Online Database for Structural Details – DeTra

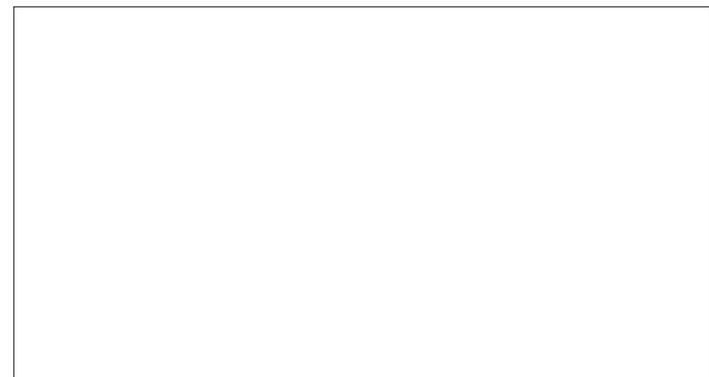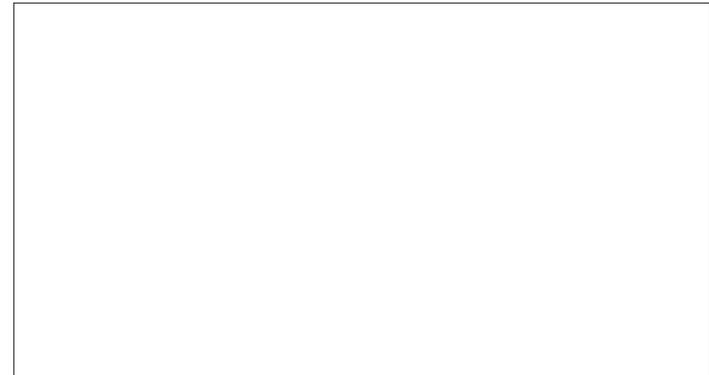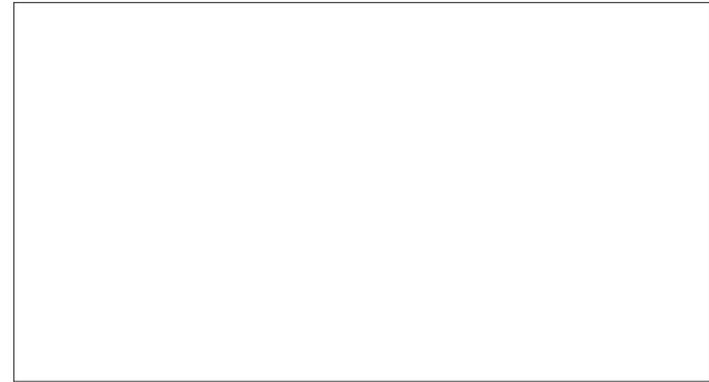Robert Pahle
Arizona State University

Friedhelm Stein
University of Siegen

Abstract

DeTra is a research project that arose from the question: "How is it possible to assist students and professionals in architecture, dealing with structural details?" Our solution is a structural detail database, which assists by presenting example solutions of similar designs. This research was conducted in two overlapping parts. The first part of the research included the definition of a structure and a language to describe structural details—flexible enough to enable complex computer based queries, simple enough to be understandable. Major problems were the inclusion of vague terms, different meanings for the same word, and different words for the same fact. The second part was to create internet-based computer software, which utilizes the developed concepts and allows their evaluation. Thereby the system can be used with different access methods to the same data collection.

   This approach intends to present both standard detail examples and project-related detail examples. For that reason the structural connections will be presented including all available project data. The information includes texts, sketches, drawings, photos, animations, and the database description. Our implementation handles this content. According to the holistic presentation of the search results a strong tool for evaluation is given to the user.

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1   Introduction

In illustration 1 you find a sketch of a preliminary design. In order to realize such a concept, it is necessary to make decisions on many different aspects, such as structure, building construction, and design. One of these aspects is the detailed design of the structural junctions. At first glance, it looks like a simple structured problem. There are a limited number of trusses joining together in one point, each one with a well-defined angle and profile. But, in real life you can find thousands of different solutions for the same "simple" problem. Apparently, there must be a lot more of additional aspects which determine the final design of each structural junction. Unfortunately, many of the additional aspects are not precisely definable. For instance: "How does it fit to the neighborhood?"

How do architects normally handle such a situation? They screen journals, books, or papers. There are books on steel construction, books on frames, and articles on specific projects, but you won't find books about structural details dealing with the complete array of structural junctions. That's why it is quite difficult for students of architecture to deal with the design of structural details.

