Rethinking Conceptual Structures and their Expression – Part 1: An Essay about Concept Formation and Symbology

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ABSTRACT: Meaningful communication between people, organizations and information processing systems - using any form of symbolic expression - requires the unambiguous and precise definition of terms. And although symbolic arguments can be expressed with formal rigour, it is still unclear what symbols or terms mean for individual people, organisations or information processing systems. Even formal and official standards use subjective and imprecise definitions of terms. This paper detaches conceptual structures from symbols, analyses their cognitive origin, and proposes an approach that may support a more precise and view independent expression of knowledge.

1 THE CHALLENGE OF COMMUNICATION

1.1 *Communication through symbolic representation*

Large construction projects require the involvement of many people and organisations, often using various information systems. The success of a project depends partially on the quality of information and on the effectiveness of communication. There is an increasing interest to share information in electronic form, so that up-to-date information can be accessed without delay by all interested parties. Moreover, there is a trend to migrate from document oriented information sources to data orientation.

Information can be defined as knowledge that is expressed in symbolic form. Author and reader (or user) must agree about the symbols used and about the concepts that they represent. This requirement applies to information of any kind in any form.

People that are part of a community associate similar – but not necessarily the same - concepts with a particular symbol. Such conceptual differences may cause miscommunication.

1.2 *Discipline views*

A factor that contributes to the problem of communication is that different disciplines have different 'views' on a given subject. Information that is relevant for one discipline, may be irrelevant to another. Moreover, a term may have different meanings for different disciplines. The term 'floor', for example, has a different meaning for a building user, an architect, a structural engineer or a supplier of elevators.

1.3 *Standards and Formal Specifications*

The need for a precise definition of terms used in construction exists already many decades. It has led to several national and international standards such as Sfb and BSAB in Sweden, CPI and Plowden in the UK and ISO 6707. Such classifications standardise terms, but not meaning.

With the emerging need for the sharing of electronic data in construction projects, standards have been developed – or are still in development – that define the structure and semantics of data. Examples are ISO 10303 parts 225, 228 and 230, and the IAI/IFC's for construction.

Also for legal purposes such as laws and regulations it is common practice to define terms. All member states of the European Union have developed their own definitions of terms for construction.

Although standards are developed with the intention to support a consistent usage of terms, the standards themselves are usually inconsistent and use different and imprecise definitions. As an example, the term 'wall' is defined as follows:

- ISO 6707 - *Wall*: a vertical construction usually in masonry or in concrete which bounds or subdivides a construction works and fulfils a load bearing or retaining function.
- IAI – *Wall*: a vertical construction that bounds or subdivides spaces. Walls are usually vertical, or nearly vertical, planar elements, often designed to bear structural loads.
- The Netherlands national regulation for construction (Bouwbesluit) does not recognize the term 'wall' but uses in stead the term '*space-divider*':

a construction that subdivides spaces. Elsewhere, this regulation defines that a construction is a load-bearing part of a building.
– Encyclopedia Brittanica – *Wall*: Structural element used to divide or enclose, and, in building construction, to form the periphery of a room or a building.

These examples raise questions such as:
1 What is vertical, or 'near-vertical' (ISO, IAI)? What are space-dividing structures that are not vertical or horizontal? See also figure 1.
2 Is a non-planar vertical structure, such as a cylindrical space divider, not a wall (IAI)?
3 What is a construction (ISO, IAI)?
4 Is a Roof also a Wall (Encycl.Britt.)?
5 What is meant with 'subdivision or enclosure of spaces'? Does a curtain subdivide or enclose spaces? Or a fence? And can a window be a wall?

In other words: what are we talking about?

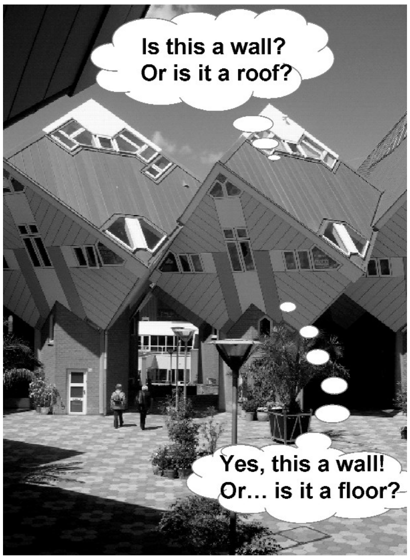

Figure 1. The 'Cube-houses' in Rotterdam, the Netherlands, challenge conventional Building terminology.

