Distributed Case-based Support for the Architectural Conceptualization Phase

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Abstract For the early phase of conceptualization in the architectural design a case-based retrieval approach for finding building designs that have similar semantic and topological structures to a currently created one, can provide a helpful tool for inspiration and comparison of architect's own ideas with the solutions available in a case base of previously created designs. The approach presented in this research summary is aimed to provide such a tool that can deal with queries and cases that can be represented as graphs. Moreover, in the late phases of the research, the approach should be extended for application beyond architectural design and provide a generic framework for distributed case-based search of similar graphs for other suitable domains. Constraints of the search, explanations, initialization of the case base, and the knowledge about user behaviour are the important aspects of the concept of the framework.

Keywords: case-based design, case-based retrieval, distributed CBR

1 Introduction

The conceptualization phase of architectural or industrial design is considered a process of knowledge-intensive reasoning for the purpose of finding ideas and concepts that are helpful for the solution of the current design task. For architectural domain, a combination of methods of case-based design (CBD) and computer-aided architectural design (CAAD) can provide helpful solutions to support the conceptualization phase. The retrieval of similar designs to a currently created one is mostly a key feature of such a solution. The basic CBD/CAAD research project *Metis – Knowledge-based search and query methods for the development of semantic information models for use in early design phases* of the German Research Center for Artificial Intelligence (DFKI) and the KSD Research Group of the TU Munich aims to determine such solutions by considering building

design as representation of semantically enhanced graphs. During the project activities a comprehensive modular retrieval system for the purpose of finding of similar designs was elaborated. It consists of different retrieval engines and supporting modules and can be connected to a user interface for constructing of queries and receiving of results.

2 Focus Phases and Goals of the PhD Research

In the first phase of my PhD thesis research I focused on the tasks of consolidation, extension, and evaluation of the distributed multi-algorithmic case-based retrieval engine for architectural designs *MetisCBR* (which became one of the retrieval engines of the above mentioned modular system), according to the project's research goals and requirements. The systems differs from other approaches for CBR-assisted architectural design in its underlying structure (which is distributed, i.e., based on a multi-agent system with possibility to accomplish retrieval processes in parallel and achieve results in reasonable time amount). Research work, that describes the system more in detail and evaluates its retrieval performance, has been published during this first phase. This work consists of the following contributions:

- The description of the mode of operation of the system [2], where the underlying concepts of the system's CBR-based retrieval of architectural designs with (case-based) agents are described. In this work the overview over the system architecture, the distribution of the retrieval process between several agent categories (such as case-based, managing, and service agents), and the retrieval coordination concept is presented. The most essential feature of the system, the retrieval containers that are responsible for the actual search for similar architectural designs (or its parts), is described in detail.
- The description of the domain model of the system [1], where the underlying structure of a case within the case base of the system is presented in detail including the influential concepts for this structure, the attributes, and similarity measures. The basic retrieval strategy is presented as well. This work also includes an evaluation of the model and the strategy with an exemplary design query.
- The system-wide concept of the ontology-based communication architecture [4], that describes how the agents of the system communicate using the specific domain ontology and communication patterns. This work also includes an overview over the early concept of the explanation module for the system (see also Section 2.3).
- A comprehensive cross-comparison and evaluation [3] of MetisCBR's rule- *and* case-based retrieval coordination component and a rule-based coordination service of the KSD Research Group that has access to the exact subgraph matching methods and direct search in the databases. In this study the human experts of the architectural design domain evaluate the results of both systems for different user scenarios using different rating criteria. The computed similarity values returned by the systems are analyzed as well.

The next phases of my PhD research will be focused on the conceptualization, initial implementation, and a stepwise evaluation of a generic distributed case-based retrieval framework that can be applied to other domains than architecture. The main requirement for domains to be considered for the retrieval framework will be that a typical query can be represented as a graph for which similar (sub-)graphs (cases) should be retrieved. Architectural domain will remain the showcase domain for demonstration of the abilities of the system, as it differs from other domains in context of the targeted user group, variable complexity of retrieval requirements (e.g., search for sub-structures only is often a case), and case base-related challenges (e.g., the case base of architectural designs of the Metis project consists of a relatively small number of cases, but they strongly vary in constructional aspects). Another important aspect of the difference between architecture and other domains is the case representation of graphs: in architectural domain, and especially in the Metis project, a graph represents a single floor plan of a building, whereas for example in the process-oriented CBR it represents the process steps.

The main research and development activities during the work on this framework will be focused on the following aspects:

- Elaboration of distributed CBR-based retrieval, learning, and explanation methods that can help to overcome the complexity of subgraph isomorphism.
- Determination of hard and soft constraints under which such a CBR-based subgraph isomorphism detection can deal with given search requests.

The Figure 1 demonstrates the research process of my PhD work in an overview of the phases that it consists of. In the following sections the main research goals of the next phase are described in detail.

