# Geodesy and Semantics
## Progress by Graphs

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### 1. Abstract

In Germany, basic geodetic research is coordinated by the German Geodetic Commission. Presently, semantic modeling is emerging from image analysis. In this respect, new challenges are identified besides well known problems which are put into a new context, like *terms*, *concepts*, *knowledge representation*, *isomorphism*. It has been shown that nets and graphs of all kind form suitable tools for knowledge representation and knowledge processing.

As an example, ERIK GRAFAREND is displayed in a semantic graph.


### 2. Research Coordination by the German Geodetic Commission (DGK)

„Quo vadis geodesia" honors ERIK GRAFAREND and his contributions to our professional field. In addition to the many distinctions and responsibilities, he recently was elected Chairman of the Scientific Board of the German Geodetic Commission („Vorsitzender des Wissenschaftlichen Beirats der Deutschen Geodätischen Kommission"). This is a very demanding and important position since the „German Geodetic Commission" (DGK) affiliated to the Bavarian Academy of Science, coordinates teaching and research in the German geodetic community. It has to be pointed out, that „Geodesy" in German covers a somewhat broader understanding than as is conventionally the case within the English context. This means, that the DGK includes - besides the „core Geodesy" - surveying, cartography, photogrammetry, remote sensing and land management. The fixed number of the 45 ordinary members integrated in the DGK are elected; they represent geodetic competence in the broad sense and try to focus diverging activities.

Positive results may be shown for research programs emerging from the DGK on long-term themes of the international scientific community. An example from the „core Geodesy" is the „Forschungseinrichtung Satellitengeodäsie" established in 1983 as a follow up to the scientific program SFB 78, which integrated academics as well as experts from federal administration and which led to the installation of the Geodetic Fundamental Station in Wettzell in 1972.

Within the DGK, particularly within the Scientific Board, challenging research themes are defined, thoroughly discussed and formulated for submission as long-term projects. The overall aim is scientific progress in the geodetic field through contribution from different areas and resulting synergetic effects.

Another activity in this respect is the joint program „Semantic Modeling", funded by the German Science Foundation (DFG) since 1993. At the end of the 80´s, an idea emerged in the DGK to try something similar to the very successful "Satellite Geodesy Program" in the photogrammetric domain. Under the chairmanship of FRITZ ACKERMANN a group of a dozen experts from photogrammetry, cartography and computer science developed a program on „Semantic Modeling". A first phase integrated research teams from 8 German universities, documented in W. FÖRSTNER/L. PLÜMER

(Eds., (1997)). The second phase is coming to an end in the year 2000, documented by a second SMATI workshop (SMATI 1999, Munich).

## 3. Limitations of Geometric Models

According to the famous definition of F. R. HELMERT (1880), Geodesy is “the science of the measurement and mapping the earth´s surface“ (translation taken from TORGE 1980). This definition is basically given from a *geometrical* point of view. The realisation of this task requires primarily geometrical tools. However, today there is an overall tendency to incorporate more rigorously attributes in order to describe the earth like concepts, semantics, context and related tools.

The geometrical description of objects, at least from the conventional geodetic point of view, uses analytical models which were introduced by Greek philosophers and scientists. We have to stress the fact, that these models are very useful; but they are nonetheless *models* and may not fit to the „real world“ as they describe reality only in a limited way. There is evidently no „point“ in the real world, a fact, which causes some difficulties. To quote LAKOFF (1988):

*“Theories may become so ingrained in our culture or in our intellectual life that we do not even recognise them as theories .........“.*

The real world is perceived by human beings as continuous while it is represented in digital image processing by discrete primitives. This contradiction is reflected by the complementary models in spatial and frequency domain, too.

Geometry may be considered as just an attribute of objects among others. In geodesy, however, including cartography and photogrammetry, geometric properties are given a prominent importance. On the other hand, interpretation of the surveyed objects has always played an important role in cartography and photogrammetry. Nevertheless, one was not aware of this condition, as object attributes (i. e. semantic features) were spontaneously added to the measured geometric parameters by the human.

