THE FINGERPRINT OF ARCHITECTURE: SKETCH-BASED DESIGN METHODS FOR RESEARCHING BUILDING LAYOUTS THROUGH THE SEMANTIC FINGERPRINTING OF FLOOR PLANS

C. Langenhan, F. Petzold
Faculty of Architecture, TU München, Germany

Abstract

The paper focuses on the early stages of the design process where the architect needs assistance in finding reference projects and describes different aspects of a concept for retrieving previous design solutions with similar structural characteristics. A semantic fingerprint is proposed that contains a clear spatial description of an architectural dataset that is independent of its source format. The proposed system offers a computational approach to extracting a few characteristic and prominent features of a floor plan which are then used to generate a semantic fingerprint. The fingerprint inherits spatial-topological as well as semantic information and serves as a signature with which to identify projects with similar characteristics to the architect's own explorations during the design process. The architectural design process can be described as a sketch-based process of analyzing and creation. In the paper, we examine the development of IT-technologies to provide a sketch-based submission and retrieval system for publishing and researching building layouts including their manipulation and subsequent use.

Keywords: new media, case-based reasoning, taxonomy.

«ОТПЕЧАТОК ПАЛЬЦА» АРХИТЕКТУРЫ: ПРОЕКТНЫЕ МЕТОДЫ НА ОСНОВЕ ЭСКИЗА ДЛЯ ИССЛЕДОВАНИЯ ПОЛОЖЕНИЯ ЗДАНИЯ ЧЕРЕЗ СЕМАНТИЧЕСКОЕ СНЯТИЕ «ОТПЕЧАТКОВ ПАЛЬЦЕВ» ПЛАНОВ ЭТАЖА

С. Лангенхан, Ф. Петцольд
Факультет архитектуры, ТУ Мюнхена, Германия

Аннотация

Статья сосредотачивается на ранних стадиях проектного процесса, где архитектор нуждается в помощи в определении справочного проекта и описывает различные аспекты общего представления для восстановления предыдущих проектных решений с подобными структурными особенностями. Предлагается семантический «отпечаток пальца», который содержит ясное пространственное описание архитектурного набора данных, независимое от его исходного формата. Представляемая система предлагает вычислительный подход к выбору нескольких характерных и видных особенностей плана этажа, которые затем используются, чтобы произвести семантический «отпечаток пальца». «Отпечаток пальца» наследует как пространственно-топологическую, так и семантическую информацию и служит ключом, чтобы идентифицировать проекты с подобными характеристиками с собственными исследованиями архитектора в течение проектного процесса. Процесс архитектурного проектирования может быть описан как процесс анализа и создания на основе эскиза. В статье мы рассматриваем развитие технологий IT, чтобы обеспечить на основе эскиза подачу и поисковую систему для опубликования и исследования расположения здания, включая манипуляции и последующее использование.

Ключевые слова: новые способы, рассуждение на основе случая, таксономия.

Introduction

The rapid development of information technology in architectural planning raises questions about the storage and use of growing amounts of data. Information about architecture is available digitally but not accessible. There is a lack of adequate retrieval methods, including suitable approaches to the storage, indexing and management of information. Traditionally planning information is represented in the form of floor plans, elevations, sections and textual descriptions. State of the art digital representations include renderings, computer aided design (CAD) and Building Information Modelling (BIM) including 2D and 3D file formats such as Industry Foundation Classes (IFC). We examine two main data sources: community-collated data on the internet and corporate data used in company infrastructures.

During the process of designing, planning, building and the management of projects, a large amount of data is created. The information is stored in various forms, sources, platforms and different formats such as text documents (e-mails, technical reports, contracts, etc.), 3D models, BIMs, CAD drawings, diagrams, schemes, pictures and so on. Observing the design process of buildings reveals that the initial design phase serves as the foundation for the quality of the later outcome. During the design process, architects often refer to existing information about previously designed and built architecture. Such references are typically used to see how others have solved a similar architectural problem or simply for inspiration.

Current electronic search methods use textual information rather than graphical information. The configuration of space and the relations between physical structures are hard to represent using keywords, in fact transforming these structural configurations into verbally expressed typologies tends to result in unclear and often imprecise descriptions of architecture. Classifications are made in terms of types, morphology, similarity or patterns but the quantitative and qualitative comparison of functional as well as structural features is as yet not possible. A universal description and query language is indispensable for storing descriptive metadata independent of file type and source as well as structural, graphical or textual information.

