A perspective based approach to design

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Abstract. Urban design is a creative task that demands the balancing of issues from multiple domains such as architecture, zoning laws, traffic planning, and others. As such, classic design models based on the assumption of the designer wandering through a monolithic design space guided by largely predetermined requirements turn out not to hold here, instead the designer constantly alters his point of view and will frequently re-evaluate his precepts to arrive at better or even simply innovative solutions. We are working on a formalization of this state of affairs. Instead of a global design space, the design is described in terms of perspectives between which the designer shifts during work. Design knowledge is incorporated both in the description of the perspectives and the translations that occur between them.

1 Introduction

A design can be described as a mapping process from a set of specifications to a set of object descriptions [18]. This comes from the fact that in order to be a useful tool, a computer has to yield predictable and therefore deterministic results. Creative design on the other hand not only involves unpredictable results but very often involves the adaptation of domain models during the design [7, 19]. Moreover, the choice of representation for a design problem to a large degree determines the set of possible solutions [14]. Therefore, computer support for design should provide for heterogeneous representation of design problems and admit modifications of any implicit assumptions at any stage of the design process. This paper aims at modelling the relationship between the open and flexible aspects of a design on one hand, and the deterministic aspects on the other, by explicitly representing the design in terms of the designer's perspectives. Instead of a view of the design process as a rigid sequence of design steps with infrequent revisions of the design goals, we gain a view that is characterized by interleaving of design object and design constraint changes (where the constraints may include restrictions that were originally phrased as design goals, a property relevant for innovative or creative design processes [16]).

While the interchange between the different perspectives is treated on a very simple level in this paper, more powerful mechanisms and representations can be imagined. Multi agent systems have been shown to be valuable tools for understanding design processes [9, 15]. In order to support design processes, artificial agents could take the responsibility for certain aspects of the design, leaving the human designer(s) with less cognitive load and therefore more freedom in the design process [13]. Human designers can be considered natural agents in such a co-operative distributed problem solving setup.

In the next section, we present an example of a creative design process that exhibits the properties which we wish to see incorporated in design representations. In Section 2, we present a formalization that captures the intent of the perspective-based view. We close with discussion and outlook.

1.1 An Urban Design Example

We now examine a designer's behavior in the context of a task that incorporates multiple, shifting sets of criteria and design parameters. The example design task is to create an urban design for a limited site, shown in Figure 1. At the time of the design, there are no roads, no technical infrastructure and no buildings on the site, but a railway forms the western and an existing road the eastern border of the area.

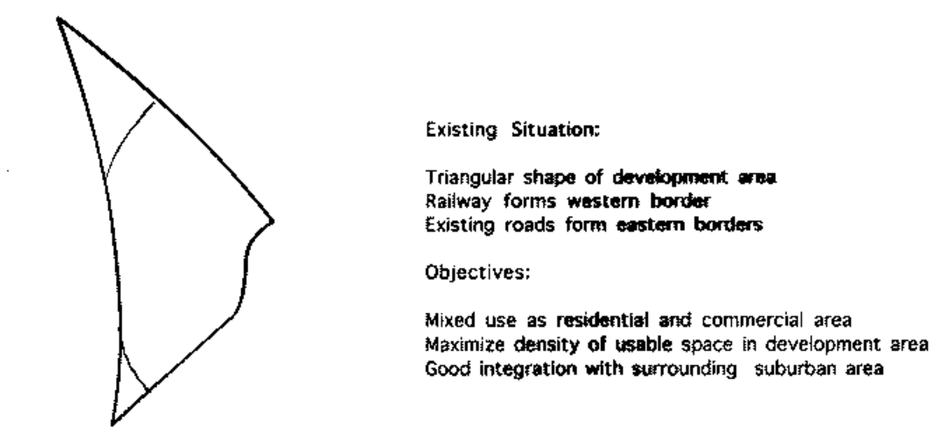

Fig. 1. Boundary conditions

Let us assume the external priorities of achieving a mixed residential and commercial use with maximum density and a good integration with the surrounding sub-urban area. Residential use means houses for private use, living and commercial activities that do not generate pollution and noise. Commercial use on the other hand is understood to encompass office buildings, factories, and storage compounds. The density measure can be expressed as the ratio of usable developed space to used surface area, and Integration describes the number and quality of connections to the surrounding street and public transport network, as well as compatibility of new building types to be erected on the site with existing types in the area or its surroundings.

