LINGUISTIC CONFUSION IN SEMANTIC MODELLING

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"Es genügt noch nicht, um sich einander zu verstehen, daß man dieselben Worte gebraucht; man muß dieselben Worte auch für dieselbe Gattung innerer Erlebnisse gebrauchen, man muß zuletzt seine Erfahrung miteinander gemein haben"

Friedrich Nietzsche
("Jenseits von Gut und Böse")

ABSTRACT

The consistent development of digital photogrammetry necessarily leads to wholly new works ("paradigm shift"). Computer assisted capture and processing of attribute data requires semantic models which demand methods different from those applied by geometrical models. A completely new range of problem are linguistic aspects of semantic modelling. The present paper seeks to point out common features of semantinc modelling in linguistics and image processing. This is shown by means of a transformation concept ("real world - iconic level - symbolic level") and systematically ordered examples ("semantic nets", "system of concepts", "unprecise concepts", "inexact distribution", "inadequate methods")

KURZFASSUNG

Die konsequente Entwicklung digitaler Photogrammetrie führt notwendigerweise zu Aufgaben völlig neuer Art ("Paradigmasprung"). Rechnergestützte Extraktion und Verarbeitung von Attributdaten benötigt semantische Modelle, welche andere Methoden erfordern als geometrische Modelle. Ein ganz neuer Problemkreis in diesem Zusammenhang sind linguistische Aspekte bei semantischer Modellierung. Die vorliegende Publikation versucht, Gemeinsamkeiten semantischer Modellierung in Linguistik und Bildverarbeitung herauszustellen. Dies geschieht anhand eines Transformationskonzepts ("reale Welt - ikonische Ebene - symbolische Ebene") und systematisch geordneter Beispiele ("semantisches Netz", "unscharfe Begriffe", "unscharfe Verteilungen", "nicht angepaßte Methodik").

1 A PARADIGM SHIFT, ITS ORIGIN AND ITS CONSEQUENCES

A paradigm shift in any discipline is to be understood as the overall, radical change of a closed set of concepts and rules into another closed set of concepts and rules of both technical and/or non-technical nature.

Photogrammetric image processing has undergone various transformations on its development from analogue over analytic towards digital methods.

The novel element in the step from analogue to analytical processing was the introduction and consistent use of coordinates. This opened the possibility of modelling the *geometrical aspects* of the real world in numerical form.

The step from analytical to digital processing is represented by the fact that by this approach the entire analogue image becomes available to the computer in numerical form. Geometrical data are now supplemented by a scale of gray values. The paradigm shift proper (Ackermann, 1995), however, did not occur when analogue methods were substituted by analytical ones but when these gave way to purely digital processing by taking advantage of the entirely new set of possibilities with the *consistent use of the possibilities offered by the new approach.*

Analytical photogrammetry limits modelling to just the *geometry* of the image. This naturally makes available only a very narrow range of the great amount of information contained in the image. Carriers of geometric information are image coordinates. Photogrammetric models for image geometry based on the rules of analytical geometry have been very exhaustively designed and practically applied during the last decades.

Digital photogrammetry, which stands here for a part of image processing by a digital computer made available beside geometrical image information an entirely new field of interest: the semantic information (sema: greek for "sign"). "Semantics of the image" simply signifies "meaningful content" in the sense of attribute data as opposed to geometrical data. The treatment of this type of information, however, requires not only a dramatic change of tools but also a new way of "seeing" the image content since well established mathematical models like those applied in analytical geometry are no longer satisfactory.

