FORMALIZING AND IMPLEMENTING KNOWLEDGE REPRESENTATION ON THE BASIS OF CONCEPTIONS
Position Statement

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Keywords: Subject-dependency, Context, Conception, Knowledge representation, Modeling.

Abstract: Bernd Mahr's Model of Conception is already studied in view of its philosophical background, its mathematical formalization in regard to consistency and its set theoretic implications. The ongoing work on which this paper states its position, concerns its mathematical formalization in regard to knowledge representation as well as its implementation in this respect.

1 INTRODUCTION

To know something involves a knowing subject which may be a person, a machine, a civilisation, or a community that knows. However, the knowing subject is often abstracted out of knowledge representation.

Another factor to knowledge is its dependency on context. John McCarthy emphasizes this dependency in his statement in (McCarthy, 1987): "Whenever we write an axiom, a critic can say that the axiom is true only in a certain context."

A model which takes both, the subject and context into account is Bernd Mahr's Model of Conception (Mahr, 2010). The aim of the model is, to realize the propositional content of knowledge in an appropriate way. In this paper we will argue for the following position:

> The Model of Conception can be mathematically appropriately realized and implemented.

We will first introduce Bernd Mahr's Model of Conception and take a look into the literature that deals with conceptions and context. Then we explain, which properties of a good formalization and implementation of the model we would expect.

2 BERND MAHR'S MODEL OF CONCEPTION

According to (Mahr, 2010) knowledge is an intentional mental state, which in turn is based on a conception. The term *conception* is used in a wide variety of senses: We say that *something is conceived of by somebody* and mean situations where somebody perceives something with his senses in a certain way; where somebody thinks of something somehow; where somebody wishes something to be; or where somebody understands that certain things are related to each other in a certain way.

In the Model of Conception the term *conception* is modeled by relating it to the three other terms *subject*, *object*, and *context* and by deriving from these the notion of the *content* of a conception.

It is the idea of the model to see none of these four terms in isonlation or as the basic one, but that they are explained only by being related to each other. Thus, the Model of Conception can also be seen as a model of "object", of "context", or of "content".

2.1 Clauses of the Model of Conception

Bernd Mahr's Model of Conception is a conceptual model given by thirteen clauses in natural language. The clauses are taken from (Mahr, 2010) and we added some remarks oriented towards knowledge:

1. An *entity* is something that is. Anything that is, is an *entity*.
2. An *entity* is the content of some conception.
3. Any two *entities* are different.

Both, the concepts of conception and content are explained in later clauses. However, they are entities

Karbe T..
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DOI: 10.5220/0003691603170321
In *Proceedings of the International Conference on Knowledge Engineering and Ontology Development* (KEOD-2011), pages 317-321
ISBN: 978-989-8425-80-5

themselves and so this clause results in a circular relation, which states that both, conceptions and contents are themselves a content of some conception.

4. A *relationship* is an entity by which entities are related.
5. An entity belongs to a *relationship*, if it is one of the entities which are related by this relationship.

Relationships are the basic building blocks of meaning and knowledge. They connect entities and the meaning of an entity is derived only from its connection to the others.

6. A *complex* is an entity by which entities belong to relationships.
7. A relationship belongs to a *complex*, if the entities which belong to this relationship belong to this relationship by this complex.
8. An entity belongs to a *complex*, if it belongs to a relationship which belongs to this complex.

Complexes allow to speak about groups of relationships.

9. A *conception* is a relationship by which an entity, identifiable as the subject of this conception, an entity, identifiable as the object (or subject matter) of this conception, and a complex, identifiable as the context of this conception, are related.
10. The *content of a conception* is a complex, to which exactly those relationships belong, which belong to the context of this conception, and to which the subject matter of this conception belongs.

As the name states, conceptions are central in the model of conception. They relate the subject of a conception to the object and the context and from a conception one can derive its content which can be seen as its meaning.

11. A *situation* is a complex in which all entities which belong to this complex are conceptions.

One can use situations to model the interplay between different conceptions. Especially communication between different subjects could be represented as a chain of situations.

12. A *universe* is a complex to which with every entity which belongs to it, also belongs a conception, whose content is this entity.
13. A *universe* is called reflexive, if it belongs to itself.