Figure 2 shows initial attempts to arrive at a basic partitioning of the site according to usage types (residential, commercial).

Upon closer examination, it turns out that the proximity of the railway on the western border is an obstacle for residential development due to increased noise and the isolating effect of the railroad. On the other hand, a rail connection can be an advantage for commercial use. Therefore, the designer decides to designate the south-eastern part to residential development and the rest of the site to commercial use.

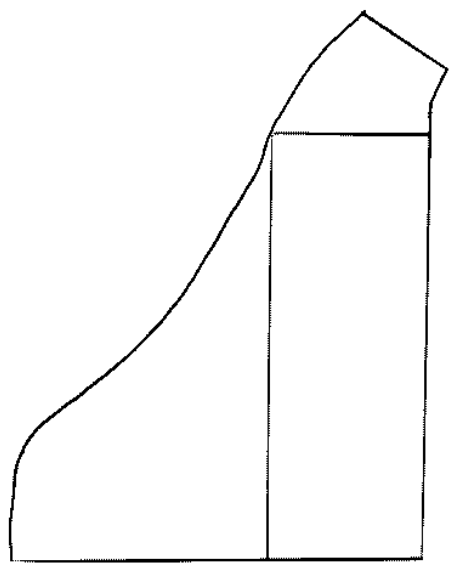

Fig. 2. Resulting partitioning of site (simplified)

The limits of the residential and commercial sub-sites are implicitly considered to be streets of some kind. Now the designer concentrates on the residential area. In order to come to an understanding of the possible density, an initial typology must be chosen. Since the area is adjacent to a less developed suburban area, typologies relying on high buildings, such as the high-rise building typology, are not taken into consideration. The initial decision is to fill the area with only single family houses (similar to those shown in Figure 3). This typology is very popular but also requires more space than other typologies.

Taking the minimum distance for single family houses into account, a regular rectilinear pattern with strict east/west roads might be the initial result for building arrangement, and could be used to give a first estimate of the possible density for this type.

This pattern is the result of constraints and the goal of maximizing urban density, but the pattern itself is of course too monotonous. But the designer takes this first approach as the basis for some experimentation with street layouts, such as a wave-like form.

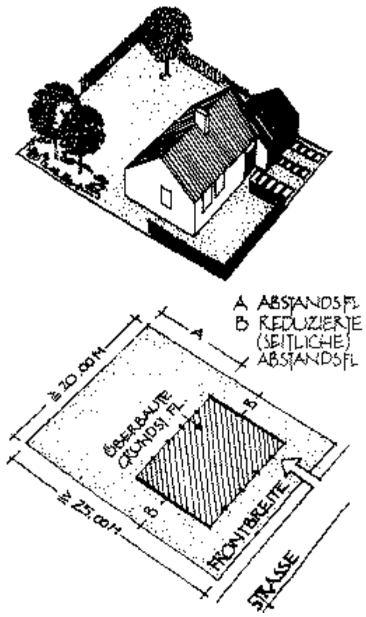

Fig. 3. Single family home

Figure 4 shows the a sketch which the initial waveform sketch and individual houses having been subsequently sketched in.

When density turns out to be lower than desired, a wave-like pattern is examined since it would allow for higher density without becoming unpleasantly monotonous, but the increase in density turns out to be insufficient. The required density could instead be achieved by the use of a less popular typology such as the row houses shown in Figure 5.