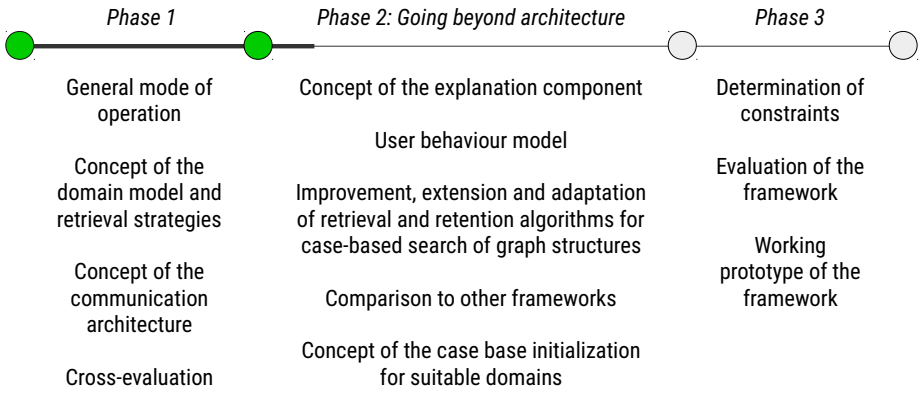

Figure 1. PhD research phases for the distributed case-based retrieval framework.

2.1 Retrieval and Retention Algorithms

The CBR retrieval algorithms currently available in the system will be extended, improved, and adapted according to the results of the (cross-)evaluations with other retrieval approaches of the previously mentioned modular system (with optional participation of external approaches). For this purpose, a comprehensive user study is currently planned to be conducted that is based on the hypothesis that different user scenarios in the architectural domain can have one or more contexts in common. That is, the study should result in initial sets of user scenarios and contexts suitable for each algorithm. The properties of the scenarios and contexts will be seen as constraints under which this retrieval algorithm is the best possible choice. Such user evaluations of results that the algorithms are returning will be conducted periodically and play a role of a key step on the way to narrower exactness of the constraints.

Parallel to the improvement of the retrieval algorithms, a collection of retention algorithms suitable for needs of the framework will be conceptualized to provide learning ability for the agents of the system. Some of the agents are already able to learn cases (that are the previous queries), this will be extended for other agents in order to provide the features of indexing and fast response with suitable results on all retrieval levels.

2.2 Model for User Behaviour During Conceptualization Phase

During the next phase of my research I am also planning on creating a patterned model of user behaviour during conceptualization of an object (in this particular case: an architect that creates a building design) *that can be represented as a graph*. For this purpose the analysis of currently existing models and experience gained during the project's activities will be combined to provide an initial base for the model, that will be then modified and adapted according to user studies that will be conducted especially for this purpose. An important aspect of the model and of the studies will be the strict consideration of graph-based conceptualization objects.

2.3 Explanation Component

An additional context-based component that provides an explanation why a particular result was included in the result set, or why it was placed on this position in the set, or why the result set consists of results of a certain type, will be implemented in the retrieval framework and is currently elaborated as a particular task in a bachelor thesis. The explanation contexts can refer to retrieval primitives (such as semantic fingerprints [5] that are used for the architectural domain) or to other common features of results (such as that the results can have a common identifier, e.g. the floor plans can belong to the same building, and can be grouped by this context). The concept of the explanation component can be adapted by another search engines of the common modular system: they should support the foundations of this context-based explanation concept, but provide own methods of detailed composition of explanations.

2.4 Case Base Structure Initialization for Suitable Domains

A very important task for transition from the architectural domain into the generic purpose of the framework will be the task of initialization of the case base for a given domain. To accomplish this task, the methods of information extraction, file format (e.g., XML) parsing and data linkage will be implemented to provide an automated method of creation of structure of the case base. It will be also possible to adapt the structure by a user (e.g., domain expert) to provide more realistic model for cases to be retrieved. The research question that I am going to answer with this step is if it is possible for a CBR application to initialize the graph-based representation of cases fully automatically by itself, which grade of human influence during the initialization is needed, and how domain-dependent such an initialization could be.

2.5 Comparison to Other Frameworks

The (distributed) CBR architectures and frameworks like SEASALT [7] or DRAMA [6] provide approaches for conceptualization of an experience sharing system for the given purpose or domain (e.g., travel medicine or aerospace). During the further research activities I am going to compare such approaches with the generic framework of my PhD work. For this purpose, these approaches will be exemplary applied to the domain of retrieval of similar graph-based cases. This comparison should result in a suitability evaluation of the examined systems for this purpose, it will also show which features from the opposite systems can be adopted by another system.

3 Current Progress

Currently the research and development activities in context of the generic retrieval framework are in the stage of prototypical integration in the above mentioned modular system architecture that includes, among other things, the web-based user interface for query construction, a result augmentation module for visualization of mapping of components between query and result, and an analysis module that is able to apply common data analysis techniques to the results returned by search engines of the system. The improvement and evaluation of visualization of the results of the retrieval and the corresponding data analysis are the upcoming tasks of the modular system.

The next steps for the retrieval framework include adjustment of the scoring approach of results for all retrieval algorithms and the initial implementation of the explanation component. After that a research and a user study is planned to be conducted, in order to create the first version of the above mentioned user behaviour model, that will hopefully provide insights and patterns that can reconstruct the conceptualization process when an object that can be represented as graph is going to be conceptualized.

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