Even standards for direct interpretation by computer applications, based on formally specified schemas or ontologies, have weak foundations. ISO 10303 (STEP), the IAI Industry Foundation Classes, as well as the new generation of OWL based ontologies, use terms of which the meaning is described in plain English. Certain ontologies restrict definition to a single word. But dictionaries give often multiple definitions for each word, and different dictionaries give different definitions.

1.4 *The philosophy of meaning*

'Meaning' and 'semantics' have been subject of many studies, theories and debates in linguistics, psychology, philosophy, computer sciences and mathematics. Most theories find their origin in the work of the Greek philosophers, more in particular that of Aristotle. Aristotle writes in *De Interpretatione*:

'Spoken words are symbols of experiences in the psyche, written words are symbols of the spoken. As writing, so is speech not the same for all people. But the experiences themselves, of which these words are primarily signs, are the same for everyone, and so are the objects of which those experiences are likenesses'.

The above is a 'free translation' that meets the purpose of the current discussion reasonably well.

The term 'semantics' is derived from the Greek word 'sema', which means 'sign'. Words in a language are signs or symbols that refer to 'experiences in the psyche'. This idea of Aristotle is often depicted in the form of a meaning triangle, with has at its corners: a symbol (occasionally referred to as a term or sign), a concept (i.e. an idea or thought) and a referent. For most symbols, the referent is not a single 'thing' but a set of things. This set is then referred to as the *extension* of the symbol. The extension of the word 'horse', for example, is the set of (all) horses. The inverse of extension is *intension*: that what a word means or signifies.

Most existing theories concerning 'meaning' are based on either extension or intension. ISO 10303 (STEP) defines the term 'concept' as: 'an abstraction derived from the observation of particular instances' [Danner et al 91]. This is an extensional definition. But what about things that cannot be seen, but are abstract or imagined? And what if the things that are observed are not the same? Only if two parties point to the same physical things and decide to give these things the same name, they may be able to communicate effectively. For an international standard, the above definition is inadequate. Also, it does not solve the aforementioned problem with the concept 'floor'.

In logic and mathematics, the term 'semantics' is restricted to expressions. It does not address what a symbol represents. For example, an argument in logic is said to be semantically correct if valid conclusions can be drawn from a valid set of premises. Logic and mathematics are abstract sciences that are detached from reality. The latter is accurately described by Bertrand Russell [Russell 1901]:

'Pure mathematics consists entirely of such asseverations as that, if such and such a proposition is true of anything, then such and such another proposition is true of that thing. It is essential not to discuss whether the first proposition is really true, and not to mention what the anything is of which it is supposed to be true... If our hypothesis is about anything and not about some one or more particular things, then our deductions constitute mathematics. Thus mathematics may be defined as the subject in which we never know what we are talking about, nor whether what we are saying is true'.

The same holds for formal logic or any science that is build on top of formal logic, including computer science. For many applications this may not be a concern, but models of reality or of things that are supposed to be part of reality must have a firmer foundation. The issue discussed in this paper is about the formation and scope of concepts, detached from existing theories for symbolic representation.

2 UNDERSTANDING THE PROCESS OF CONCEPT FORMATION

2.1 *From subjective cognition...*

How do people learn and develop knowledge? In recent decades, significant new knowledge has become available through neurological and psychological research [f.e. Maturana 1998 and Neisser 1976].

Humans learn by experience. But the huge amount of information that the human senses provide is 'analysed' and interpreted in an unconscious process before it results in awareness. This process is called *Perception*. An awareness that results from a sensory experience will be called a *Notion*.

Many sensory experiences do not lead to awareness. The few experiences that do, leave an impression that is far from objective.

