# Acquiring Implicit Knowledge by Cognitive Semantics Mapping

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**Abstract.** This paper describes one way of representation of expert's knowledge aimed at revealing implicit semantics associated with the chosen domain. For this, two important techniques are combined. First, a space of metaphors is selected to complement a given set of the domain stimuli. An expert then performs a subjective scaling quiz on both domain stimuli and metaphors. Second, a geometrical representation of expert's answers is built and analyzed. The result is interpreted in terms of theories of psychological meaning. The paper discusses the approach and proposes a template for arbitrary experiments of such ways of knowledge elicitation.

## 1 Introduction

Recent years have witnessed increased interest in knowledge modeling in a cognitive context. Increasingly, the focus has been on exploring the structure of individual knowledge space. These include ontologies, frames, rules and semantic network. Researchers and practitioners in areas such as cognitive science, intelligent systems, HCI, and ontological engineering are increasingly recognizing the importance of the hidden implicit factors in developing believable, realistic and robust knowledge bases, and effective intelligent systems.

Knowledge Engineering (KE) traditionally emphasized and developed a range of techniques and tools to support knowledge acquisition, conceptual structuring and representation modelling [1], [7]. These techniques may lead to rather superficial or unrealistic models if there is no proper account for so called 'cognitive factors', which are introduced by different parties involved in a knowledge-based system design (the expert, the knowledge engineer or the analyst, the user or the stakeholder).

Each of these people has her/his own world (or domain) model, which contains the following components:

- Language (vocabulary), which obviously divides into the common and the professional one;
- System of values;
- System of meanings.

The first of these components is most difficult to neglect and most easy to account for. For the system of meanings, however, this situation is opposite.

The term 'meaning' is treated differently by, e.g. classical linguistics and the modern cognitive science. Here we adopt the latter approach and focus on what does a particular object or concept really mean for the person. The system of meanings comprises an important part of the person's world model and overlaps with his or her system of values.

Every specific subject domain maintains its own combination of the formalized and reproducible knowledge on the one hand and the unique professional experience of its experts on the other hand. The more is the role of the latter in a particular do-main the more important is to account for the expert's system of meanings.

Uniqueness of a person's experience and, consequently, her/his world model, is important for him or herself and possibly for close others. It may be so important for her/his consultant psychologist that it leads Kelly to claim that every respondent deserves building and studying her/his individual psychological 'theory', hence the term 'Personal Constructs' Kelly introduced. But the uniqueness of the world model of a professional expert, materializing, e.g. in her/his intuition, may be important for much wider scope of individuals.

The approach this paper concerns shows the wider capacities of the (so called) psycho-semantic methodology that allow reconstructing implicit semantics of the expert's knowledge using the subjective scaling where the choice of cognitive stimuli is rooted in the metaphor theory. Such way of knowledge elicitation and mapping reveals the hidden latent knowledge that may be even unconscious.

## 2 An Overview of the Metaphor Theory

The purely linguistic theory of metaphor is developed by Richards, Black, Riqeur and others. A more cognitive approach to metaphor is given in [4]. It is explained here in terms of the concept of the person's world model, which was introduced above.

The use of metaphor helps to transfer person's unique experience (see above) to other through a "system of associated commonplaces" (see [2]). Metaphor functions as a filter. It shadows some details of an object and highlights the other ones, thus organizing our view on things. Moreover, metaphor connotatively emphasizes this specific view. Metaphor "provokes" a certain "attitude" (a value-driven approach) to a thing and causes a shift in our perception of that thing. Via a metaphor the person "tutors" others how to deal or to handle that thing operationally rather than describes what it actually is.

Each metaphor has two objects it refers to and compares to each other. One is called 'tenor' and it's the actual thing under consideration. Another one is called 'vehicle' and it's what actually makes the comparison a metaphor. To be able to function as filter for those features of the 'tenor', which are not obvious but rather unexpected to the listener, the 'vehicle' should be quite distant from the tenor in terms of their intrinsic ontological properties.

Let's summarize what makes metaphor relevant to our approach:

- Metaphor is a filter, which extracts some hidden, unexpected or non-trivial features of the object.

- Metaphor emphasizes some of these features and attracts one's attention to them.
- The main characteristic of these features is that they answer the question "how to deal with...?" rather than "what is it?"
- When applied to a set of objects, connected by some meaningful relationships, metaphor builds a "parallel" space of objects, which is isomorphic to the first one w.r.t. these relationships.