The semantic fingerprint proposed by Langenhan (2008) is a description and query language for creating an index of floor plans to store metadata about architecture, which can be used as signature for retrieving reference projects. Rather than using today’s keyword-based search methods, it employs geometrical search strategies. A graphical user interface supports sketch-based as well as textual retrieval strategies to search for spatial configurations, for example by drawing rooms and their relations to one another. The main goal is to extract significant features of spatial configurations and transform these features into a spatial query language for retrieving architectural information. The fingerprint enables the user to digitally document information about architecture by creating an index of significant features that can be retrieved and used in a normal everyday manner.

The section “Related work: CBD” discusses past approaches to supporting the design process using Artificial Intelligent (AI) technologies. The section “Storing: raster graphics, CAD and BIM” describes state of the art methods for digitally saving geometrical 2D and 3D information. The section “Indexing: semantic fingerprint” presents the extraction process, features and taxonomy used to create the meta-signature. The section “Retrieval: sketch-based” specifies the combined graphical-textual search process and finally, the section “Conclusion and future work” provides an overview of possible developments.

Related Work: CBD

In the early stages of the architectural design process, users are only rarely able to specify the required information. Case-based reasoning (CBR) is an area of AI and describes a knowledge management process based on conclusion by analogy. It attempts to assess similarities according to the basic premise that similar problems have similar solutions. In CBR a case consists of a problem and solution description. By entering a new problem description to obtain similar solutions the CBR system first searches for an old problem description. Figure 1 illustrates the basic concept of CBR. Aamodt and Plaza (1994) describe this adaptation of the thinking process inside the CBR cycle with the verbs retrieve, reuse, revise and retain.

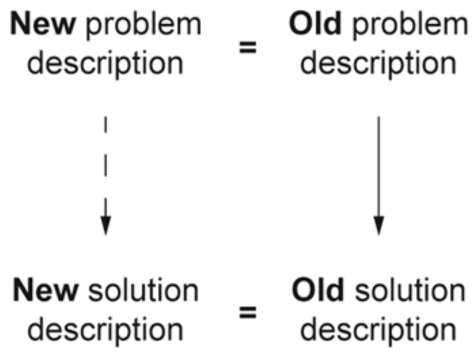

Fig. 1. CBR basic concept

Since the middle of the 1990s the approach of applying CBR to design and architectural tasks has been known as Case-Based Design (CBD). The case-base contains information on buildings that have already been built or designed, enabling the computer to adapt solutions accordingly, on its own or with help from the architects. Figure 2 provides a brief overview of some CBD systems based on two studies published by Heylighen in 2001 and by Richter et al. in 2007 regarding the proposed approach. The marked fields show whether the appropriate feature was realised in the concept.

CBD application \ application feature	Data Storage			Input System			Output System						
	Floor plans + text	Abstraction	Topology	Graphic	Verbal	Adaptation	Reference projects	Applying solutions	Graphical Information	Learning	Subproblems	Semantic net	Analogy
Archie-II	X	X			X		X		X		X	X	
CADRE	X	X	X	X	X	X		X	X	X	X		
FABEL	X	X	X	X	X	X	X	X	X		X		X
IDIOM		X	X	X	X	X		X	X				
PRECEDENTS	X	X			X		X		X		X	X	
SEED Layout		X			X	X	X	X	X		X		
SL_CB	X	X			X	X	X	X	X				
TRACE		X	X	X	X		X	X	X				
CaseBook	X		X	X	X		X						
MONEO	X	X			X		X		X				X
CBA	X	X			X		X					X	
DYNAMO	X	X		X	X		X		X	X		X	

Fig. 2. CBD systems

Six of the CBD prototypes (CADRE, FABEL, IDIOM, SEED Layout, SL_CB and TRACE) aim to partially or completely automate the generation of building layouts by applying the retrieved solution. Two of these prototypes (CADRE and IDIOM) leave the selection of the reference project to the user. The remaining four (FABLE, SEED, SL_CB and TRACE) apply the solution to the given architectural problem automatically and generate building layouts independently with very little user input.

The PRECEDENTS project can be seen as a counter example to these concepts. As the name already indicates, the architect is actively enlisted in finding reference projects. This approach is conceptually close to classical verbally driven architectural databases. By contrast, the graphical input used in CaseBook appears to be more suitable for formulating the retrieval query due to the visual way architects work.