The introduction of row houses would solve the density requirement but will again lead to a dull and less creative outcome. The existing assumptions on typologies, required density and lighting and the shape of the residential area are limiting the possible allocation of buildings and streets to a point that only leaves very uninspired and boring designs. The designer could now reconsider the choices made the beginning of the design process like the shape of residential development. But he wants to experiment with possible variations of shapes and their impact on the resulting density. He chooses to ignore the limitations of existing typologies, lighting and accessibility for the time being and moves individual rooms, introduces a 90 degree turn of first floors in the underlying row house. He remembers the original idea of a wave-like form and applies it only to the first floor of buildings, as shown in Figure 6.

The result is that the designer has created a new type of residential house, and the new typology is used as the general design guideline for the residential area. The original set of constraints describing possible designs has been altered. Figure 7 shows

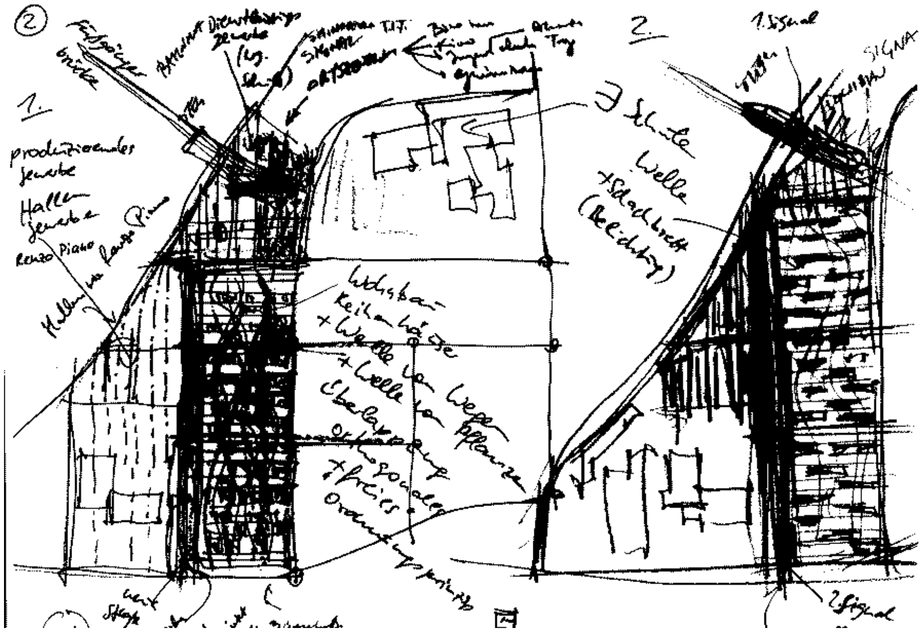

Fig. 4. Initial thoughts on partitioning the site (original sketch)

