's theory of relativity or Darwin's theory of evolution. In the context of the paper theories are assumed to be small units. Philosophers like Roberto Casati and H.N. Castañeda would rather refer to theoritas – small theories – to distinguish them from fully fledged theories [3].

We expect that formal models about people’s commonsense understanding of space help to address interoperability problems under a new paradigm, make robots more “intelligent”, and human-machine interfaces more usable.

II. HYPOTHESIS

We hypothesize that human spatial conceptualizations can be built using algebras. Here algebras in their simplest definition are assumed, as being a set of sorts, operations, and axioms. A change in a spatial description can be reflected in those algebras by an adaptation of axioms.

III. THE SANDBOX

For testing the hypothesis space related experiments of developmental psychology are simulated with an agent based approach. Here we do not carry out empirical studies on our own. We rely on a plethora of available studies [2, 4, 5]. The interpretations of these studies are used to build the conceptual model of a spatial cognizing agent.

An agent can be seen as anything that perceives its environment through sensors and acts on its environment through effectors [6]. The knowledge base of the agent is structured in algebras. A two tiered reality beliefs model allows to model errors in an agent’s perception by separating facts from beliefs. This distinction is vital for modeling situations where agents are puzzled. This always happens when beliefs about the “real world” do not fit together with the actual facts.

Current results show that the spatial cognizing agent has to rely on external sources of information through perception and on self-reflection mechanisms in order to gain more advanced conceptualizations. The agent can hold more than one spatial conceptualization of a certain fact in the environment and makes use of all of them. In the following section an example is discussed to show the methodology of the present thesis.

IV. AN ALGEBRA BASED AGENT

When looking for lost objects, like keys, we follow a number of rules. Empirical experiments showed that these rules develop in childhood and that the same rules seem to appear in infants as old as some months when watching an object disappear [4, 5].

First we look at the place the keys have last been visible, if we have no success in finding them we continue to search in the place they usually are. In the case of no success we go back the path we moved along recently. If all these rules fail an irrational search strategy in random places could be applied, before we give up searching the object. These rules form the basis for the development of the following algebras.

Two algebras in a pseudo code notation are presented. The operation *isAt* returns TRUE when the agent has knowledge about the current object's position and FALSE when he has no clue where to look for the lost object. The function *loc o* stands for the current perception of the agent about the object location. The functions *last o, usual o, and path o* stand for the prediction of the object location for an *object o* at the last-visible-seen, usual-seen, and along-trajectory-moving-seen object location. The *placeholder a* is instantiated with an agent's state of mind at a certain time point. An initial theory for a lost object seems to consider just the last-visible-seen-location. The initial algebra is shown in equation (1).

```
Algebra Lost a where
Operations
   isAt: a -> o -> Bool                    (1)
Axioms
   isAt = loc o == lastseen o
```

This kind of theory will not work as contradictions between observations and predictions will occur. The object can not always be retrieved in the last seen position. Further perception will lead to new evidence that objects can be retrieved also in positions like the usual-seen location. A new theory will be formed and will predict that the lost object could be at the last-visible-seen-location OR a usual-seen location.

In order to reflect this insight in the previous algebra the isAt axiom has to be adapted. As objects also move in space, new contradiction will arise. Another exchange of the isAt axiom will be necessary. Disappeared objects can also reappear along the path they moved. The more advanced algebra that is achieved after two transitions is shown in equation (2).

```
Algebra Lost o where
Operations
   isAt: a -> o -> Bool
Axioms
   isAt = (loc o == lastseen o) ||          (2)
          (loc o == usualseen o) ||
          (loc o == path o)
```

The conceptualization of the location of a lost object changed from the initial to an advanced algebra, because contradictions were observed. The change in the algebra for lost objects is reflected in an adaptation of the axiom. This proofs the hypothesis, that human spatial representations can be modelled using algebra, for the selected example.

V. FUTURE RESEARCH

We assume that spatial theories are very small in the number of axioms. More spatial theories have to be formalized to confirm this assumption. Especially models for agents that move in their environment are needed.

Future research will also address multiple agent systems, where commonsense concepts about space can be exchanged among agents. Agents that are exposed to the same perceptions in an environment should end up in the same spatial conceptualizations of the environment. Still some agents may hold different conceptualizations as they are exposed to a different set of perceptions. In order to link different spatial conceptualizations structural similarities in the models will be exploited to build new algebraic specifications.

The investigation of formal models about humans' commonsense understanding of space will enable geographic information systems to interoperate better with other systems and also with the human user. Information and not just data!

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