On the other hand, it is evident that geometry and semantics cannot be separated: each object in an image has its very specific coordinates, but coordinates which do not designate

<table>
<tr><th>FRENCH</th><th>GERMAN</th><th>DANISH</th><th>ITALIAN</th><th>ENGLISH</th><th>SPANISH</th></tr>
<tr><td>arbre</td><td>Baum</td><td rowspan="3">trae</td><td>albero</td><td>tree</td><td>árbol</td></tr>
<tr><td rowspan="6">bois</td><td rowspan="4">Holz</td><td rowspan="3">legno</td><td rowspan="2">timber</td><td>madera</td></tr>
<tr><td rowspan="2">leña</td></tr>
<tr><td rowspan="6">skov</td><td rowspan="4">wood</td></tr>
<tr><td rowspan="3">bosco</td><td rowspan="2">monte</td></tr>
<tr><td rowspan="4">Wald</td></tr>
<tr><td rowspan="2">bosque</td></tr>
<tr><td rowspan="2">forêt</td><td rowspan="2">foresta</td><td rowspan="2">forest</td></tr>
<tr><td>selva</td></tr>
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Table 1: Comparison of equivalents in five European languages

an object have no meaning and make no sense. In times of analogue and analytical image processing this was not particularly noticed due to the fact that the semantic processing of the image content fell entirely to the human operator.

In a fully digital environment, the human operator in charge is assisted by the computer and will in the long run be largely substituted by the machine. The effort of modelling the congnitive process with the support of digital procedures leads to a paradigm shift. Among the many problems related to this entirely new approach we shall devote our attention to only one: the linguistic aspect.

The intimate relationship between language and the real world, between concept and object, between *significante* and *significado* has been first analysed by Ferdinand de Saussure (1916) and very sharply defined by Ludwig Wittgenstein (1921):

"The sentence is an image of reality"

Formulated the other way round, we obtain:

"The reality of an image is verbalisation"

An image, be it mental or digital, abstract or concrete, only acquires sense when the semantic information contained in it can be communicated.

Analysis and modelling of semantic image information depends largely on language. The question is to find out how far modern linguistic and language theory may be of help in structuring semantic problems at image processing (Rapp, 1995).

2 LINGUISTICS, SEMANTICS AND FIELDS OF KNOWLEDGE

The digital image with its scale of gray values is a carrier of semantic information which must be "interpreted". So is human language.

Human language uses sounds and signs instead of gray values to convey meaning. A linguistic message is a string of mental images conveniently coded in sounds and signs according to certain rules, that will be decoded (understood) by those who master the code and are able to attach the correct meaning to such strings of sounds or signs i.e. to extract the semantic information, reconstruct the images the emitter of the message had in mind.

Differing sensibilities and capabilities as well as language and culture dependent constraints, make of human beings imperfect interpreters of the "real world": some cultures see - and speak of - only three colours in the rainbow whereas we have learnt that there are seven; some understand mountains + valley as only one mental unit whereas we dissect them as separate entities with some misterious limit in between. If we add to the culturally imposed fragmentation of reality our individual perception influenced by personal background and experience, discrepancies are still deeper.

An example of the way in which different languages segment part of the real world is shown in Table 1 where Umberto Eco's example has been expanded to include English and Spanish "equivalents".

We see here that even languages pertaining to the "occidental" world look upon Nature in different ways. What mental image does the concept "Wald" awake in a Dane and in a Spaniard when they see the word or the corresponding symbol on a map? Does it correspond to the semantic field of the German term? Is it fair to translate the Spanish "bosque" into the Danish "skov" knowing that both terms cover conceptual fields which are so different? How to know which of the Spanish words does apply when translating "skov" into Spanish? There is hardly any exact equivalent between the terms of two languages even when traditionally they are treated as synonymous in bilingual dictionaries.

A great deal of attention has been devoted in terminology to the definition of the field of knowledge so as to establish the structure of conceptual systems (the semantic space corresponding to individual terms or concepts). In this area in particular, thinking is still largely dominated by the traditional pen and paper processing techniques and by the relatively simple relationships that have sufficed until now (Sager, 1990). Here we have another paradigm shift which has not been fully recognised and assimilated.

Communication sciences and computation have come to the help of linguists opening new horizons in the study of language: modelling has entered linguistics. A model of knowledge is conceived in linguistics as a multidimensional space in which intersecting axes represent some kind of conceptual primitives or characteristics. They may also be seen as features or components. A concept, i.e. a unit of knowledge, can thus be represented and identified by reference to its coordinates along each axis. The sum of all the values with respect to each axis is then equivalent to defining the unique position of the concept in the knowledge space.