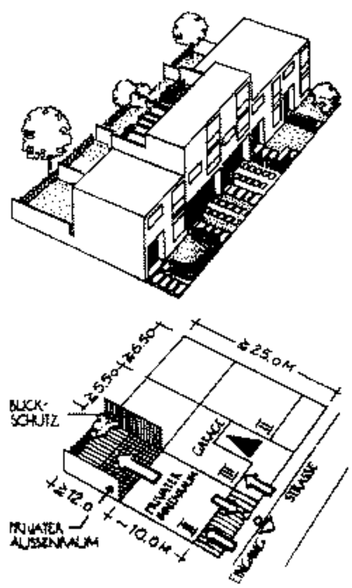

Fig. 5. Row houses

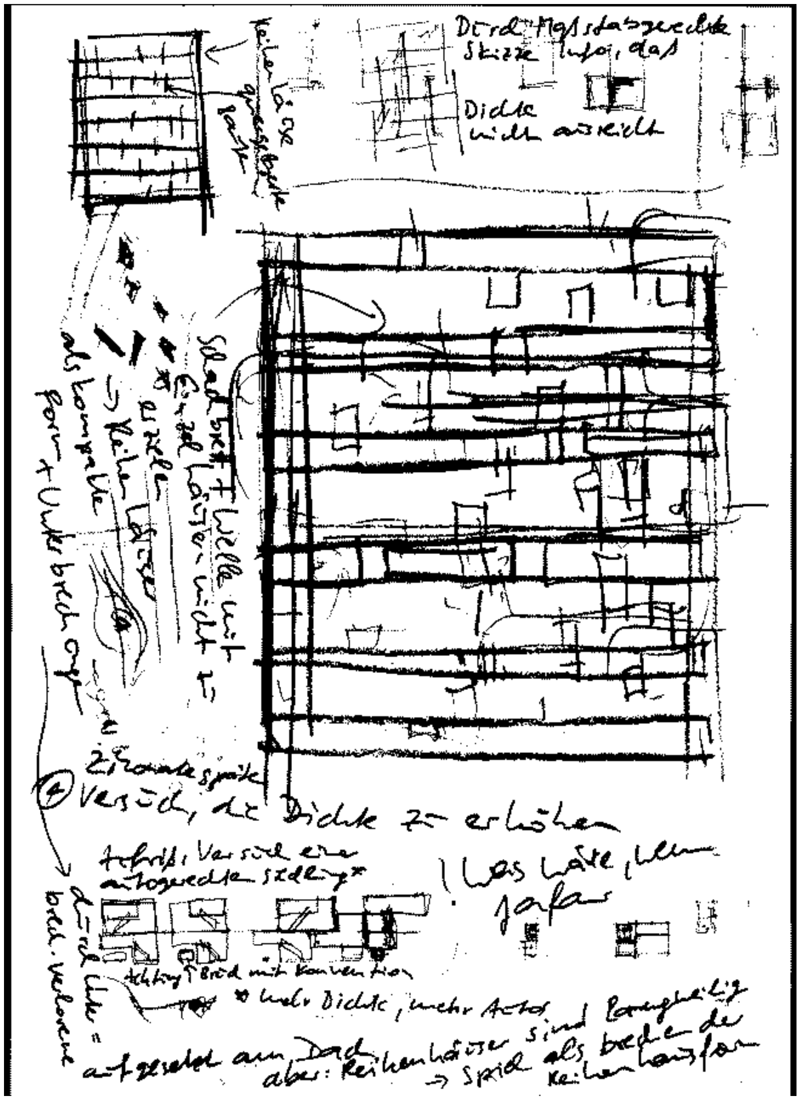

Fig. 6. Creative Alteration of Underlying Typology

a representative of the class of possible designs that can be produced as a result (by instantiating building sizes and distances). The urban design itself consists of the new constraints as well as the set of examples that exhibit the application of the constraints.