This situation changes dramatically when the computer has to be trained to take over not only the geometric domain but also the semantics, for instance in image understanding. This step requires „modeling of semantics“, which has proved to be a challenging task for the geodesist who exhibits a tendency to overestimate geometrical properties.

Rigorously spoken, it is not possible to separate geometry and semantics. Both features are essential for complete object description.

## 4. The Nature of Knowledge

When entering computer vision geometric and semantic features have to be modeled together in a much broader context. The more general concept of *knowledge* is taken, which is a very useful metaphor (LAKOFF,G.AND M. JOHNSON, 1980), when describing retrieval from pictorial information assisted by the computer.

There are several definitions of knowledge. KEITH DEVLIN (1991) formulates: „knowledge involves a mental state and a concept of truth“. This is a very cautious attempt to describe the environment. MAKATO NAGAO (1990) forms an equation: „knowledge = cognition + logic“. The latter definition is obviously more useful, as „cognition“ is a more human oriented, general concept than „truth“. Finally,

„logic“ includes a systematic model of knowledge which seems to be essential. Logic, order, rules, systematization etc. might be indispensable properties included in knowledge. We shall discuss this again in the next paragraphs.

Without losing the level of general acceptance we have to discriminate factual and procedural knowledge. Factual knowledge lists facts whereas procedural knowledge gives rules for action. In image analysis both contribute synergetically. We are going to show later that both domains must not be separated.

It is no wonder, that the two natures of „knowledge“ are evident in many different disciplines. In language science for instance *words* correspond to facts whereas *meaning* is based on rules within a context. In mathematics and computer science *declarative* algorithmic languages, like PROLOG are separated from *procedural* languages like FORTRAN. In philosophy, *representationistic* views (i. e. ARISTOTELES, FREGE) have to be discriminated from *instrumentalistic* approaches (like PLATON, WITTGENSTEIN), - see R.KELLER (1995), H.P. BÄHR (1998). Finally, in psychology, *male* is attributed to facts and *female* to rules.[1].

## 5. Knowledge Representation and Knowledge Processing by Graphs

What are the available tools to represent and to process knowledge? According to NAGAO this has to be based on logical rules. There are many alternatives but we think that graphs (networks) offer the best tool to structure knowledge. This is due to the twofold nature of knowledge, factual and procedural, as discussed in the previous section. Graphs may easily take *nodes* for the concepts (or facts) and the connecting *edges* for the context (or rules). Beside this, graphs allow the easy inclusion of topological features.

In image analysis, in language - or in whatever field where knowledge has to be represented and processed - facts, like objects or concepts are often overestimated or given too much importance in comparison to the interrelations which model the context like meaning or semantics.

In artificial intelligence, many solutions have been proposed for representing knowledge in nets (see H.KOCH et al. (1997)). Artificial neural networks try to simulate the process of learning in the human brain. They form an *implicit* representation of knowledge, i.e. knowledge representation and knowledge processing are elements of the same system. Information is introduced by the human operator during the analysis procedure. This is also true for Delaunay-Triangulation, another network tool which has shown good performance in image processing (K.-J. SCHILLING and TH. VÖGTLE (1996)). Graphs for implicit representation of knowledge follow a pragmatic approach. There is no rigorous modeling of the nets but just a heuristic approach.

This is not the case for *explicit* representation of knowledge in networks. Knowledge is thoroughly modeled a priori (according to NAGAO) in Semantic Nets or Markoff Random Fields to mention just two alternatives. Nevertheless, these tools allow not only knowledge representation but also knowledge processing.

Both, *implicit* representation or *explicit* representation of knowledge by graphs are adequate to serve the twofold nature of knowledge as described before. Besides the facts, they model the interrelations between concepts which contain the context. The context, however, determines the *meaning*, the *semantics* of both linguistic or visual features. To quote WITTGENSTEIN (1953): „ *for a large class of*

[1] *“Willst Du erfahren was sich ziemt, so frage nur bei edlen Frauen nach”* (Goethe, Torquato Tasso)

*cases though not for all in which we employ the word „meaning" it can be defined thus: The meaning of a word is its use in the language*". WITTGENSTEIN puts the word, the fact, in its individual context. The appropriate tool to do this in computer graphics is within a network.