## 3 Eliciting a System of Meanings via Classical Subjective Scaling

Subjective scaling is a formalized interview, where a respondent is given a series of questions with the closed form lists of answers. The list of answers is the same for all questions. Each question contains an invariant part – the instruction – and a varying pair of stimuli which are subject to comparison. There are certain methodological constraints on the choice of stimuli, e.g. all of them should be taxonomically homogeneous. But in general this choice is more the result of art than of a formal procedure. All pairs of stimuli are presented to the respondent in a specially arranged random order, so that each stimulus appears in the sequence of interview with a reasonably homogeneous frequency. An example of the interview form is presented on Fig. 1.

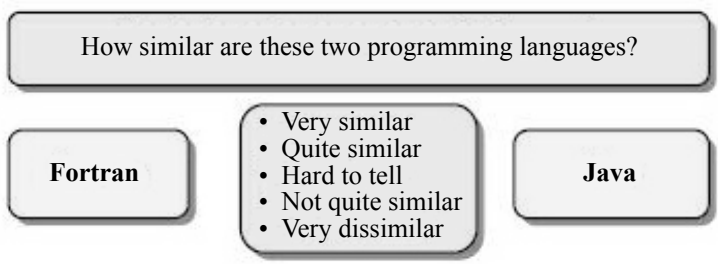


**Fig. 1.** Layout for a Subjective Scaling Interview.

A numeric (usually integer) value (not visible to the respondent) is assigned to each category in the list of answers. In the case shown on Fig. 1 one can have a scale ranging from 1 for the "Very similar" category up to 5 for the "Very dissimilar" one. The chosen value, upon each respondent's selection, is recorded into a triangular matrix. This matrix is processed by one of the subclass of the multivariate statistical methods, called multidimensional scaling [3]. The aim of such processing is to unfold these ratings as if they were "distances" in some flat Euclidean space. If such unfolding occurs "successful", i.e. the resulting geometrical distances between the points, representing our experiment objects, reproduce the original ratings with enough accuracy; we may interpret that space as an adequate approximation to the respondent's world model (i.e. its projection on the domain of interest).

The interpretation of such a geometrical model is usually twofold:

First, one may try to discover the meaning of the resulting *coordinate* axes in that space. These axes roughly correspond to *factors* in factor analysis. Thus, having "explained" these axes, we get information about the basic categories, or basic (*latent*) constructs with which the respondent evaluates and orders the elements of his/her world model.

Second, one may look on the compact *clusters* of points in that space and try to interpret them as "unnamed" (again, latent) taxonomic units, residing in the respondent's "personal" cognitive model of the domain.

In the current paper we illustrate both the classical and the metaphoric versions of subjective scaling by studying the 'domain' of programming languages. Obviously, this domain is more appealing to the audience than many more professional examples, e.g. one described in [10]. Other reasons are:

This domain provides enough room for the expert's experience and intuition.

It's easy to pick 'experts' in programming languages. To be specific, we restricted ourselves to professional programmers, working in the field of artificial intelligence.

The interpretation of results is straightforward.

This research is also of special interest because of "white spots" is the field of investigation of programmers' problem-solving behavior [9].

The basic concept space, i.e. the set of elements, representing the domain of interest, was built of a list of several more or less popular programming languages, including:

- The AI languages;
- The traditional procedural languages;
- The so called "macro", or "script" languages, usually met in the operating system shells, word processors, etc.

For the reasons of article space, we present here the complete result and interpretation of only one of our experiments.

Our respondent is a high level system programmer, working in a team, which develops software tools for artificial intelligence. His professional programming language is C (not C++). Processing of his answers on the first stage of the experiment has resulted in the following graph of the two most dominant axes (see Fig.2).

This graph evidently reflects the usual, generally accepted taxonomy of programming languages and expresses little new with respect to the shallow, verbal knowledge of everybody, who is aware of this domain. It is interesting, that despite of its objective correctness, the respondent felt "uncomfortable" with this picture. Furthermore, it appeared unexpectedly difficult for the respondent to explain this picture.

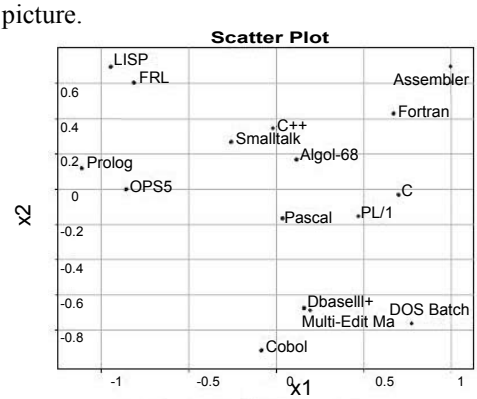


**Fig. 2.** Results of Classical Subjective Scaling.

We interpret this difficulty as a consequence of the respondent's high professionalism, when the "scholar" taxonomy of objects is replaced by a "personal" one which was elaborated during the professional practice and reflects the respondent's specific domain experience.