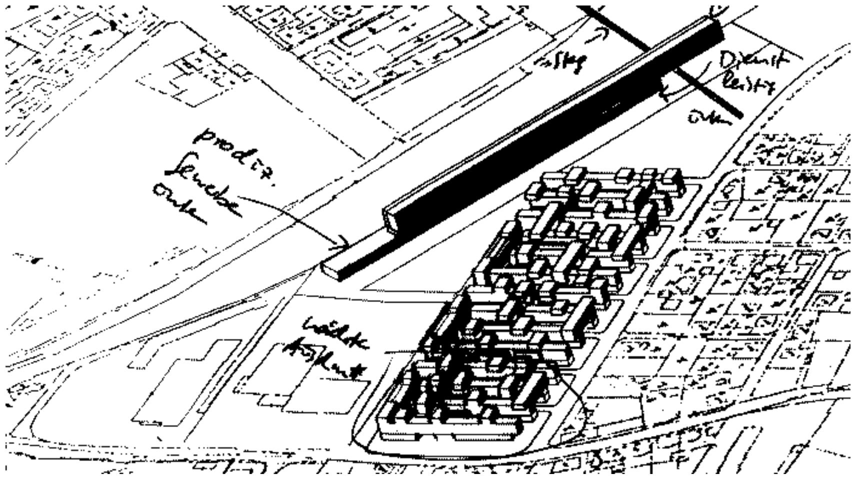

Fig. 7. Final Design

2 A Perspective Based Design Model

2.1 Perspective in Architectural Design

Architecture and urban design have evolved out of classical building professions by means of abstraction: The geometrical perspective and the use of scales enabled the architect to concentrate on geometric properties of objects independently of materials used or the building process itself [2]. Perspective can be translated as ”view”, since it is the image one receives of a building if seen from a certain viewpoint. But the geometric perspective as developed in Italy in the Renaissance is not the only way to describe the image an individual perceives at a given point and time. It is one possible form of abstraction based on certain assumption on the nature of human eyes, the behavior of light in our environment and the geometry around us [8]. In a more general sense, the word perspective can be used to describe a view of a situation. Perspective as a term is also used to describe views on data sets or simply different ways to look at things. The term distributed perspectives is introduced to describe the concept of incomplete and possibly inconsistent design information distributed over different representations, stages, design teams or computers.

2.2 Modeling Perspectives

In order to support a view of the design process that results in the creation (or shaping) of an appropriate set of design solutions rather than the selection of a single design solution, our formalization takes the view that the design process takes place in a set of multiple design spaces, with the focus shifting between the different spaces in a flexible manner. We refer to these different design spaces as perspectives.

Formally, we describe a perspective by a pair $\langle O,S\rangle$, where O, the object description, a set of ground facts, and S, the specification, is a set of formulas typically referring to the the predicates occurring in O. Note that the definition of O is equivalent to the definition of a design object description in [3].

In general, multiple perspectives will exist for a given design task. We refer to a particular perspective $\langle O,S\rangle$ as internally consistent if O satisfies S (or, if $O \cup S$ is consistent).

Example: In the urban design example, perspectives would include: typology (referring to the type of house and its relation to the ground it is built on), 2D technical (referring to the street grid), area (referring to the geometrical properties), building density, lighting, and others.

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Perspective typology is:
predicates: type, > ("preference")
object description:
        type(single_family)
specification:
        single_family > row_house > ....> high_rise

Perspective 2D-tech is:
predicates: street_grid
object description:
        street_grid(regular)
specification:

Perspective area is:
predicates: corner,side,...
object description:
        corner(c1,123,30),border_segment(line1,c1,c2)...
specification:

Perspective 3D is:
predicates: "geometric predicates"
object description: "in terms of spatial coordinates"
specification:
        2 objects cannot be in the same place
        streets must be positioned on the ground
        houses must be positioned on the ground
        ...
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Perspective lighting:
predicates: ”arithmetic comparison”
object description:
specification: lighting(House,Angle) $\rightarrow$ Angle $\leq$ 45

Perspective density:
predicates: ”arithmetic comparison”
object description:
specification: density(X) $\stackrel{t}{\Rightarrow}$ X $\geq$ 2

Figure 8 shows the interplay (translations) between the various perspectives in the example.

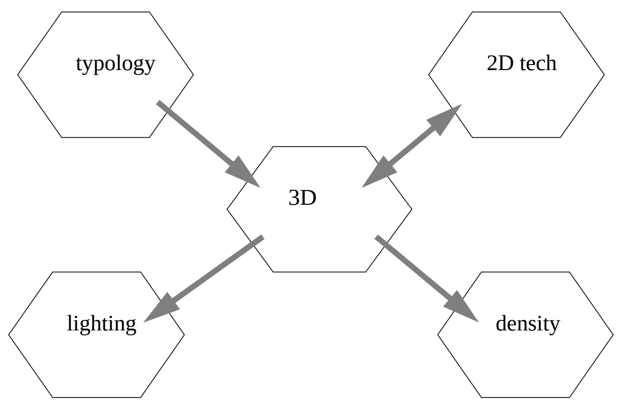

Fig. 8. Perspectives in Urban Design Example

2.3 Translations

During the design task, there are two kinds of individual design steps performed by the designer. For now, we only consider the first kind; it could involve the addition, removal, and alteration of facts from the object descriptions, as well as the addition and removal of specification constraints within a particular perspective. An example for the first category would be the actual insertion of houses into the design. An example of the second would be a changed specification of how many streets in the internal grid of the 2D-tech perspective would have to connect to streets external to a given area. (Note that by *specifications* we mean restrictions specified on the design object by the designer, not restrictions that are given to the designer as part of the problem description. The latter we refer to as *requirements*.