There is assumed to be a certain degree of dependency between dimensions - the characteristic "square" may limit the possibility of attribution of other primitive characteristics by rejecting a simultaneous characteristic of "round". Some structures may be conceived as hierachical, so that "square" may imply "geometrical". If structured concepts are admitted, it becomes possible to represent intersections, relationships and dependencies between concepts and groups of concepts. Since, however, most transmission of knowledge uses the discrete medium of language, we must accept the constraints of approximation imposed by linguistic communication. Therefore Sager (1990) postulates that the value of a concept with respect to a given axis is generally defined as a range and only exceptionally as a point. A concept must therefore normally be considered as occupying a region or a set of points in space and not a single point.

3 CONCEPTUAL LEVELS AND THEIR TRANSFORMATION IN IMAGE PROCESSING

We shall not indulge here in philosophical thinking about the nature of the "real world" since it would go beyond the scope of this paper. We shall just consider that the real world may be viewed from three conceptual levels, according to Figure 1: the level of reality, the iconic level and the symbolic level. The step from one level to the other occurs through transformations, here called "Projection" and "Semantic Modelling". In Linguistics we speak in this case of "Representation" and "Coding".

The explanation for transformation reality-photographic image (iconic level) is attained by means of physical models. Other transformations of this type are, for example, topographic maps. In any case we are faced with generalisation, i.e. geometrically and sematically reduced representations. Both the level of reality and the iconc level are readily recognizable by man since they involve analogue information.

Semantic modelling as far as this paper is concerned, is the transformation of the iconic level into the symbolic level. The result is a symbolic description of the real world. This allows the direct comparison of different types of images, maps, master plans, etc. in a way in which it had not been possible at the iconic level. Comparison and interaction are now feasible with the aid of a digital computer, the procedure being based, for instance, on declarative languages.

Transformations themselves require linguistic elements since they proceed following topological and logical interrelationships, with the help of grammars, graphs, semantic nets or production systems. At this level new abstractions are required, but the most important factor is the transformation (coding) of the fundamental information of the iconic level into the symbolic level with the least possible loss of information.

A very particular significance should here be assigned to language as a carrier of information. The degree of generalization, grammar, methodology and logical interrelation of signs and sounds also places language at the symbolic level. When speakers or writers/readers interact using the same semantic model, communication can be established. But this is not enough to ensure correct communication: another very important variable enters the game when context is taken into account. Yet, there is no general consensus about the relative importance of context and linguists are still discussing whether transference of meaning is possible without context (Sager, 1990).

Transferred to the understanding of images, this would mean to question "absolute symbolization". If context is so important to emit and understand a message correctly at the linguistic level, this means that there could be more to it than mere geometry and attributes at the image processing level .

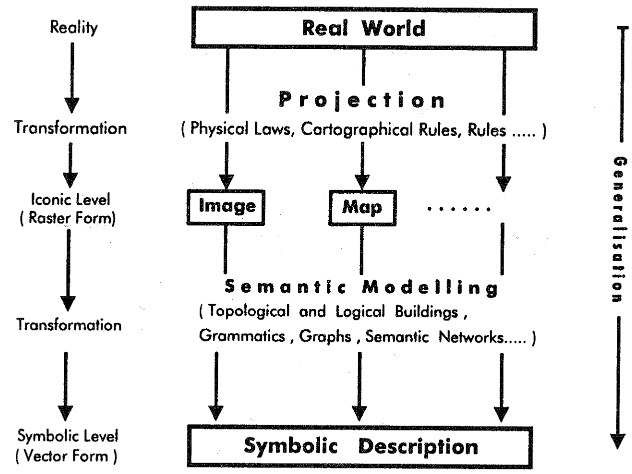

Fig. 1 : Conceptual levels and their transfomations

4 THE SYMBOLIC LEVEL: SEMANTIC NETS AND INTELLIGIBILITY

Fig. 2 shows a semantic net, how it is used to describe the modelling of parts of an image on the symbolic level (Bähr, Quint, Stilla, 1995). The scheme consists of nodes and links. Objects contained in an image or a map are represented by nodes (terms, concepts); their relationships are represented by different types of lines: *part links, specialization links* and *intstance links* each of which express different functions.