## 4 Metaphor-based Subjective Scaling

Let's conservatively extend the procedure of the classical subjective scaling to in-corporate basic building blocks of metaphor, that is, the 'tenor' and the 'vehicle'. We retain the original list of stimuli unchanged, and these will represent tenors for the metaphors we'd like to form. The vehicles are taken from another list of stimuli, of a reasonably comparable size to that of the main one. This list requires some special considerations. First, vehicle should be quite ontologically distant from tenors, as mentioned above. Second, metaphoric objects should be appealing to the experts as well as to the stakeholders of the research, including the audience of our publication.

To continue the example of the domain of programming languages, we used three versions of 'metaphoric spaces': animals, cars and tale/folklore heroes.

The interview procedure was adjusted to include only the comparisons of tenors to vehicles. The form layout looked similar to one, shown above, but representing a statement of the form: "X ... is just a ... Y". The categories for answers were also numbered to give maximum similarity to "Yes!" and maximum dissimilarity to "No!". The sets of respondents' answers were processed with correspondingly modified methods of multidimensional scaling.

The most interesting results were obtained with the literature heroes' version. In our paper we present just one of the collected results. The set of chosen tale, animation and the children literature "heroes" was:

- Muenchhausen, a famous liar, visionary;
- Foolish Ivanushka, Russian fairy tale hero;
- Pinoccio;
- Karlson;
- Donkey Eeyore, Miln's book hero and others.

All of them are well known for the Russian-speaking respondents.

The graph, visualizing the answers of one of our respondents (same as in the above section), is shown in Fig. 3.

Because of the context dependent functionality of the metaphor objects, it is impossible to interpret this result "as is", considering only the generally accepted characteristics of the objects, involved in it. Therefore, the analysis of this graph concluded in a joint interpretation session, when the respondent was asked to explain the layout of the graph in his proper, individual terms.

First, the respondent emphasized overall "agreement" with that picture, there occurred nothing which would disturb him.

Second, we see the obvious difference of this picture from the first one. The possible explanation is rooted on the difference between the "objective" classification of domain elements and respondent's personal attitude to them, which reflects her/his professional skill and expertise.

The meaning of the two major axes was verbalized as follows:

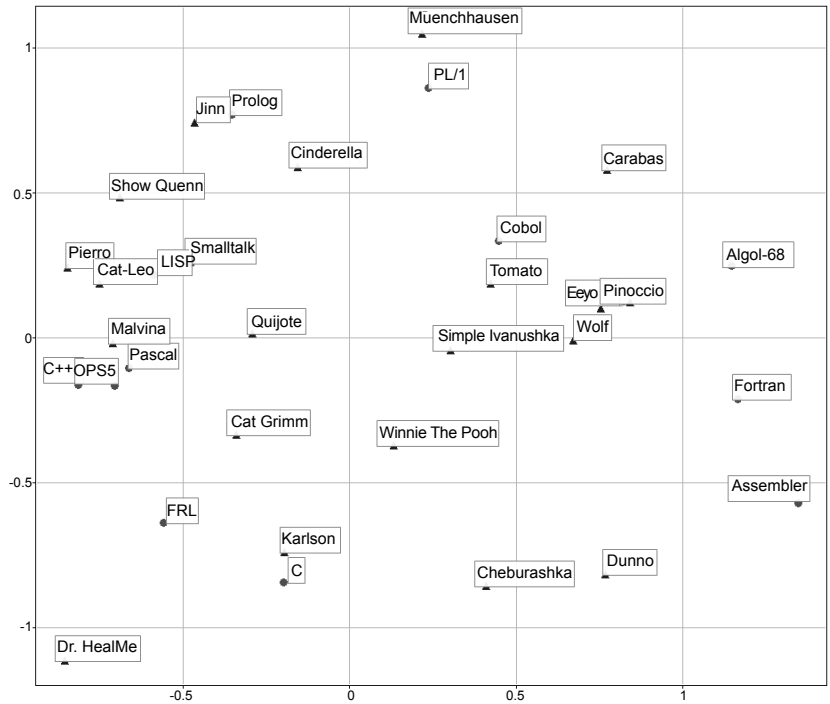


**Fig. 3.** The Results of the Metaphor-Driven Subjective Scaling.

- Axis 1 (Horizontal)

*The Negative Pole (Left)*

"Crude", eclectic creatures without an internal integrating nucleus.

*The Positive Pole (Right)*

Creatures with refined, subtle properties, combined with significant conceptual integrity.

- Axis 2 (Vertical)

*The Negative Pole (Lower)*

"Extraversion" (respondent's term), i.e. intention to operate accordingly to the external cir-cumstances, to what is required by the situation met in reality, whatever attitude to it might be.