An important feature of CBR is the ability of such applications to learn. This feature is addressed in CADRE and DYNAMO. DYNAMO proposes a kind of manual re-indexing. User input allows the parameters of the database to be changed or added to according to how it is to be interpreted. Another important feature is that of dividing a problem into sub-problems, which was realised in FABEL.

The study by Richter et al. in 2007 identifies an acquisition bottleneck in putting complete case descriptions (problem and solution) into the case base. We assume this is due to a lack of adequate input strategies, indexing methods and knowledge management procedures. First of all, a user interface should support the graphical sketch-based workflow of architects combined with textual, schematic and tabular input strategies. Secondly, a lightweight indexing strategy such as the semantic fingerprint is needed in contrast to the overall data storage method used. Thirdly, the problem and solution descriptions need to be stored according to the CBR paradigm. Most of the CBD prototypes do not properly implement this fundamental CBR attribute.

Storing: raster graphics, CAD, semantic model

The use of metadata enhanced digital floor plans with additional information offers the opportunity to create smart objects that allow users to have easier access to planning material. Enriching geometrical data with semantic information allows the application, and hence the user, to identify rooms, doors or chairs. Nowadays we look to semantic models to describe this data representation. Examples of semantic models are BIM, IFC and the semantic fingerprint.

Furthermore, 3D knowledge-rich parametric modelling systems are central to BIM and the life cycle of a building. As buildings are composed of geometric components, geometric information forms a substantial part of BIM. In addition, further related knowledge is added to the BIM, such as project information, lighting analyses or quantities and properties of building components and so forth.

Modern architectural design is done using Computer Aided Design (CAD) software. Several vendors, such as Autodesk (Revit Architecture), Graphisoft (ArchiCAD) and Nemetschek (Allplan) offer software packages with their own data formats to store information about the building. However, according to the BIM paradigm interoperability is vital for reducing costs and supporting all stakeholders.

The International Alliance for Interoperability (IAI) (IAI 2010) established an open specification that is not controlled by a single vendor. The file format Industry Foundation Classes (IFC) is an interoperable BIM standard for CAD applications.

Indexing: Semantic fingerprint

We assume every extracted floor plan inherits a finite number of features. Furthermore, these structural and functional features can be found in every project. The fingerprint contains features that serve as a meta-signature for the reasoning process. In addition to the usual dataset providing information about a project, every project is also given a semantic fingerprint, which inherits the architectural situation of the building in terms of its spatial boundaries and their characteristics. By providing a sketch of the required architectural configuration, the user creates a digital search fingerprint for the query. This search fingerprint can then be compared with the fingerprints in the database.

The semantic fingerprint structure proposed by Langenhan (2008) represents the spatial, functional structure and is used to formalise the structure of a floor plan. Four main concepts (Level, Unit, Zone and Room) are used to describe the spaces in a housing construction and their relations. Figure 3 illustrates some entities corresponding to the concepts.

Concepts	Level	Unit	Zone	Room
Entities	Attic Floor	Circulation	Circulation Zone	Bedroom
	Upper Floor	Apartment	Living Zone	Workroom
	Ground Floor	Terrace	Function Zone	Bathroom
	Basement	Balcony	Sleeping Zone	Kitchen
				Corridor
				Staircase

Fig. 3. Taxonomy – Example of entities

A building and its corresponding floor plan are separated into levels. Each level is divided into multiple units, which could be an apartment or a terrace, for instance. Units can be further divided into zones. Examples of zones are the 'living zone', the 'sleeping zone' and the 'function zone'. A zone groups together different rooms which can be seen as 'atomic' parts of the structure. On every layer the different spaces can have either a direct, adjacent or no relation. If two spaces have a common wall and a door which links the spaces, this is defined as a connection. An adjacent relation is indicated by a shared wall without a door.

To create a semantic fingerprint we propose a semi-automatic means of extracting floor plan features (Weber et al., 2010) by applying image recognition techniques (Dosch et al., 2000; Lu et al., 2006; Or et al., 2005) along with machine learning methods that classify the structural information and present the results to the architect who then approves or modifies the fingerprint. With the support of semi-automatic extraction, an architect is able to formalise knowledge about past projects.

Currently the focus (Weber et al. 2010, Weber 2010) is on the detection of single rooms and their interconnections. Figures 4 and 5 illustrate first results of the automatic extraction algorithm. Future work will involve classifying the type of room by using symbol recognition (Tabbone et al., 2003) and optical character recognition (OCR) for each piece of textual information (Tombre et al., 2002). Furthermore a rule-based system could be applied in order to group rooms into zones and zones into units.