The logical structure of the semantic net depicted in Fig. 2 may be verbalised in the following way:

> "Vegetation, sealed surfaces and water are components of the concept "park" (connected to it by *part links*). Trees and grass are also to be found in a park (*part links*). Trees and grass are special types of vegetation (*specialization links*). Bariloche National Park and Hyde Park are local instances of park (*instance links*). Hyde Park Corner is a sector of Hyde Park (*part link*). It is a "meeting place" which is part of the concept "park" like, for example, "playing ground". Hyde Park Corner is a unique and localized instance of "meeting place" (*instance link*).

Compared to the iconic level, the structuring of a semantic net at the symbolic level is conceptually much clearer. It becomes evident, however, that both objects and their relationships are influenced to the highest degree by verbalization (terms and concepts) and thus are subject to imprecisions. These imprecisions are not only transferred together with transformations but also reproduce themselves negatively in the logical structure of the whole semantic net. No rigorous theory of this type of "error propagation" has yet been formulated but such a theory would be a prerequisite for semantic modelling not only of the deterministic but also of the stochastic component of the semantic net.

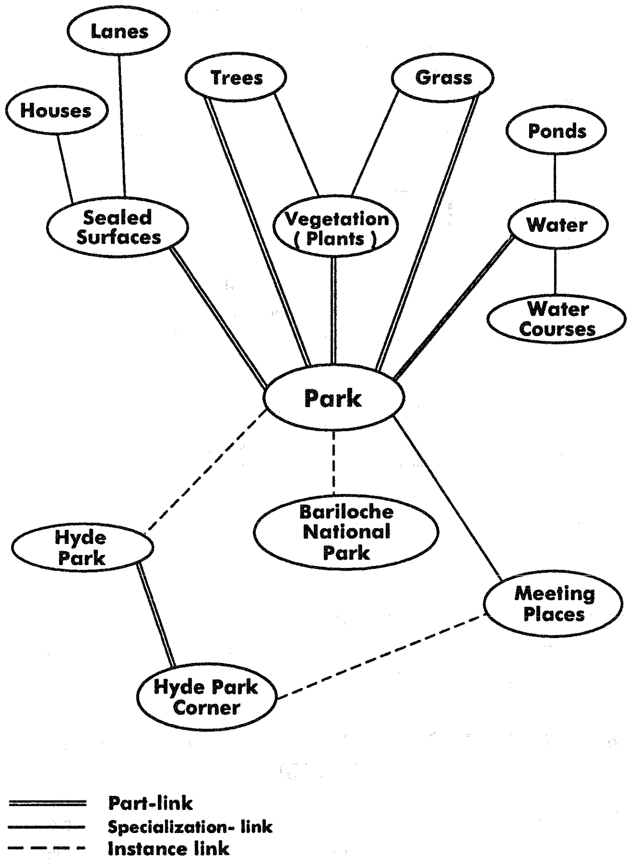

Figure 2: A semantic net

5 CONFUSION DUE TO UNPRECISE CONCEPTS

There are concepts and terms which are overloaded with semantic content and therefore have become unprecise. Linguists call them homonyms and we use them in everyday life without being aware of this phenomenon. If we take, for example, the term "garden", we see that it means: a place where flowers are grown in "flower *garden*"; it does not mean a place where children are grown in "kinder*garden*" but a place where very small children receive their first education. A "japanese *garden*" is not a garden in Japan but a certain arrangement of small ponds and bridges, trees and bushes, grass and flowers not to speak of "the *Garden* of Eden" the mental image of which surely differs in all of us.