Semantic networks (like in H. NIEMANN et al. (1990) and F.QUINT (1997)) are formally structured. This is not the case in neural nets that we humans build through continuous learning. D. HOFSTADTER ( 1979, see Fig. 1.) gives us an insight in a „tiny portion of the author´s semantic network". He groups his associations and relations between the main concepts of his book, GÖDEL, ESCHER and BACH. Figure 1 shows a small segment of the „tiny portion" given in his book directly associated with *Bach*. There is one cluster formed by *Bach*, *Goldberg*, *music*, *canons*, *fugues*, *musical offering*. Another group is composed by *semantic*, *language, sameness* and *isomorphisms*.

## 6. Sameness in Geodesy and in Semantics

In section 4 we stressed the fact that a semantic network reflects the design of a particular individual. Consequently, Figure 1 gives the associations of DOUGLAS HOFSTADTER. Nevertheless, we may follow him „more or less". It is most probable, that all possible readers of this text associate „Bach" with „Music". However, the association of „Music" and „Language" as given in Fig. 1 may be less common; it is part of the particular message DOUGLAS HOFSTADTER gives in his famous book on „GÖDEL, ESCHER, BACH: An Eternal Golden Braid". There are different reasons for accepting or not accepting an individual semantic network. As for the trivial case, concepts may be simply lacking - I am, for instance, not so sure that every reader has grasped the term „musical offering" („musikalisches Opfer"). It is obvious that *language* plays a most important role in semantic networks. This aspect will not be treated here in more detail (see H.-P. BÄHR and A.SCHWENDER (1996)).

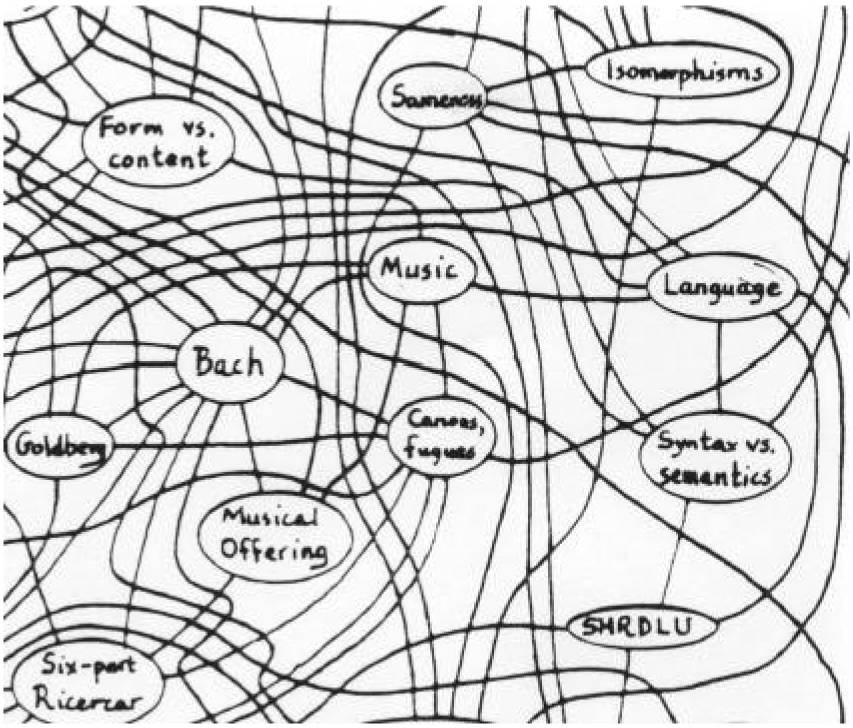


Fig. 1: A tiny portion of Hofstadter´s semantic network (HOFSTADTER 1979)

A fundamental question is how to define sameness in semantic networks. It cannot be done, obviously, just by “matching” the nodes, i.e. the concepts. As we showed earlier, the interrelations between the „facts“, the context, has seriously to be taken into account.
Interestingly, in Geodesy we encounter basically the same problem. It corresponds for instance to the question: „Does a measurement fit“? In image processing the definition of „homogeneity“ leads to the same problem. The assignment of a pattern of spectral signatures to a predefined class is of the same nature. A real world pattern will never fit exactly, same like individual semantic networks. Nevertheless, *sameness may be accepted under certain given conditions*.

