Meta-modeling using Space

Understanding models in terms of locations and movements

Jens Gulden

Hermann von Helmholtz-Zentrum für Kulturtechnik, Humboldt-Universität zu Berlin
Formale Modelle, Logik und Programmierung (FLP), Technische Universität Berlin

jgulden@cs.tu-berlin.de

We[1] present an approach for meta-modeling using concepts derived from physical space and movements.

Theory: Treating models as qualitative data in multidimensional space provides a framework for reasoning about models, which in the long run will be applicable for creating, evaluating and comparing modeling languages and tools. Elaborating such a framework can initially be achieved by describing existing models and modeling languages in spatial terms, i. e. constructing spatial meta-models.

Known approaches from other research areas dealing with qua*n*titative data have already proven multidimensional spaces to be useful for handling huge amounts of numerical data and enabling the design of flexible ad-hoc query languages based on spatial operations.[2]

Multidimensional euclidian space provides a natural meta-model of a fully interconnectable system. Given a euclidian space with an arbitrary number of axes and discrete, qualitative axis-intercepts, each coordinate in this space represents one possible connection among the qualitative values of the axis intercepts.

Cognitive sciences[3] and recent approaches in philosophy[4] propose that experiences made as physical beings in our spatial environment are important constituents for higher-level understanding and reasoning. Conceptual modeling can be explained as metaphorically moving in space and performing navigational operations.[5]

Understanding models in terms of locations and movements contributes to an overall the-

[1]The work presented here has been developed by the project “Aufklärung des Modellbegriffs”, as part of the research group “Bild Schrift Zahl” at the Hermann von Helmholtz-Zentrum für Kulturtechnik, Humboldt-University Berlin, DFG FOR 391.

[2]An example is the MOLAP-approach, a technique to store and query huge amounts of quantitative data in so-called “datacubes” and retrieve them using operations as “slicing”, “dicing”, “drill-down” etc. See [Hol99], [CCS93]. Comparable approaches are known in the area of geographic information systems (GIS) to cope with vast amounts of measured values, see e. g. [CM05b].

[3]See e. g. [Lak87].

[4]See e. g. [Joh87].

[5]See [Gär00].

ory of conceptual modeling, as it implies a proposal for a normalized representation of models, independent from any specific modeling language or notation. Such a normalized representation allows to define the notion of equivalence between models and modeling languages, and thus provides means for comparing them. Automatic transformation between models expressed in different modeling languages might to a certain extent be successful on such a basis. A normalized representation can also provide additional theoretical terminology for clean distinctions between model content and model projections (e. g. visualizations), and thus can extend the conceptual range with which to scientifically reflect on models.

Design: For an initial elaboration of our approach, we have chosen to derive spatial meta-models from an existing modeling language, the Unified Modeling Language (UML)[6] by constructing spatial representations from example model instances. Following this method, the first step to generate a spatial representation of an existing model in a given modeling language is to identify euclidian subspaces as semantic domains[7] which are capable of expressing the semantics of the corresponding original language constructs. In the second step, locations in these spaces are marked as being meaningful, thus expressing the facts stated by the model-instance as points in space. We call the totality of identified subspaces the *modelspace*. Points which mark locations in space as being meaningful are named *allocations*.[8] In spatial representations, modelspaces serve as partial meta-models of the original modeling-language, and allocations represent instances of model content, i. e. the facts expressed by the model.

Implementation: In order to gain tool support for our research activities, we have developed two software-applications which are capable of projecting high-dimensional modelspaces into low-dimensional spaces which are navigable.

The first software-tool is a Java desktop application which allows to project modelspaces into nested 3D-cubes. The projection can be moved, rotated, zoomed etc. using the mouse. This way, models can be explored spatially and be navigated in physical terms.

The second application supports projecting multidimensional modelspaces into nested 2D-tables. The software runs as a web-application accessed through a web-browser. Projections into nested 2D-tables can interactively be modified through form elements in the web-page.

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[6] See [BJR99].

[7] See e. g. [Ber01] on semantic domains as part of the theory of denotational semantics.

[8] See [CM05a], [Gul05].

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