Current State and Further Development of a Case-Based Framework for Early Phases of Architectural Conceptual Design

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Abstract This work provides a summary of the most recent publications in the context of the case-based architectural design support system MetisCBR. It also provides an overview of the features that are currently being developed to extend the functionality of the system.

Keywords: case-based design, retrieval strategies, cognitive model, explanation

1 Introduction

MetisCBR [4] is a case-based framework that was created as a purely CBR-based retrieval engine to support the early phases in architectural conceptual design. The framework's goal is to increase the efficiency of the design process, i.e., to provide the target user group (architects) with a tool that can find helpful and inspirational designs for the given task (or its sub-tasks). By means of applying the techniques of case-based reasoning [1] (especially the methods of case-based design), an architectural design process can be enriched with data available from experiences made by architects during the creation of previous similar designs (i.e., similarly structured or designed for similar purpose). The framework is currently developed as part of an ongoing PhD work and is used for prototypical implementation of the functionalities for research intentions and of the results of the accompanying studies. The basis of MetisCBR is built on the case-based learning agents paradigm, that is, the agents learn from previous experiences (in our case interpreted as retrieval processes for search of similar architectural designs) in order to apply the best possible strategy or to avoid the application of the strategy with a possible negative outcome. Currently, the framework is in its advanced stage of development where the initial functionality (retrieval and learning of previous queries) will be extended to the process-oriented functionality with retrieval, adaptation, explanation, and extended learning features. The current architecture of MetisCBR is shown in Figure 1.

In this paper, we will present the most recent work published in the context of our research. We will also report which of the features named above we are going to develop next to enhance the functionality of MetisCBR for our further research activities.

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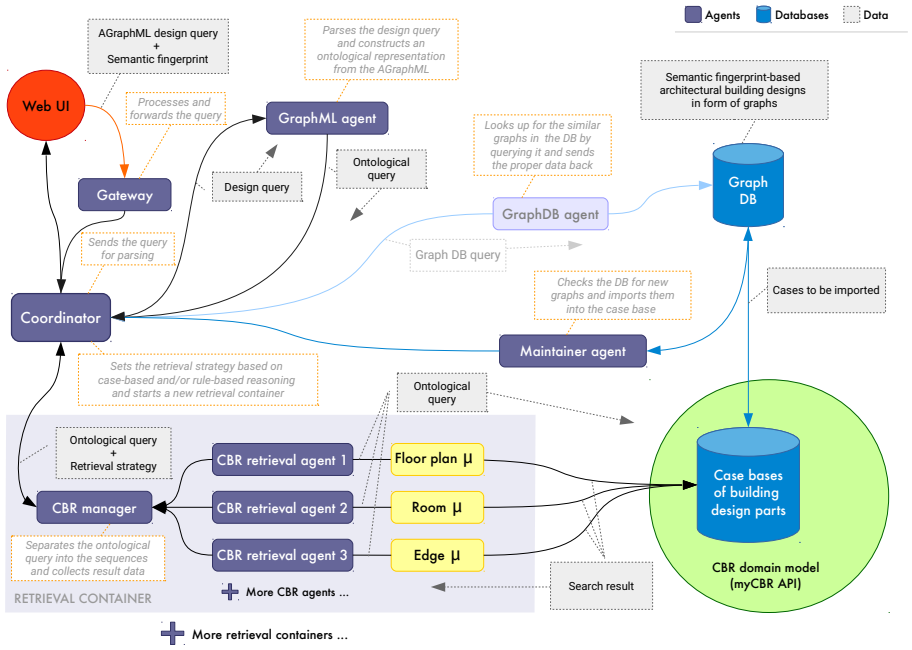

Figure 1. The current general structure of MetisCBR. The coordination agent *(Coordinator)* is responsible for the whole retrieval process: it selects the most suitable retrieval strategy for the current query and creates a retrieval container that conducts the actual retrieval with CBR methods within the case base of previous designs. The container can resolve the complete query or parts of it (the concrete task depends on user criteria), it is also possible to run multiple containers concurrently. Other agents of the system help to transform the query into the language format understandable for agents *(GraphML agent)*, communicate with the user interface *(Gateway)* or maintain the case base of building designs *(Maintainer)*. This Figure is an adapted version of Figure from [4].

2 Recent Work

Our most recent published work dealt mostly with comparison of MetisCBR to other retrieval engines with identical purpose (i.e., the search for similar architectural designs) and with initial extension to a process-oriented system. In the next sections we describe this recent work.

2.1 Comparative Evaluations

The goal of the evaluations was to examine under which *architectural scenarios* (i.e., tasks of constructing a building design for a certain purpose, e.g., *an apartment for elderly married couple*) MetisCBR would perform best and what the current technical boundaries of the system are (e.g., what is the most complex possible query that the system currently can handle).

The first comparative evaluation [5] was conducted between our framework and a retrieval coordination middleware *KSD Coordinator* that has access to the methods of exact subgraph matching and database search. This evaluation has shown that MetisCBR is currently more suitable for scenarios where a sufficient number of cases (i.e., architectural designs) should be found to provide an inspirational space for an architect. However, when it comes to the scenarios where an exact connection within a building design should be detected to take a look at this connection in other context, a subgraph isomorphism method would be a preferable one.