Only when we are asked to explain concepts do we discover how difficult it is to come to a clear definition, to choose the distinctive characteristics, those which describe the most important features or the features of interest. For example, how can "sealed surfaces" be described? Which are the key elements? Constructors involved in the construction of buildings might understand "roofs, walls and floors covered by a waterproof material so as to keep humidity out of rooms"; urbanists would define sealed surfaces by "surfaces that do not absorb rainwater". Photogrammetrists on the other hand might define them as surfaces having a certain spectral signature. Words like "park" as represented in Figure 2, may stand for a special type of public greens, an existing area within an urban settlement or a surface foreseen in a master plan to be developed into a park in the future; moreover, the concept also covers a specially beautiful sector of the landscape which is protected by law.

A single term with multiple meanings can be compared to a single spectral signature which represents different land use classes in Remote Sensing (Fig 3).

Figure 3 shows land use classes in a confusion matrix. Forest, meadow, swamp and park might show similar sectral signatures and might accordingly be assigned to the same class. An object "square" could be assigned indistinctly to "sealed surface", "road", "parking site", "industrial area" and "residential area". The question which is the correct designation in each case is clarified through context.

This kind of non-identity of the representations is an enormous problem for semantic modelling.

6 CONFUSION DUE TO INACCURATE DISTRIBUTION

Another source of inaccuracy and uncertainties when it comes to the description of objects at the symbolic level are unsharp boundaries. In the real world sharp boundaries do not exist but are individually defined by discrete assignment.

This also applies to apparently simple concepts like "building". In the German cadaster, for example, not only the building, the constructed structure but the whole parcel is given the label "bebaut" (occupied by a building) no matter whether such structure occupies the whole lot or not.

Instances for objects with imprecise definitions are all forms of "mixtures" (e.g. mixed forest or biotope). The distribution of species and the occurrence of disease also fall into this category.

The problem of unsharp boundaries has to do with inexact quantities. When does "water" deserve the label "polluted water"? Where is the limit between "scarcely populated" area and "densely populated" area? Still worse: where are the boundaries of objects which due to their very nature do not have clear cut limits (mountains and valleys) and are therefore defined without precision?

Errors resulting from the combination of this type of elements are extremely difficult to model, especially when the term designating such phenomena is polysemous (has many meanings). The stochastic description of geometrical parameters appears to be almost trivial when compared to the corresponding modelling of semantic parameters.

7 CONFUSION DUE TO INAPPROPRIATE METHODS

Linguistic difficulties with semantic modelling are not limited to terminology, to concepts and terms. They are overlapped by a phenomenon related to methodology and to graphic primitives.

An example will make this clear: we use the tools of Analytical Geometry for the semantic modelling of images although neither points nor lines exist in the real world or in photographical images, not to mention "digital" ones. Nevertheless we use such elements and the related models without being aware of the difference with reality. It is not surprising, therefore, if such models are only able to model reality in quite an imperfect way. The convention "points and lines" belongs to the domain of the symbolic level. They are artificial concepts, genially conceived and have been useful for thousands of years but they are foreign to the real world.

Another example of the fact that semantic modelling still clings to concepts and metaphors which are characteristic

	Sealed Surface	Road	Parking Site	Square	Indust. Area	Resid. Area	Water	Park	Swamp	Grassland	Forest
Forest								X	X	X	X
Grassland								X	X	X	
Swamp							X	X	X		
Park						X	X	X			
Water							X				
Resid. Area	X	X	X	X	X	X					
Indust. Area	X	X	X	X	X						
Square	X	X	X	X							
Parking Site	X	X	X								
Road	X	X									
Sealed Surface	X										

Figure 3: Confusion matrix for land use semantics

of the analogue and analytical world (Kuhn, 1993) are the concepts "generalisation, resolution and scale". The concept "scale" loses meaning when we describe the real world by means of analytical methods, i.e. with coordinates. Coordinates conform to reality by principle in scale 1:1. The concept of "scale" as we use it in every day science, is therefore always related to the *visualisation* of the real world.