Successive experiences may be remembered at a certain level of detail. Repeated experiences with the same or similar phenomena result in the development of cognitive structures in the human brain, called *Schemata* [Neisser 1976]. A schema is an understanding of a larger whole: it is a complex of interrelated and remembered experiences. Properties or features that successive experiences have in common, are reinforced, others may be forgotten. A perceptive schema for a particular animal, for example, is therefore never a precise description of that animal; it is at most a caricature.

Schemata may result from any array of impressions with particular Notions in common; hence they may apply to things of the same kind, or to the same individual creature in successive encounters. Properties or features that are not noted do not add to the formation of schemata. Hence, schemata are subjective and depend heavily on the ability of a perceiver to note commonalities or differences.

Schemata play on their turn an important role in perception. New impressions are compared with existing schemata. They enable the perceiver to recognize things and to anticipate. A person who was attacked by an aggressive dog once may be cautious during new encounters.

Schemata may be detached from their original experiences and become independent sources of information for the human mind. In that form they become *concepts*. Certain concepts may be associated with symbols such as words, so that they can be communicated to other people. But as the number of concepts in the human mind is larger and also more complex than a language can represent, any expression is at most an approximation of actual knowledge in the human mind.

2.2 *... to objective cognition*

Perception is subjective. No two human individuals have the same experiences, and even if they are confronted with the same phenomenon they may interpret it in different ways. Assuming that the human senses do not differ significantly, these differences are primarily caused by the schemata that guide the extraction of knowledge from an observation.

Perception can be made less dependent of human interpretation by a more rigorous process of observation and interpretation: the (empirical) scientific method. Modern empirical science is also based on experience, but it uses calibrated instruments in stead of human senses. It uses also a more or less standardized process of interpretation, in which disturbance by systematic errors is minimized. A scientific experiment can be repeated and verified by others, and a publication is reviewed by independent experts before the results are exposed to a wider audience.

A scientific experiment and the interpretation of its results is never free from perceptive distortion; a scientific theory is at most an approximation of reality. But as this process is less dependent on individual factors and can be repeated by others, it is considered as an *objective* cognitive process.

3 A SIMPLIFIED MODEL OF COGNITIVE CONCEPTUAL STRUCTURES

In a simplified model of the cognitive process, conceptual knowledge is formed by Notions and Schemata. From hereon, the term 'Schema' will be replaced by 'Perceptive Frame' - or shortly 'Frame' - in order to avoid confusion with the term 'schema' that has a different meaning in the field of Information Technology.

3.1 *Notions*

A Notion will be defined as: a sensory experience that results in awareness. Notions are usually perceived as properties or features of a phenomenon. But they do not only depend on the phenomenon itself: also the sensory and perceptive system plays a role. The sensor can be a human sense, but is preferably a calibrated instrument, used in the context of a scientifically accepted measuring process.

An example of a Notion is 'Colour'. If the observer is not able to distinguish Colour, it will not be noted. Such limitations can be caused by the sensory equipment or by other factors, such as the observation of an object in monochromatic light.

Colour is not a real property of an object. If the object is non-transparent and does not emit light by itself, colour tells something about the reflection of light by the surface of the object in different parts of the electromagnetic spectrum. How Colour is perceived depends on the sensory system. The cones in the retina of the human eye are sensitive in three distinct regions of the electromagnetic spectrum. This characteristic can be used to approximate the impression of colour by a vector with light intensity values for three regions in the spectrum, such as Red, Green and Blue for the additive colour system, or Yellow, Magenta and Cyan for the subtractive colour system. The human eye is only sensitive for radiation with a wavelength between 400 and 750 nm.

The reflection of light by the skin of an object may also be expressed as a spectral curve or as a reference Colour (such as the Pantone® colour system). Hence, there may be several different Notions that provide information about a single property.

A Notion is not the same as a property. It provides information about a property, and it is also *the only way* to obtain information about a property. A Notion may or may not be consistent with other Notions of the same property. This distinction is essential for the approach described in this paper.

Scientific communities develop standard procedures for the sensing and perception of certain Notions, so that more objective conclusions can be drawn about the intrinsic properties of an object. An example is the Notion ‘Weight’ and the Property ‘Mass’. Mass is intrinsic to a physical object, but it can only be determined through a force that acts upon it, such as the Earth’s gravitational force. What is measured in the latter case is Weight. An object weighs slightly less near the Earth’s equator than near the poles, so that a standardized measuring method is needed to derive Mass from Weight. In this case, measuring devices are calibrated with the help of a reference object with a mass of 1 kilogram.