The second evaluation conducted in [7] compared MetisCBR to another exact graph matching approach VF2 [6] and an index-based searching approach for a certain number of queries. It was also aimed to proof if the methods can handle complex queries with big number of rooms and connections. All things considered, MetisCBR was able to be rated as the second best retrieval method (preceded by the VF2 method) and earned the joint first place for the handling of the complex queries (together with the VF2 method).

2.2 Initial Extension to a Process-Oriented System

In order to improve the system performance and the quality of results returned by MetisCBR, we decided to extend it to a process-oriented system, where the retrieval strategies will be embedded in the complete conceptual design process, the processes themselves will be categorized and assigned to a user when a certain behavior is detected (i.e., the processes will be seen as *user models*). To provide structure to retrieval strategies and processes/user models, we conducted a study where the target group (architects) played the role of the system and were asked to manually find the most similar case in a case base of printed designs and to model their similarity assessment strategy afterwards. The results of this study allowed us to infer definitions for strategy and process according to architectural requirements for implementation in our system. The complete results and definitions for strategy and process are available in [3].

3 Further Development

To enhance the functionality of MetisCBR by conducting a novel research and to gain more interest in the research area of case-based design among the young academia community a number of special student (graduation) projects were recently started to initiate the system's further development. We decided to initiate research and development activities in the following directions:

- *Retrieval strategies* – implementation of a number of new strategies for the retrieval phase according to the requirements of strategy definition from [3].
- *Cognitive architectures and user models* – a comparison of MetisCBR's current system architecture with a number of well-known cognitive architectures.
- *Explanations* – conceptualization of explanation patterns for retrieval results.

The short descriptions of each project are provided in the following sections.

3.1 Retrieval Strategies Implementation

The implementation of retrieval strategies according to the definition provided in [3] is an essential part of examination of suitability of the definition for a 'real-word' use. Currently, a number of custom new strategies are being implemented as part of a bachelor thesis. An evaluation with participation of a domain expert will show if the strategies provide an improvement for the retrieval phase, i.e., if the new strategies return better results than the old ones. It is then planned that, depending on the evaluation results, these new strategies will replace or complement the currently available strategies. An exemplary new strategy previously published in [3] is provided in Figure 2.

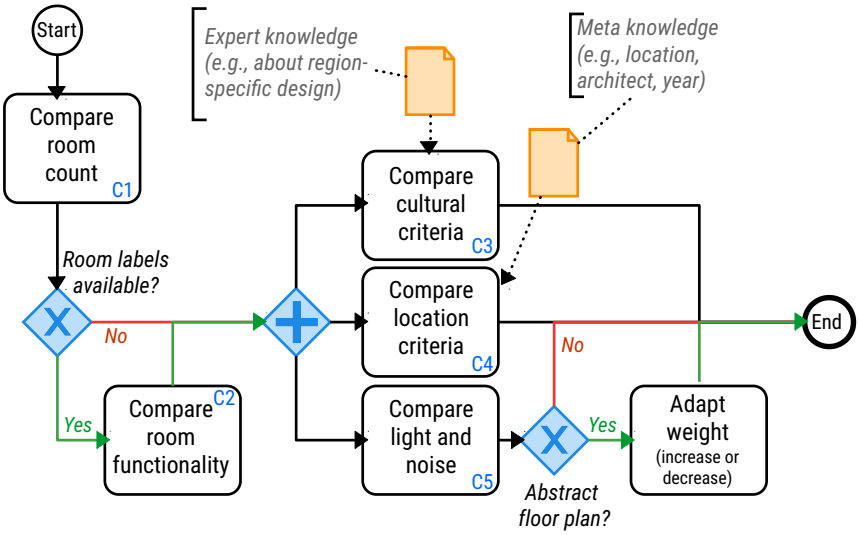

Figure 2. An exemplary strategy from [3] constructed according to the definition provided in this work (Figure from [3]).

3.2 Comparison with Cognitive Architectures

Cognitive architectures such as ACT-R [2] or Clarion [9] are some of the previously developed models of abstract human behavior. These models will be analyzed, configured to correspond to the purpose of MetisCBR and evaluated using predefined criteria. The evaluation, as well as analysis, is part of a master thesis and will show which features can be adapted from these architectures to improve MetisCBR's user models development.

3.3 Explanation Goals and Patterns

Finally, a non-graduation project has been started that is aimed to explore the explanation goals described in [8] and to adapt them for construction of explanation patterns for MetisCBR w.r.t. these goals. This project is the next

step of addition of an explanation component for results returned during the retrieval phase. This explanation component will help us to improve user's trust in the system, as it will provide an additional data to the results by enriching them with information about relevance and justification of single results.

4 Conclusion

Concluding, we can summarize that the development of MetisCBR has stepped into its next planned phase, i.e., the system does not conduct retrieval only, but will provide additional functions, such as explanation and personalization of search behavior (user models), followed by adaptation and extended learning features in the upcoming phases.

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