However, alterations in one perspective, either of design objects or constraints, will often also imply alterations concerning a different perspective, such as the shift to a different typology resulting in different numerical house dimensions in the 3D model. These dependencies between perspectives are specified in terms of translation functions. A translation A $\overset{t}{\Rightarrow}$ B is a mapping from specifications in perspective A to requirements in perspective B. In particular, evaluations of design objects according to different criteria such as lighting or building density could be expressed in terms of translations to the appropriate lighting or density perspective. Typical translations in our example would be:

typology $\overset{t}{\Rightarrow}$ 3D
2D-tech $\overset{t}{\Rightarrow}$ 3D
3D $\overset{t}{\Rightarrow}$ density
3D $\overset{t}{\Rightarrow}$ lighting

Given a set of perspectives ⟨Oi,Si⟩ and translations between those perspectives, we say that perspective B is consistent with A (or consistent in relation to translation function $f_{A \overset{t}{\Rightarrow} B}$), if the translation function $f_{A \overset{t}{\Rightarrow} B}$ exists, SA is the specification of perspective A, SB is the specification of perspective B, and $f_{A \overset{t}{\Rightarrow} B(SA)}$ is consistent with SB.

A consistent design is a design such that (a) all perspectives are internally consistent, and (b) for each pair A,B of perspectives, A is consistent with B if a translation from B to A exists.

The second kind of design step referred to above would now consist of alterations to the definition of the design translations themselves, e.g., using different default properties for the spatial arrangement of houses in a given typology.

The distinction between specifications and requirements is a major distinguishing element from design approaches such as the DESIRE system [3]. The relaxations of design constraints that occur as part of creative design processes as described in the introduction are reflected by according different priorities to requirements (external to perspectives) and specifications (internal) when checking consistency. Inter-perspective consistency violations can be tracked as envisioned in [9].

2.4 Related Work

In [6], a centralized repository for design information is proposed that can be accessed by multiple tools involved in the design process. Hardcoded ”filter” processes map information to the central repository and back.

An approach that expresses multiple viewpoints for a design was described in [4], specifically aimed at the representation of software designs. There is no global consistency check, instead viewpoint-internal and pairwise inter-viewpoint consistency checks are assumed to be triggered at appropriate points determined by the particular software development method used. When an inconsistency is determined, a set of potential resolution actions defined by the method designer can be applied. In [17], perspectives are considered as the main mechanism for modularizing a design process, and

”viewpoints” are introduced as subdivisions inside perspectives. For structural descriptions, the information content of descriptions in different viewpoints can be compared.

3 Implementation

The distributed perspectives prototype has been implemented on the basis of a multi-agent system. Agent-based programming was applied more in the sense of software engineering [10] than as an implementation of the belief-desire-intention theory [12]. The human designer performs changes in some of the available perspectives and agents are used for translating between perspectives. Therefore, there is no control structure for designing (the human designer is free to choose among possible design steps).

Fig. 9 shows the software architecture chosen on the example of a translation function from the 2D layout perspective to the 3D layout perspective. The 2D layout perspective is implemented as an extension of the commercial CAD software, Microstation. Design support is provided through one or many design agents implemented in the JESS [5]. Communication between perspectives and translation functions is implemented through the JADE agent framework [1].

Translation of the 2D layout specifications into 3D layout requirements is provided in the following fashion: If a new or updated grid is selected in the 2D layout perspective, the JADE agent sends a message to all relevant translation functions containing the updated specifications. The JESS system implementing the translation function from the 2D layout to 3D layout receives this message, translates the 2D grid specifications to 3D layout requirements and adds rules for achieving these requirements. Then the translation function JESS system sends a message to any relevant perspectives containing new rules for the 3D layout through a JADE agent. The 3D layout perspective receives this message through a JADE agent and a design support agent incorporates the new rules into its rule base. Depending on the kind of translation performed, the new rules can be used for design automation or design critique.