3.2 *Perceptive Frames*

A Perceptive Frame (or, simply, a Frame) will be defined here as the set of notions that is relevant for a particular task. A Frame guides the extraction of information from sensory experiences.

No distinction will be made here between the sensor and the system that interprets sensed data. In reality both play a role, but for practical reasons it is convenient and sufficient to consider sensing and interpretation as a single mechanism.

Domain experts in construction projects extract information that is relevant for their job; the rest is omitted. A structural engineer translates the weight of building components, the planned activities inside the building, and external agents (such as wind force or earth quakes) into static or dynamic forces that act upon the main structure.

This process of extraction and simplification is not different from perception: domain experts use perceptive frames that contain only relevant notions.

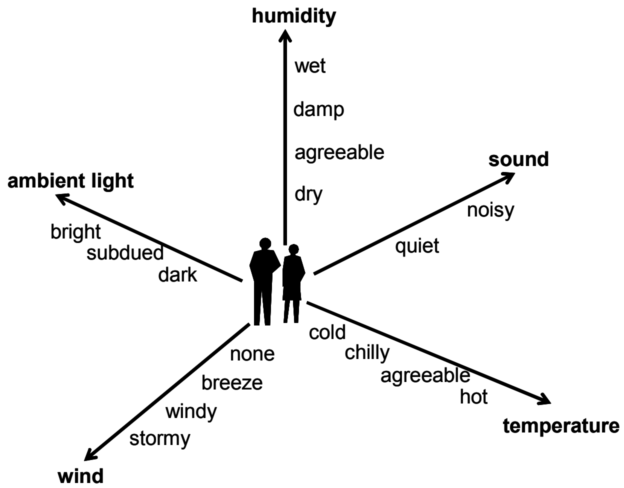

Figure 2. Example of a subjective Perceptive Frame for the description of ‘Shelter’, having five relevant Notions.

The forgotten role of Differentiators

The use of Notions as a means for concept definition is not new. The Greek philosopher Plato developed a method for definition, based on division of classes. It was applied in almost unchanged form by Aristotle.

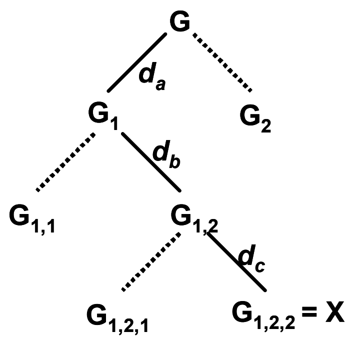

Figure 3 Definition of Meaning by Division of Classes

To determine what X is, first determine the largest class G to which X belongs. Then, divide G into parts (say G_1 and G_2) and determine to which (sub)class X belongs. Suppose this is G_1. Divide G_1 on its turn into parts (say $G_{1,1}$ and $G_{1,2}$) and locate X in one of these.

This procedure is continued until a subdivision is reached that is identical to X. The nature of X is then given by the entire division, which can be represented as an inverted tree; see figure 3. The class to which a thing belongs is called its Genus, and the characteristic that differentiates it within this class is called Differentia. Combining a Genus with a Differentia defines a (sub)class, and the entire set of differentiae needed to arrive at X

– indicated as d_a, d_b and d_c in figure 3 - defines X [Barnes 1995].

This idea is widely used for the classification of things, such as biological species. It is also adopted for the specification of information systems in the form of conceptual schemas or object hierarchies. In these cases, the principle is known as specialization.

Strangely enough, differentiae are absent in most modern specification and implementation languages. Only two languages, known to the author, support differentiae: IDEF1x (or: ICAM Definition Method 1 extended) and UML (Unified Modelling Language). In both cases, differentiae are called discriminators. *Their usage is free of obligation and does not play a role in the definition of meaning. Most modellers ignore them.*

Plato's differentiae differ on one important point from the Notions proposed in this paper. In Greek philosophy - and applied in same form in today's information technology - differentiae are part of a class hierarchy. They refer to characterizations or properties of the things that are being classified. The Notions proposed in the present theory are independent of the things being classified: they are part of Perceptive Systems.