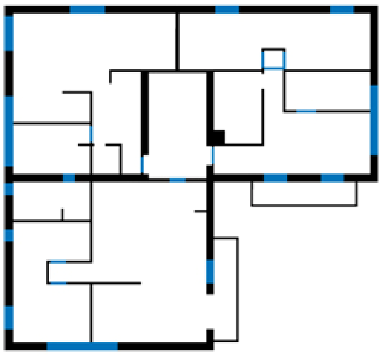

Fig. 4. Door, wall and window detection

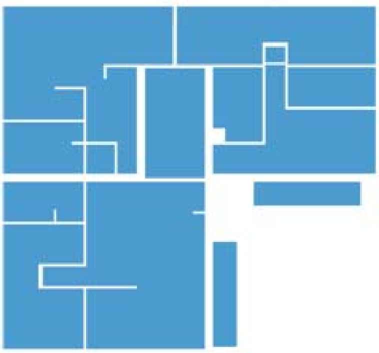

Fig. 5. Room detection

The semi-automatic extraction of features from raster graphics shown above can likewise be used to analyse and index mass data available on the internet. This provides access to community knowledge about architecture. Another approach is to use standardised intelligent data formats, already containing semantic information, such as the IFC, to extract a semantic fingerprint. This corporate data exists predominantly in company infrastructures and is a potential second source of information.

Retrieval: Sketch-based

Usability is the main aim of Human-Computer Interaction (HCI) research. It is essential for designing interfaces that allow users to intuitively work and interact with applications. Appropriate metaphors and devices have to be used to allow easy and fast interaction. Architects prefer to sketch in their initial design phase to create an image of the building in their mind.

Today the electronic way of interacting with spatial information is predominantly text-based and requires users to deal with architectural data primarily through alphanumeric command languages. Formulating a query by typing a command in some query language or by selecting from pull-down menus is a tedious process. It requires extensive training in the use of the respective query language and the users need to translate a spatial image they may have in their mind into a non-spatial language.

We propose a sketch-based visual-query-language constituted by the semantic fingerprint to overcome this jump in the workflow. The user interface focuses on specifying space and their relations by drawing them. This query style supports the spatial thinking approach that architects use, who often have a visual representation in mind without being able to provide an accurate description of the spatial configuration.

To create a schematic query (Langenhan, 2008) the architect sketches a space using layers for the level, rooms, zones and units, as illustrated in Figure 6. The mock-up (Langenhan, 2008) shows sliders (1) for editing the schematic sketch in layout mode, spaces (2) and relations (3). Navigation within the layers and the actual spatial configuration (5) as well as specifying the semantic structure is done using the space navigator (4). The results (6) of the visual query shows up on the right-hand side.

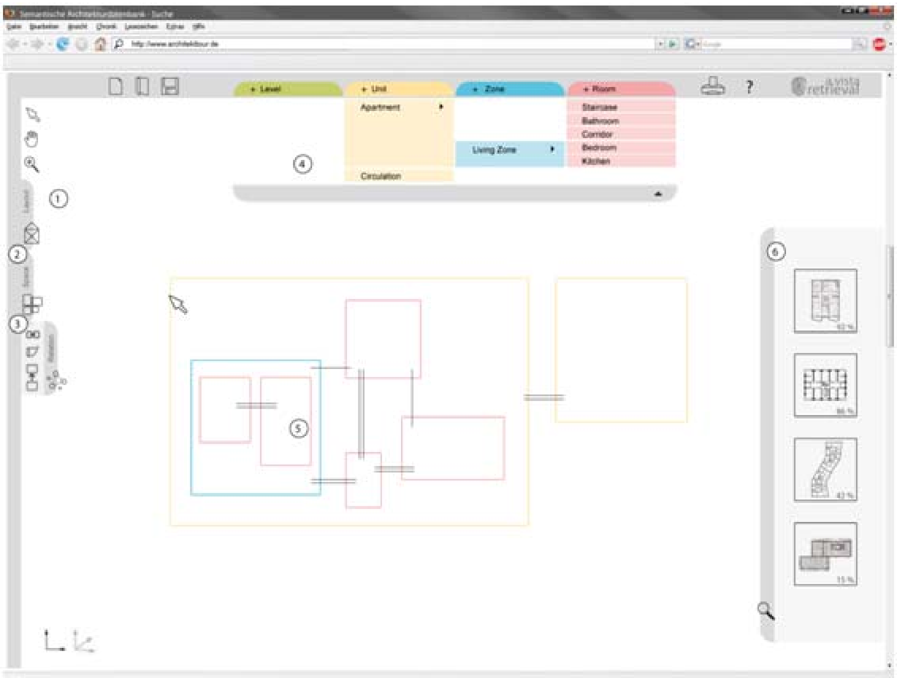

Fig. 6. Mock-up retrieval (www.architekttour.de)