*The Positive Pole (Upper)*

"Introversion", i.e. intention to act accordingly to some internal principles, whatever inadequate they would be w.r.t. the current objective context. Orientation on "miracle" as a possible problem solution.

This interpretation is made by the respondent without any influence or guidance by the researcher. One can hardly expect that such information could be captured during traditional interview.

The relative grouping of the languages also corresponds to the way our respondent would recommend (or not) using this or that programming language in a given con-text. Therefore, the 'metaphoric' graph closer than the classical one reveals the professional expertise of our respondent and the fact that this particular respondent would be invited as an expert in programming languages.

The classical result, being in full conformance with the textbook knowledge on the domain, corresponds to the use of that textbook rather than a human expert in a particular problem context.

## 5 The Metaphoric Subjective Scaling as a Semantics Elicitation Tool

Knowledge Reengineering methodology as one of the most developed tool to approach domain semantics, is still more art than science [6] and metaphor subjective scaling may serve as one of the most effective methods in the wide palette of the set of its techniques.

The strongest point in this approach is the ability to elicit the hidden cognitive constructs that reengineer the whole semantic space of expert's knowledge patterns. These hidden constructs create the real conceptual model of expert's vision of the domain. We all know how the world should be, but only few know how it is. Metaphoric scaling reveals that implicit priorities, values and attitudes. Such method may be not as often used as other KE techniques. At Fig. 3 we propose our classification of well-known methods and the role of metaphoric scaling may be rather modest. But as a complimentary method it may facilitate the general KE strategy with a novel bias.

The possible drawback of metaphoric approach is the search of a proper set of metaphors. Such search requires the special creative skills and a wide mental outlook of the knowledge analyst. During our experiments we tried to apply severat metaphoric sets – e.g. cars, animals, furniture, construction tools, etc. The difficulty is not only in the right set of metaphors but in its matching and clarity to the interviewed expert. The socio-cultural and gender differences may also play the crucial role in the overall feasibility of the approach.

## 6 Conclusion

Saving and disseminating knowledge and experience is one of the main challenges for current knowledge management (KM). Our approach addresses the challenges of KM by modeling the implicit knowledge structures, i.e., specific knowledge patterns situated in a particular problem solving context.

The described experimental technique of cognitive science shows its applicability for the problem of knowledge acquisition and reengineering problems in soft subject domains, where a practically relevant expertise depends on the intuition and the experience of a live human expert.

Of course, experiments in cognitive science, involving interviewing people, are tedious, error-prone and difficult to extrapolate onto the whole (target) population. Nevertheless, once properly interpreted, these experiments can provide a useful insight for a knowledge engineer. They also tend to increase the 'objectiveness' in this area of research, though not up to the level, normal for natural sciences.

The objective of this paper was to propose an interdisciplinary approach where psycho-semantics can be used as a knowledge engineering and re-engineering tool.

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## References

1. Adeli, H. Knowledge Engineering. McGraw-Hill, New-York (1994)
2. Black, M. Models and Metaphor. Ithaca, Cornell University Press (1962)
3. Cox, T.F., Cox M.A.A. Multidimensional Scaling. CRC Press (2001) Gordon, D. Therapeutic Metaphors: Helping Others Through the Looking Glass. Meta Publications (1978)
4. Richards, I. A. 1936. The Philosophy of Rhetoric. Oxford, Oxford University Press (1936)
5. Gavrilova, T. Ontological Engineering for Practical Knowledge Work // LNAI 4693, Proc. of 11th Int. Conf. "Knowledge-Based Intelligent Information and Engineering Systems KES 2007", Italy, Springer, 1154-1162 (2007)
6. Gómez-Pérez, A., Fernández-López, M., Corcho, O. Ontological Engineering with examples from the areas of Knowledge Management, e-Commerce and the Semantic Web, Springer (2004)
7. Ricoeur, P. The Rule of Metaphor: Multi-Disciplinary Studies in the Creation of Meaning in Language, trans. Robert Czerny with Kathleen McLaughlin and John Costello, S. J., London: Routledge and Kegan Paul 1978. (Toronto: University of Toronto Press 1977) (1975)
8. Sutcliffe, A.G., Maiden, N.A. Analysing the Novice Analyst: Cognitive Models in Software Engineering. Int.J.Man-Machine Studies 36, 719-740 (1992)
9. Voinov, A.V., Demikova, N.S., Kobrinsky, B.A. 2006. Vocabulary Scaling in Medical Informatics: Knowledge Engineering and Intellectual Data Analysis. In: Proc. Intl. Conf. on AI-2006, Obninsk