3.3 *The role of Notions in Concept Formation*

Notions in the present theory are *independent of the things being classified*: they are part of Perceptive Systems, represented here by Perceptive Frames. This important difference with classic theory (see boxed text above) is illustrated by an example.

Suppose that the Notion of Colour would play a role in concept formation. The ability to sense and perceive Colour must be attributed to a Perceptive System. Without this ability, the Perceptive System is not capable to make a distinction based on Colour. Furthermore, conceptual differentiation based on Colour may not be restricted to a single class-hierarchy.

Although the value of a Notion tells something about the subject that is being examined, it depends on the Perceptive System whether it is interested in noting it, and, if so, how the Notion is valued.

This understanding is essential for resolving the problem of different 'views' on a given subject: only by the distinction between Notions and Properties, it is potentially possible to resolve conflicts that are caused by different Perceptive Systems.

3.4 *An example*

The following example makes this idea more concrete. Figure 4 shows a Perceptive Frame for 'Persons'. This Frame differentiates the Genus 'Person' by means of two notions: (a) Age and (b) Gender.

The Notion of Age supports the distinction between (1) adult persons and (2) children. The Notion of Gender distinguishes (3) male persons from (4) female persons. The two Notions can be applied together, and that results in four additional concepts: (5) boy (= a minor male person), (6) girl (= a minor female person), (7) man (= an adult male person), and (8) woman (= an adult female person).

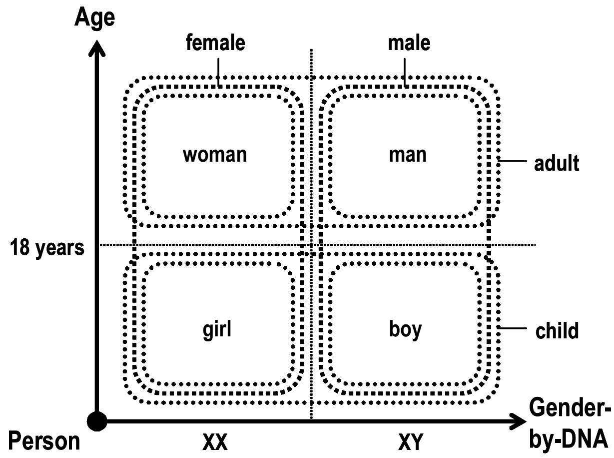

Figure 4. A Frame for concepts relating to Persons based on two Notions: Age and Gender.

It is recommended to use concrete (i.e. measurable and verifiable) notions, such as the legal age and biological gender (i.e. gender according to a DNA test). This makes the description of these concepts precise and objective.

Alternative notions for the same property may be 'Legal Gender' (i.e. Gender according to passport or civil registry) or 'Informal Gender' (i.e. Appearance). In most cases, these alternative notions will produce the same results. But in the case of transsexual persons or travestites, the outcome may be different.

Different Notions are part of different Frames, and it is recommended to keep Notions within a Frame consistent. In this example, it is possible to define a Legal Frame (using Legal Age and Legal gender as Notions), a Biological Frame and an Informal Frame.

The above example demonstrates also that two different Notions with just two subclasses each result in *eight* different concepts related to 'Person'. If more notions are used, the number of resulting concepts increases exponentially.

4 A CONCEPTUAL ARCHITECTURE FOR CONSTRUCTION

4.1 *An Architectural Frame for Space Dividers*

Figure 5 shows an Architectural Perceptive Frame for Vertical Space Dividers. The Genus of this example is 'Vertical Space Divider'. The Frame consists of two Notions that act as differentiators: (a) Human Passage, and (b) Visual Transparency.

'Human Passage' and 'Visual Transparency' can both be differentiated into: (1) Closed, (2) Controllable, and (3) Open.

For 'Human Passage', 'Open' means that nothing blocks a person to pass the Vertical Space Divider. 'Closed' means that it is impossible to pass the Vertical Space Divider. 'Controllable' means that the passage can be open or closed. A Space Divider with Controllable Human Passage is better known as 'Door'. Further details about the type of control may result in further detailed concepts of 'Door'. For example, the Notion may be further differentiated into manual control versus automatic control, lockable or non-lockable, and so on.