4 Conclusion and Outlook

The design model presented in this paper can be used as the basis for distributed computer supported co-operative design support systems. The perspective based approach provides the ability to separate knowledge sources about individual aspects of the problem domain. The perspective-based consistency definitions facilitates the shift to a creative design model where design requirements can be subject to re-evaluation depending on design decisions made in different perspectives, one of the defining properties in creative design. Design solutions created with such a system are potentially more flexible in that variations of a given design can be generated easily by using translation functions. Complete sets of previous design perspectives with their respective translation functions offer the opportunity of re-living the design space used to generate a specific design solution. In this fashion, design rationale is implicitly conserved for future use.

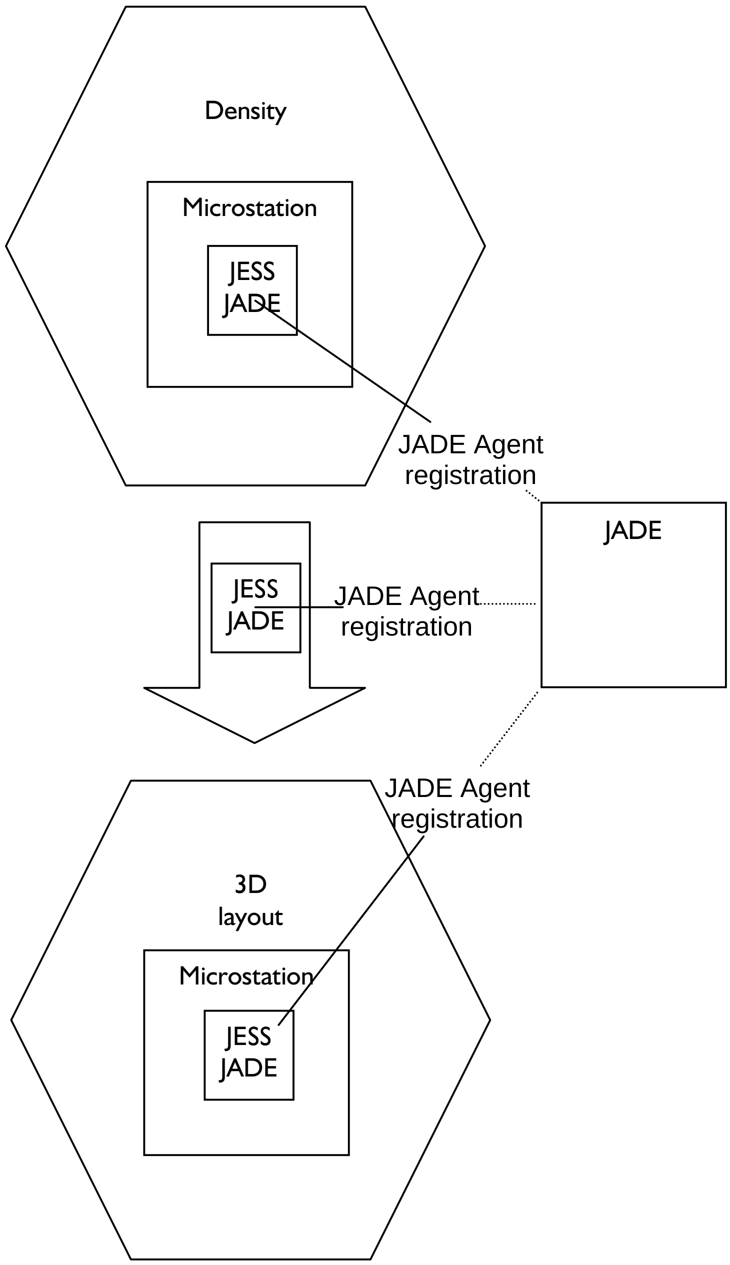

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Fig. 9. Translation function implementation

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