This does not apply to generalisation, at least not to an important part of it. The so-called "generalisation during data capture" is basically scale-independent. Scale onlys acquire importance when considering a posterior visualisation of the captured information. The concept "generalisation" is very helpful for semantic modelling, which is not the case of the concept "scale". It was shown in Figure 1 that transformations of the real world over the iconic to the symbolic level always impliy generalisation of the "generalisation during data capture" type.

"Resolution", finally, is a concept that has many aspects. Originally it described the quality of sensors and their components. In this sense, the modulation transfer function is a measure of the resolution of sensors which describes mathematically in a very elegant way the effects of each component. For semantic modelling this is of little use. The concept of resolution in this context must be understood as the capacity to recognize and label an object. If this is to be accomplished today with modern tools and the assistance of a computer, it should be stated here that even with analogue processes, resolution was defined in relationship with "recognizability of objects".

The discussion over the terms "point", "line", "generalisation", "resolution" and "scale" shows that they stand for images that have each of them be developed in an individual technological context and that they are only wholly applicable there. In a different technical context the direct transference can only lead to confusion which is basicalle of linguistic nature in a similar way as unprecise terms.

8 CONCLUSION: OLD PATTERNS OF THINKING BLOCK SOLUTIONS

New materials and new tools, *consistently used*, must lead to new products. This requires a wide theoretical analysis, even new patterns of thinking.

In oposition to the coordinates of the analytical photogrammetry, the new material, "digital images" carries not only geometrical but also semantic information. The value of the new products is characterised by attribute data, less by geometrical data. The methods of adequately describing such data are today in full evolution. The human operator shall in the future be substituted in the highest possible degree by computer assisted procedures

It is our main aim to show that new patterns of thinking are required or, in other words: without the disposition to radically question apparently logical model assumptions (in the real world there do not exist such things as "points"!) *false assumptions* are created, blocking scientific progesss. It should then not be surprising when *complicated theories* and *unsatisfactory results* are obtained.

An example shall suffice: The (*false*) *assumption* that the Earth is the centre of the Universe, lead to *complicated theories* to explain the plante epicycle, precisely an *unsatisfactory result*.

That is why image semantics cannot be treated, for example, with the methods of Analytical Geometry. It is apparently feasible, but it *complicates the theory* and *unsatisfactory results are obtained.*

REFERENCES

Ackermann, Friedrich, 1995. Digitale Photogrammetrie - ein Paradigmasprung. Zeitschrift für Photogrammetrie und Fernerkundung, pp. 106-115.

Bähr, Hans-Peter, Franz Quint and Uwe Stilla, 1995. Modellbasierte Verfahren der Luftbildanalyse zur Kartenfortführung. Zeitschrift für Photogrammetrie und Fernerkundung. pp. 224-234.

Eco, Umberto, 1976. A Theory of Semiotics. Bloomington: Indiana University Press.

Kuhn, Werner, 1993. Metaphors Create Theories of Users. In A.U. Frank and I. Campari (Eds), Cosit 1993: Spatial Information Theory, Springer.

Kuhn, Werner, 1994. Defining Semantics of Spatial Data Transfers. In 6th. Symposium on Spatial Data Handling, Edinburgh, U.K. T.C.Waugh and R.G.Healy (Eds).

Rapp, Friedrich, 1995. Modell und Realität. Zeitschrift für Photogrammetrie und Fernerkundung, pp. 220-223.

Sager, Juan C, 1990. A Practical Course in Terminology Processing - with a bibliography by Blaise Nkwenti-Azeh. John Benjamins Publishing Company, Amsterdam/Philadelphia.

Saussure, F. de, 1916. Cours de Linguistique Générale. Paris: Fayot.

Wittgenstein, Ludwig, 1921. Tractatus logico-philosophicus. Ostwalds Annalen der Naturphilosophie, Routledge & Kegan Paul Ltd., London.