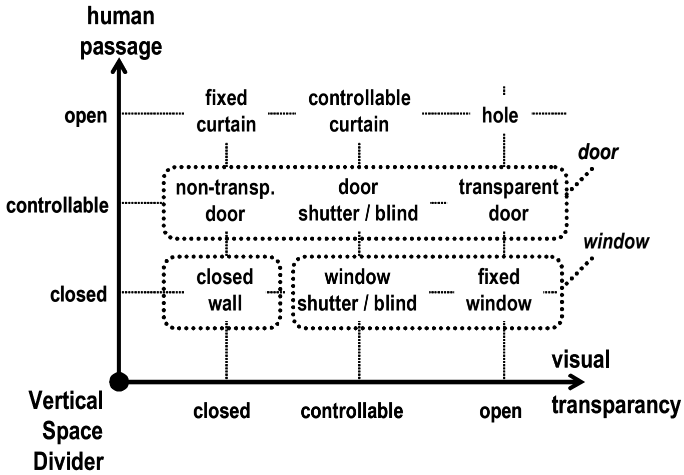

Figure 5. A Frame for Vertical Space Dividers, using two Notions: Human Passage and Visual Transparency

Other Notions that may be relevant for Space Dividers are 'Heat Transmission', 'Noise Transmission', 'Light Transmission', 'Fire Resistance' and 'Strength'.

4.2 *The need for a clean conceptual structure for Construction*

The examples given sofar are all based on a generic 'Root Concept' (or Genus) that forms the starting point for the definition of specific concepts. The disadvantage of having these together with Concepts specified by Notions is that two kinds of Definition are applied concurrently. Is it possible to develop a clean conceptual system, entirely based on Notions?

The next (more complex) example will be expressed in a lexical notation. The following conventions apply:

- Names of Perceptive Frames begin with an F.
- Names of Notions begin with an N.
- Names of Concepts begin with a C.
- A Perceptive Frame is defined by one or more Notions.
- A Perceptive Frame may import Notions from other Frames. Through such an import, conceptual integration across Frames will become easier.
- A Notion is defined by a set of possible values.
- A Concept is defined by reference to another Concept and zero, one or more differentiating Notions. In case there is no differentiating Notion, the two Concepts are equivalent.

In the following examples, there is only one Genus or Root Concept, called 'C_Anything'. This concept is by definition meaningless. Meanings of other concepts follow from the Notions used.

First, three Frames are given: (a) the Root Frame, (b) a generic Frame for Networks, and (c) a Frame for Topological concepts. These three frames form a definition hierarchy.

Frame F_Root (Genus)
Canything

Frame F_Network
Import: F_Root
Notions
NRef: {Ref, NoRef}
Derived Concepts
CNode:= **C**Anything[**N**Ref (NoRef)]
CLink:= **C**Anything[**N**Ref (Ref)]

Frame F_Topology
Import: F_Network
Notions
NDim: {0; 1; 2; 3}
NSideInside: {Side; Inside}
Derived Concepts
CVertex := **C**Node[**N**Dim(0),**N**SideInside(Inside)]
CEdge := **C**Node[**N**Dim(1),**N**SideInside(Inside)]
CFace := **C**Node[**N**Dim(2),**N**SideInside(Inside)]
CVolume := **C**Node[**N**Dim(3),**N**SideInside(Inside)]
CEdgeEnd := **C**Node[**N**Dim(0),**N**SideInside(Side)]
CEdgeSide := **C**Node[**N**Dim(1),**N**SideInside(Side)]
CFaceSide := **C**Node[**N**Dim(2),**N**SideInside(Side)]

The F_Network Frame has a single Notion that distinguishes between referential and non-referential concepts. It results in two concepts: C_Link and C_Node.