Universes are used to describe knowledge about the world with all its entities and the rules which hold in the described world implicitly.

2.2 Conceptions and Context in Literature

One of the ideas underlying the Model of Conception is the *conditio humana* expressed in the phrase "There is nothing for us, which is not through us.[1]". It explains the idea that we cannot have a conception about something that was not conceived by us. Clauses 1 and 2 reflect this principle.

Another source of influence was the philosopher Edmund Husserl, who was probably one of the first to use the term *conception*. More information about the connections between Husserl and the Model of Conception can be found in (Mahr,) and (Mahr, 2010).

The term *context* has become modern in the last few years and is extensively used in context-aware computing. However there is only a small segment of this work, which particularly focuses on the concept of context itself.

The need for representing context was probably first stated by John McCarthy in (McCarthy, 1987). Then, in (McCarthy, 1993) and (McCarthy et al., 1995) he made a first approach, by adding abstract contexts to logical formulas. Following McCarthy, Doug Lenat and Ramanathan V. Guha built their common sense knowledge base *CYC* (see (Lenat and Guha, 1990), (Guha, 1992)), which makes explicit use of contexts, which the call *microtheories*.

Further important articles concerning context where written by Dourish (Dourish, 2004), Kokinov (Kokinov, 1995), Dey (Dey, 2001), Mahr and Karbe ((Karbe and Mahr, 2011) and (Karbe, 2011). One common property, which was seen in all these papers is that context is any information that is considered *relevant*. It is therefore a challenge for all models of context to properly capture the idea of relevance.

3 REQUIREMENTS ON A FORMALIZATION REGARDING KNOWLEDGE REPRESENTATION

It is the intention of the Model of Conception, to allow for a representation of knowledge, which imposes little restrictions on the modeler. Therefore, a formalization, as well as a subsequent implementation, should have specific properties. We'll explain these properties in comparison to the basic and well known formalism of ZFC-sets (Zermelo-Fränkel set theory including the axiom of choice):

[1] Stated by the German philosopher Günther Figal.

Intensionality. In ZFC set-theory sets are extensional, which means, that two sets are the same if they contain exactly the same elements. However, we want to be able to differentiate between two relationships which relate the same entities with different meaning. An example would be a situation, where two co-workers are in the same room. They are related by being in the same room and by being co-workers, but these two relations are not the same.

Self-reference. ZFC-sets have to be well-founded, which means that the elements of a set must be constructed before the set itself can be constructed. This property also forbids self-reference. In a formalization of the Model of Conception it should be possible to represent relationships, which relate themselves to other entities. A special relationship, which would benefit from this possibility is the conception. One could represent a subject that has a conception about his conception.

Different Levels of Abstraction. It is most natural for us to switch to a more abstract, or more specific level, when we talk about something. In terms of the Model of Conception, we can have a conception about an entity in a given context as well as having a conception about a conception that was mentioned before.

Such concepts should be available to the formalization and implementation of knowledge representation.

4 FORMALIZATION OF THE MODEL OF CONCEPTION

There are several approaches to create a mathematical realization of the Model of Conception. In (Eilers, 2009) [2] Eilers provides a first "pre-model" based on ZFC. However, the axiom of foundation and the extensionality of ZFC-sets limit this first model.

To build a more appropriate realization, Eilers decided to use ε-structures. These structures are modeled in ZFC and can be seen as sets, which impose no restrictions on the element-relation. It is possible to have non-founded ε-structures and also to have two different ε-structures which contain exactly the same elements. In (Wieczorek, 2008) there is a good introduction to ε-structures.

The second model of Eilers which was based on ε-structures showed the consistency of the clauses of Bernd Mahr's Model of Conception, but still it was a rather trivial model, because it used only empty contexts in conceptions and it did not model reflexive universes.

In (Wieczorek, 2008) Tina Wieczorek formalized the model by writing the logical reading of its clauses in first order logic notation, using appropriate function and predicate symbols. She gave two axiom systems for universes, and constructed for each of these systems a Tarski-style model using ε-sets, a specialization of ε-structures.