This discussion leads to the concept of isomorphism. Isomorphism between two semantic networks does not only require sameness of facts, concepts or nodes in the graph, but also sameness of the “triggering pattern“ as described by HOFSTADTER. This includes the interrelations between the nodes, which means, that beyond a certain level of detail, there will be no identical webs existing at all.

HOFSTADTER gives the example of spider nets, which never will be fully identical. Difference can be looked at in a local or in a global context. For given conditions, two nets may be accepted as identical locally or globally.

Geodesists are well prepared to contribute to the challenging discussion on sameness of semantics, as they are trained to evaluate fitness of data. However, one should know that fitness of semantics like in feature extraction from imagery, leads to much more complex problem compared to purely geometrical questions.

## 7. Conclusion: Erik Graph-Arend Displayed in a Semantic Graph

Figure 2 shows a „tiny portion“ of the author´s semantic network focussed on ERIK GRAFAREND.

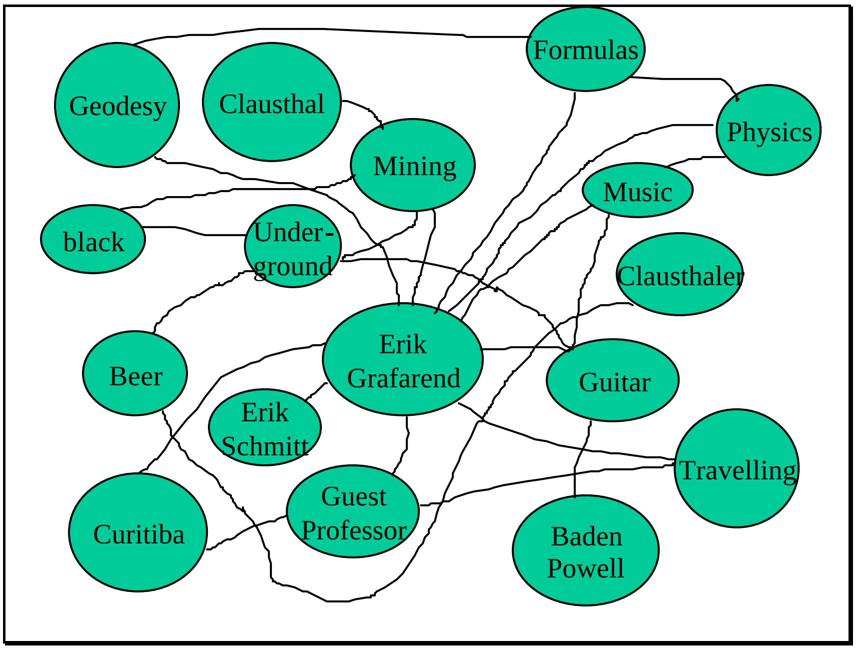


Fig. 2: Erik Grafarend in a semantic network

I did this performance, nota bene, spontaneously; there is obviously no hierarchy, no weighting, no completeness, just associations. But this is the way we are organised. Sometimes chaotic systems may be superior to formally well-structured ones. We have to confess that this is in contradiction to what had been postulated for "knowledge" in section 4.

It is true what was said earlier, that any individual who knows ERIK GRAFAREND, will have his/her own background, that means he/she would design a very special network. Anyway, some of the concepts in the nodes will necessarily match like *geodesy*, *guitar* or *formulas*. Others, like *Curitiba* or *Erik Schmitt* are characteristic for the author´s web and show limited access from outside.

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