The F_Topology Frame imports the Network Frame and adds two Notions: Dimensional Order (N_Dim) and the Notion of Side versus Inside (N_Side_Inside). The latter Notion refers to the idea that a bounded geometric shape has rims (the sides) and an area between these rims (the inside). Notion N_Side_Inside is independent of dimensional order, i.e. it applies to topological entities of dimension 1 (edge), dimension 2 (face) and dimension 3 (volume). All topological entities are considered as Nodes, relations between them are considered as Links, but these details are omitted to keep the example simple.

The following example is a Frame for Building Architecture. It imports the Notions of the F_Topology Frame but not its derived concepts.

Frame F_Building_Architecture
Import: F_Topology
Notions
NDim: {0; 1; 2; 3}
NSideInside: {Side; Inside}
NShelter: {Interior;Exterior}
NFaceOrient: {Horiz; NonHoriz}
NHorFaceSideOrient: {Up; Down}
NHumanPassage: {Closed;Controllable; Open}
NVisualTransparency: {Closed; Controllable; Open}
Derived Concepts
CSpace:= **C**Anything[**N**Dim(3),**N**SideInside(Inside)]
CSpaceBound:= **C**Anything[**N**Dim(2),**N**SideInside(Side)]
CSpaceDivider:= **C**Anything[**N**Dim(2),**N**SideInside(Inside)]
CInterior_Space:= **C**BuildSpace[**N**Shelter(Interior)]
CExterior_Space:= **C**BuildSpace[**N**Shelter(Exterior)]
CWall:= **C**SpaceDivider[**N**FaceOrient(NonHoriz)]
CFloor:= **C**SpaceDivider[**N**FaceOrient(Horiz)]
CWallSide:= **C**SpaceBound[**N**FaceOrient(NonHoriz)]
CFloorSide:= **C**SpaceBound [**N**FaceOrient(Horiz)]
CInteriorWallSide:= **C**WallSide[**N**Shelter(Interior)]
CExteriorWallSide:= **C**WallSide[**N**Shelter(Exterior)]
CFloorTop:= **C**FloorSide[**N**HorFaceSideOrient (Up)]
CCeiling:= **C**FloorSide[**N**HorFaceSideOrient (Down)]
CClosedWall:= **C**Wall[**N**HumanPassage(Closed)]
CDoor:= **C**Wall[**N**HumanPassage (Controllable)]
CHole:= **C**Wall[**N**HumanPassage (Open)]
CWindow:= **C**Wall[**N**VisualTransparency(Open)]

The 'N_Shelter' Notion makes a distinction between the interior and the exterior of a building. 'N_Face_Orientation' notes whether a Face is horizontal or not. 'N_Hor_Face_Side_Orient' notes whether the normal vector of a Face Side of a horizontal face points upward or downward. The two latter Notions are only applicable if the relevant topological entities are associated with geometric information. This detail is omitted for simplicity.

The Notions 'N_Visual_Transparency' and 'N_Human_Passage' were discussed earlier.

It is not the intention to present a complete Building model here. The example intends to show how the path between a meaningless concept (C_Anything) to concepts such as 'Wall', 'Floor', 'Ceiling', 'Door' and 'Window' can be traversed. Conforming this approach, a *Door* is defined as: *Anything (of 2-dimensional order) which divides spaces, is not horizontal, and which provides controlled passage of human beings*.

This example demonstrates how a complete definition can be given through a tree of Notions – and not more than that.

4.3 *Do we still need Symbolic Expressions of Concepts?*

In the above examples, Notions are used to specialize concepts. It is however possible to define any concept as a specialization of 'C_Anything'. For example, the 'Door' concept can also be expressed as:

CAnything[**N**Dim(2),**N**SideInside(Inside), **N**FaceOrient(NonHoriz), **N**HumanPassage (Controllable)]

And as the concept 'C_Anything' is meaningless by definition, it can also be removed from the description. Thus, any concept is formed by a set of relevant Notions, for example:

NDim(2),**N**SideInside(Inside), **N**FaceOrient(NonHoriz), **N**HumanPassage (Controllable)

... which is the equivalent of 'Door'.

The resulting structure is a co-ordinate system for multi-dimensional conceptual spaces. The ordinates within such a system make symbolic representations of concepts redundant and thus unnecessary.

