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# What Is the Use of Ontologies Concerning Organizing Data in Multidisciplinary Projects?

# Wozu dienen Ontologien bei der Organisation von Daten in multidisziplinären Projekten?

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Summary

A central task of a multidisciplinary projects is to explain and declare the concepts and connections of concepts of all the different disciplines and participants involved. Ontologies and their tools can clarify and interpret the differences between words in context of multidisciplinary users even though in a customary familiar context such words appear to have the same meaning.

Ontologies are formal descriptions of concepts that are useful to achieve sharing of computerized files. Ontologies describe things and operations that can be applied to them. They improve communication between people, especially if they communicate indirectly by sharing computerized databases, through organized concepts used to encode the perception of reality in computer representations. The configuration of the central database in which results of disciplines are allocated in a reusable way follows from the formal ontology.

The presented tiered ontology distinguishes between simple observations, physical objects that the observer conceptualizes, and the socially constructed objects of social reality. Operations connect between different concepts in a traceable way.

A tiered ontology contributes to the separation of observation of physical facts from their interpretation; they are thus important in multi-disciplinary and multi-language research teams. A formal ontology translates to a tool to help the archaeologist to record his observations in a form later reusable and integrable with the results from others!

Deutsche Zusammenfassung

Klärung der Konzepte und die Verbindung zwischen den Konzepten, welche die Teilnehmer, verschiedener Disziplinen, in einem multidisziplinären Projekt verwenden, ist eine schwierige Aufgabe. Ontologien und die zugehörigen Hilfsmittel lassen Differenzen

auch dort erkennen, wo oberflächlich die gleichen Wörter verwendet werden, die aber disziplinspezifisch interpretiert werden. Aus der formalen Ontologie ergibt sich die Organisation der zentralen Datenbank in der Ergebnisse der Untersuchungen in einer wieder verwendbaren Form anderen zur Verfügung gestellt werden.

Ontologien sind formale Beschreibungen der Konzepte; sie beschreiben die Dinge und die Operationen, die mit ihnen vorgenommen werden können. Mittels ontologisch definierter Begriffen können die verschiedenen Wahrnehmungen der Realität durch verschiedene Menschen miteinander und mit der im Computer verwalteten Form verbunden werden.

Die vorgestellte geschichtete Ontologie unterscheidet zwischen (1) einfachen Beobachtungen, (2) physischen Objekten, wie sie Beobachter beim verstehen der Welt bilden, und (3) sozial konstruierten Objekten, die in einem sozialen Kontext eine Bedeutung haben (Searle 1995). Operationen vermitteln zwischen verschiedenen Konzepten in einer nachvollziehbaren Weise.

Formale Ontologien liefern die Grundlage für die Gestaltung von Computerprogrammen, die dem Archeologen helfen, sowohl die mehr objektiven physischen Beobachtungen, die Beschreibungen der Objekte und schliesslich die weniger stabilen Interpretationen im angenommenen sozialen Kontext zu erfassen und in einem interpretierbaren Rahmen mit Daten von andern Forschungsgruppen zusammenzubringen.

# 1 Introduction

Archeologists—in my simple and naive understanding—want to make sense of the physical objects left from previous cultures they find at their sites. Making sense of physical objects in a context, where the context is long gone and now to a large degree unknown, is difficult and can lead to incorrect conclusions. Archeologists, therefore, make efforts to record the facts, what they find and separate from their interpretation from the facts. They are, in this respect, working in a similar way than good journalists or geologists, or scientists in general.

Modern ontology can help to separate observations from interpretation and lead to data collections that can later be used to construct revised interpretations. Archeology today shares its results and works in multi-disciplinary cooperation; in this environment, the separation of observations of physical facts from interpretation becomes even more important. Sharing results collected in a computerized database are more reliably to use if a formal ontology is available then when the user has to guess the data collectors understanding.

# 2 Formal Ontologies

Philosophers study since two thousand years under the heading “metaphysics” or “ontology” what exists. Computer science uses the term ontology with more modest intentions. A formal

ontology is a “formal, explicit specification of a shared conceptualization” (Gruber 1993). Building an ontology is an effort to agree on the common concepts which will be used to describe a domain of interest. An ontology codifies the agreements what we mean, when we say, for example, “bone”, “bronze”, or “place”.

## 3 Ontologies for Data Sharing

When data are shared several steps are necessary:

The first are the computer technology related changes and relatively easy:

- Transfer of data to the target system
- Change the format of the data to make them compatible with the target system.

More effort require simple changes of units and names:

- Translation of measurements, for example from feet to meter;
- Identification of individuals known by different names. Example would be: “Elizabeth II”, for Scots “Elizabeth I”, or “Karl V” for Spaniards “Carlo I”.

Most difficult is the adaptation of classification:

- When is a person an adult?
- When a family poor?

An ontology starts with so called '”ontological commitments”, which summarize our common experience and understanding of the world. They cannot be further argued and are accepted as given (axioms):

- There is one (and only one) shared physical reality.
- Physical reality is 3 dimensional and evolves in time.
- The physical reality can be observed and changed by cognizant agents.
- Nothing exists outside the physical reality.
- Matter persists and material objects are (from creation to destruction) permanent and always at one location.
- All our knowledge about the world results from observations.

Sharing understanding is improved if the ontological commitments are explicitly listed; the fewer of them, the better!

# 4 Tiered Ontology

In a tiered ontology (Frank 2001) (1) observation of the physical world, (2) representation of physical objects, and (3) socially constructed reality (in the sense of Searle (1995)) are distinguished.