Figure 6 illustrates a web-based retrieval interface that can be used with standard input devices such as a mouse or keyboard. Weber et al. (2010) implemented several prototypes on a multitouch table with combined touch and pen inputs to support semi-automatic extraction and intuitive sketch-based retrieval strategies.

Conclusion

The obvious outcome of the proposed semantic fingerprint is the ability to access valuable information. Furthermore, automatically analysed fingerprints can put forward both commonly used as well as best practice projects. It will be possible to rate architecture according to the fingerprint of a building. Besides traditional 2D and 3D visualisation techniques, other strategies such as diagrams, mental maps, visual thesauri or conceptual maps represent a useful extension to knowledge-based design in the early stages of the process.

Furthermore, we proposed a semantic structure to capture the content of floor plans inside the digital fingerprint. The retrieval is based on spatial configurations and semantic descriptions. The representation of architectural data in terms of semantic models is helpful to architects to enable them to use such information at a later date. Technologies such as semantic-based querying or even image-based querying will help to augment the design process.

References

1. Aamodt, A., Plaza, E. (1994): Case-Based Reasoning: Foundational Issues, Methodological Variations, and System Approaches, AICOM 7 (1994) 1, S. 39-59.

2. Dosch, P., Tombre, K., Ah-Soon, C., Masini, G. (2000): A complete system for the analysis of architectural drawings. International Journal on Document Analysis and Recognition 3(2), 102–116 (2000).

3. Heylighen, A., Neuckermans, H. (2001): A case base of case-based design tools for architecture. Computer-Aided Design 33(14) 1111 – 1122.

4. IAI (2010): Industry Foundation Classes. Industrieallianz für Interoperabilität e.V. Electronic Publication: http://www.buildingsmart.de/ [13.08.2010].

5. Langenhan, C. (2008): a.vista - Semantische Suche Web 3.0 für die Architektur, Diploma Thesis, Bauhaus-Universität Weimar, May 2008.

6. Lu, T., Yang, H., Yang, R., Cai, S. (2006): Automatic analysis and integration of architectural drawings. International Journal of Document Analysis and Recognition (IJDAR) 9(1), 31–47.

7. Or, S.h., Wong, K.h., Yu, Y.k., Chang, M.M.y., Kong, H. (2005): Highly Automatic Approach to Architectural Floorplan Image Understanding & Model Generation. Pattern Recognition.

8. Richter, K., Heylighen, A., Donath, D. (2007): Looking back to the future – an updated case base of case-based design tools for architecture. Knowledge Modelling – eCAADe.

9. Tabbone, S., Wendling, L., Tombre, K. (2003): Matching of graphical symbols in line-drawing images using angular signature information. International Journal on Document Analysis and Recognition 6(2), 115–125.

10. Tombre, K., Tabbone, S., Pélissier, L., Lamiroy, B., Dosch, P. (2002): Text/graphics separation revisited. Lecture Notes in Computer Science, 200–211.

11. Weber M., Langenhan C., Roth-Berghofer T., Liwicki M., Dengel A., Petzold F. (2010). a.SCatch: Semantic Structure for Architectural Floor Plan Retrieval. In: Montani, Stefania und Bichindaritz, Isabelle (Ed.), Advances in Case-Based Reasoning, Proc. of ICCBR 2010.
12. Weber M. (2010). a.SCatch - A Semantic Finder for Architectural Floor Plans. Master Thesis, University of Kaiserlautern, July 2010.

DATA ABOUT THE AUTHORS

C. Langenhan, F. Petzold
Faculty of Architecture, TU München, Germany
langenhan | petzold [@ai.ar.tum.de]
http://www.ai.ar.tum.de

ДАННЫЕ ОБ АВТОРАХ

С. Лангенхан, Ф. Петцольд
Факультет архитектуры, ТУ Мюнхена, Германия
langenhan | petzold [@ai.ar.tum.de]
http://www.ai.ar.tum.de