4.4 *Do we still need Integration?*

To understand the answer to this question, it is convenient to return first to the example of 'Person'. Suppose that this case is modelled by means of a symbolic expression, for example the Express language (ISO 10303-11).

Knowledge about an individual person, say a 7 year old boy, can be represented in nine different ways, of which only two will be given here:

```
TYPE Gender =
  ENUMERATION OF (female, male)
END_TYPE

SCHEMA 1
  ENTITY male_person
    Age: REAL
  END_ENTITY
END_SCHEMA

SCHEMA 2
  ENTITY child
    Gender: Gender
    Age: REAL
  END_ENTITY
END_SCHEMA
```

At the level of a conceptual schema or an ontology it is unclear that the two entity types describe the same boy, and that the information at the data level is equivalent. The two entity types are semantically not equivalent. In fact, they represent two different views of the same reality.

The only way to transfer data from one schema to the other is to develop a mapping from one to the other, with the inclusion of rules that guarantee a semantically correct transfer.

This problem can be reduced but not solved by the introduction of a common supertype, for example the entity 'Person'. It has one attribute that is inherited by its subtypes: ‘Age’. However, it is still not possible to see that an instance of ‘male_person’ may actually refer to the same boy as an instance of ‘child’. This problem is caused by the fact that important knowledge is hidden in the specialization tree. The difference between ‘Person’ and ‘Male_Person’ is ‘Gender’, but this knowledge is not made explicit. Using the notation presented in this paper, this same case may be expressed as:

NGender: {Female; Male}
NAge: {Z+}
CBoy:= **C**Person[**N**Gender(male),**N**Age(<18)]
and
X:= **C**Person[**N**Gender(male),**N**Age(7)]

where X represents all available information about the individual person.

The Notions that differentiate concepts are treated here in the same way as normal attributes, so that the description itself is independent of a chosen view.

As it is possible to replace ‘C_Person’ by its defining set of Notions (see 4.3), this conclusion is valid for *any* information.

Hence, in the approach presented in this paper, integration problems are limited to situations where a single property results in two or more different Notions. The property ‘Gender’, for example, may be obtained via three different Frames, each using different methods to obtain the required information. This results in three incompatible Notions: ‘Biological Gender’, ‘Legal Gender’ and ‘Informal Gender’.

Such conflicts can be resolved if the involved parties agree about one and the same method for noting Gender, or if they recognize the three Notions as separate, independent Properties.

5 SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

5.1 *Summary*

Most theories on meaning (or definitions, semantics) address the meaning of symbols (or terms, words, expressions). It happens frequently that two people (or disciplines, applications) associate different concepts with a common symbol. The most widely adopted way to solve this problem is to define ‘neutral’ concepts on which all parties should agree.

This approach fails because modern knowledge is much richer and varied than what symbols can represent. An artificial increase of the number of symbols is not adequate either, because using different symbols for ‘almost, but not precisely the same’ concepts creates a new hurdle for communication.

The essential question is: what are the similarities of concepts, and where do they differ?

This paper proposes a model that complies with human cognition: the process through which people learn. Essential components in this approach are *Notion* (i.e., the sensory experience that leads to awareness) and *Perceptive Frame* (i.e. a set of Notions that guides the understanding of a larger whole).

Notions provide information about properties of real world phenomena. They are not the same as properties (where properties are defined as characteristics that are inherent to phenomena). All knowledge about real world phenomena, including properties of these phenomena, is obtained through Notions. There exists no ‘neutral’, view-independent knowledge about reality.

Perceptive Frames are integrated by combining their Notions. If different Notions refer to the same property, one Notion must be chosen as the primary (preferred) Notion. It should then be possible that any knowledge, expressed within the context of an integrated Frame, can be shared or communicated without any loss of content or intent. This potential needs to be explored further.

5.2 *Conclusions and recommendations*

The approach presented in this paper focuses on the cognitive principles that result in concepts. A method based on these principles may support a precise and unambiguous definition of concepts, not disturbed by different ‘views’ on a given subject.

It is not (yet) the purpose of this paper to suggest a method as an alternative for existing modelling methods. Such a development, and the examination of practical applications and their implications require further research.

The ideas presented in this paper are part of a larger theory that will be published later this year [Gielingh 2005].

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