## *4.1 Ontology of Physical Observations*

Observations of physical properties at points are possible, at time 'now': $v = p\ (x,y,z,\ t)$. Accept that physical observations are never perfect, but errors follow usually a standard distribution and allow statistical analysis. The units for measurements are conventional, but can be objectively reproduced. Observations of physical properties result in the most 'objective' description of the factual reality.

## *4.2 Ontology of Physical Objects*

Cognizant agents organize their knowledge of the world not as physical point observations, but as objects with properties. Objects formation is a cognitive act and based on experience, such that the objects produced have permanence. Object formation, which is delimitation of the object and classification with respect to its potential use, is largely unconscious and evolutionary 'old'; we share this ability with most vertebrae.

Small, movable objects are prototypical: Human day to day interactions are first with small physical objects. They have permanence, have at any time a specific location, have weight, color etc. and these properties change slowly. The limits of movable objects are determined by moving them: what moves with the object is part of the object.

Geographic objects cause more difficulties, because they can be limited in various ways. Boundaries of a named geographic object change in time (e.g., Roman Empire, Poland), or a unit changes its name (Burma became Myanmar). Different perspectives (political, ecclesiastic etc.) lead to different subdivisions of space. Similar difficulties are observed with the delimitation of temporal objects: what are the boundaries of the Middle Age?

Observations of properties of physical objects are limited by the limitations of physical observations and the uncertainties in the object delimitation. Notice that we tend to have more agreement on physical point observation than on the delimitation and description of physical objects and thus a separation in tiers help to distinguish between facts and interpretation.

## *4.3 Ontology of Social Reality*

Humans are social animals and organize their social interaction with socially constructed concepts (Berger et al. 1996). Humans reflect the fixed social constructions in physical objects; they give a social meaning to objects in a social context: X counts as Y in context Z, e.g., pieces of paper (Ten Euro bank bill) count as money in the context of an economic unit (Euroland) (Searle 1995). Socially constructed reality is context dependent and the meaning

of an object or a concept may drastically change between contexts; a 'Ten Euro' bank bill is a piece of curiosity in the USA, but definitely not 'money'. Who counts as an adult differs substantially between societies.

Socially constructed objects and operations are, directly or indirectly, related to physical objects, but their behavior is very different than the behavior of physical objects. Strangely, properties of socially constructed objects are observable without error (a 'Ten Euro' bank bill is exactly 10 Euro, not 9.99 Euro; properties change instantaneously (a persons marital status goes from single to married in an instant (at a specific moment during a typically long ceremony).

## 5 Ontologies and Operations

Ontology has a grounding problem: what are the fixed concepts from which we start building the other ones? Two results from other disciplines—one from mathematics and one from modern neurophysiology—help:

From mathematics we get the idea that, operation link strongly between concepts : A *knife* is an object to *cut* other objects; objects can be *moved* to *locations*; etc. An ontology with operations is not just a taxonomy but a densely linked web between object concepts. It resembles an algebraic structure that is defined without further grounding up to isomorphisms. Descriptions are equivalent if they contain operations which follow the same rules; for example: Arabic and Roman positive numerals are equivalent, because the comparable operations applied to comparable numbers produce comparable results: 1 + 3 = 4 is the same as 1 + II = IV.

From neurophysiology we learn that humans are not only capable of understanding others by taking their perspective, but empathy works even at a lower neurophysiological level: I understand, for example, seeing you walk, as comparable to my own experiences of walking. If I walk or if I see another person walk activates the same so-called mirror neurons (Rizzolatti et al. 2004). Mirror neurons act as the physical neural grounding for operation concepts. All other grounding of concepts follow from here.

Humans classify objects immediately and unconsciously by what can be done with them; what operations they afford (Gibson 1979). One object may have multiple affordances and a human being in a specific situation may focus on one and ignore the other. As a consequence, the object may be classified as a box, a table (in a student apartment) or a house (in children playrooms). Nevertheless, object definitions and the actions applicable to them define the semantics (up to isomorphic mappings, e.g., by translation between languages). I stress this with the term “closed loop semantics” - observations of actions and results of actions in the real world confirm the conceptual modeling.

We assign to other humans intentions, because we construct other humans as similar to ourselves: with a mind, goals etc. Observed actions of others are used – often unconsciously – to understand other humans intentions, based on how we would have acted and reacted with similar intentions. Very little is known about how ontologies could deal with intentions.

## 6 Conclusion

What can be learned from ontological studies?

Firstly, reality comes in different tiers of 'existence' and the qualities and behaviors of concepts related to these tiers are very different. The lower tiers are more directly related to the reality of the world; concepts, classifications and terminology of higher tiers are increasingly more difficult to compare.

Secondly, the tiers of existence must be respected in representing your observations. Observations of physical properties at a point are most objective and least subject to error, especially errors of interpretation. Observation of physical object and their properties is more difficult, but can be standardized in a research team or a discipline to yield comparable results. Interpreting physical objects as social constructs depends on the context. In archeology, this context is often uncertain and future revisions possible – revisions of context affecting the interpretation of the objects automatically.

From an ontological perspective, it is therefore highly recommended to record your observations simultaneously and separately at the different tiers: what are the physical observations? What are the properties of the object? How do you interpret the object as a social sign and which context did you assume for this interpretation?

Your interpretation is important, but it may change over time or not agree with other interpretations. Integration of data is simpler if you include the 'objective' aspects. Data collections where facts are clearly separated from interpretation may be combined with other data and lead to more and better interpretation later. Integration of data is hard, if not impossible, if only interpretations were recorded.

A formal ontology translates to a tool to help the archaeologist to record his observations in a form later reusable and integrable with the results from others!

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