The models of Tina Wieczorek could represent different contexts and one of them even provided reflexive universes. However, the aim of her models was not, to use them for modeling knowledge, but to show useful properties in regard to set-theory.

The aim of the author is it, to provide a new realization of Bernd Mahr's Model of Conception, which allows for an easy modeling of conceptions with all the intended properties. This is actually work in progress.

The idea of the new realization is, to use ε-families to represent relationships. This approach allows for relationships which are intensional, as well as for different layers of abstraction and for self-reference. Further, by using families, we can model relationships in a very intuitive way: We use the index of each family-member to indicate the role of the member-entity in the relationship.

5 IMPLEMENTATION OF THE MODEL OF CONCEPTION

To implement the Model of Conception, we want to develop a datastructure which is as close as possible to the new realization above. Accordingly, we have to develop solutions for the following questions to implement the model:

- **How do we handle Infinite Structures?**
  This can be done a "lazy" approach, where elements of relationships are only calculated on demand and not before they are needed.
- **How are Conceptions related to their Subjects?**
  The model of conception does not explain, how a subject is related to its conceptions. One possible solution would be the intoduction of the world model of a subject, which represents the subject's view of the world, represented by relationships in a complex. This world model would then be the source of all the contexts which the subject uses in its conceptions.

[2] Translated into English the title would be ε-*semantic Modeling of a Model of Conception*

- **Are the Subjects of a Conception considered to be Perfect Reasoners?**
  To model subjects as perfect reasoners, their world model would have to include all the consequences of the knowledge represented in the world model. This property seems to be a too big restriction. It should be possible, to have subjects with small finite world models, as well as perfect reasoners should be possible.
- **Is the Knowledge of a Subject always Consistent?**
  As long as subjects are not considered to be perfect reasoners, it is not always possible to analyze if some pieces of information are contradictory. Consequently a world model is not nessecarily consistent.
- **What Actions can be performed on Conceptions, Situations and Universes?**
  It should be possible, to add and remove relationships to and from complexes and to calculate consequences of these changes. Changes in the world model would lead to new possible conceptions.

These questions and their answers provide a first insight into the desired design and implementation of the datastructure, which we want to develop.

6 ENHANCING SYSTEMS BY USING CONCEPTIONS

There are many systems that could benefit from the use of conceptions and a proper handling of contexts. I will list a few examples and give a short remark on how they could use the model of conception:

Intelligent Agent Systems. Intelligent agents can be seen as subjects which have conceptions. Such agents could create conceptions about their environment, as well as about the other agents which work with or against them. They also could create conceptions about conceptions of other agents and draw conclusions out of this knowledge.

An example where conceptions could be of great use is the Robocup 2D Simulation competition (see http://www.robocup.org/). Conceptions could provide the means to reason about competitors and to devolop dynamically adapting winning strategies.

Ambient Assisted Living Systems. In the field of ambient intelligence there are many approaches towards making a house aware of its context. This means, that the house assists the people who are living in it, by reacting under certain conditions. It should close the doors when its inhabitants are gone and it should start the coffee machine after waking somebody, if this person likes coffee.

By using conceptions, the system that controls the house could represent its inhabitants. Based on this information it could detect changes and learn new desired behaviours.

Natural Language Processing. It is well known that the meaning of natural language usually depends on context information. By placing a word in different contexts one derives different meanings of it. The surrounding groups of words, sentences and paragraphs (the *cotext*) are part of that context, but often other information has influence on the meaning of a word, too. The Model of Conception could provide the means to represent such diverse contexts.

Of course there are more than these three systems, which could benefit from conceptions, because of the generality of the idea. Still, all these possibilities need further investigation to understand the real value of this approach.

7 CONCLUSIONS

In this paper, Bernd Mahr's Model of Conception was presented as a basis for appropriate knowledge representation. We argued that the model can be mathematically realized and we provided a first set of ideas regarding the implementation of a datastructure for conceptions and contexts. After completing the mathematical realization of the Model of Conception, which is ongoing work, a first very basic version of a datastructure should be constructed and analyzed.

Later research would include the test of the datastructure in Robocup 2D simulation agents. This will probably result in a better understanding of the power and usability of conceptions in intelligent agent systems and lead to further extensions of the basic datastructure.

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