Such problems are quite often in architectural education. Therefore, the methodology "learning on examples" is well established in teaching for architects and designers and has proven to be very efficient.

In a joint research project of the structural design departments of Aachen University of Technology and the University of Siegen our research group aims to use this methodology for structural details. The projects name is DeTra, a combination of the first letters of the German words "DEtails von TRAgwerken" It is financially supported by the "Universitätsverbund Multimedia NRW."

2   Idea

As per description, there are huge numbers of details with similar functions. To handle such a large quantity of information fast and reasonably, it is suggested to use a computer based database. Since there will be consistently new details to put into the database, it's advisable to use a central data management
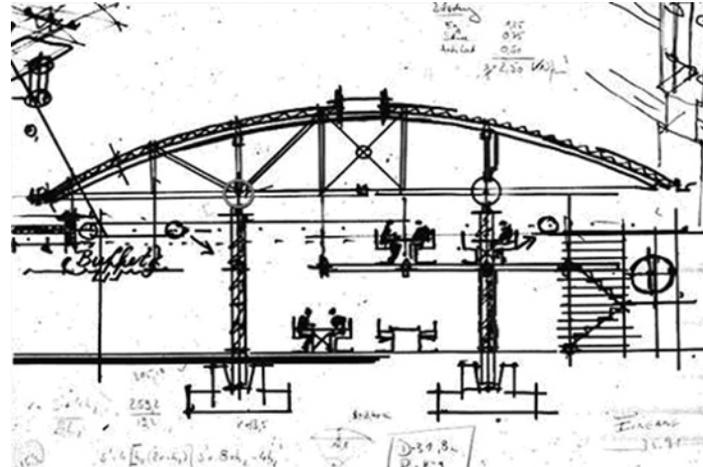

Figure 1. Sketch of a preliminary design of a café.

to access the up-to-date information at all times. The internet as a worldwide computer network is a perfect tool for such a task. In order to use such a database very easily, it makes sense to develop several different methods of access. Self-evident is the access via a website for finding relevant details with appropriate criteria. Many of the relevant criteria are already available in programs for statical calculations. Therefore, it makes sense to use this existing information directly for the request—the second method to access the database. A third version is a teaching tool for aspects of constructional design or structural design, which stresses the content with examples of the database.

To give the person who is seeking the right impression of the located details, it is important to utilize a good and logical extract of the given information. Therefore it is the idea to present a detail preferably in the connection with the building in which it is used. Only on a special request should all information of the database be displayed.

3   Related Work

Within the context of classification of structural details a large amount of work has been done to describe and classify structural details (Ackermann 1988; Ackermann & Dersch 1982; Ballast 2000; Becker 1987; Ewald 1975; Newman 1993; Roth 1994, 1996, 2001; Williams 1999). But to come up with a concept for storing structural connections in a database, there are some parts missing. First and most obvious are the vague descriptions of design. Architects especially like to describe their work in vague terms like "compact," "solid," or "flexible." Second, the language between customers, architects, and structural engineers is not always clear cut. There are misinterpretations and misunderstandings among them. For that reason, it is not easy to define a description for a specific detail which is definite. Third, classifications of structural connections do not follow one scheme. Therefore, the design of a database which suits all

possible designs is extremely complex.

There are some commercial products available which allow searching for structural details (Architectural Details Inc. 2003; Detail 2003; Newman 1997). These products provide a data collection and a predefined way to approach the information, but they are lacking any possibility to describe the anticipated detail exactly and then search for appropriate solutions. Another problem with these commercial products is the aim to find exactly one solution for a problem. Often this solution is available in a drawing format like AutoCAD's DXF or DWG and can be integrated into a drawing immediately. Our approach tries to find as many as possible examples to a given problem. The architect or student is encouraged to adapt his own detail from many different solutions presented in a comprehensive manner with respect to the project where they have been used.

4   Description of structural details

The implementation of a highly detailed structural connection search is only possible if there is an adequate descriptive language for structural details. As seen in the discussion of related works, there are only few attempts to standardize terminology and descriptive patterns for structural details. This problem is even more difficult since vague terms like "a heavy junction," describing the architectural design, are very important communicative elements in the description of a detail. On the other hand, there are a lot of predetermined terms like purlin structural situations. Count and measurable descriptions like materials, stress, etc. are a third possibility.

Many details are created by specific persons for specific projects. This information is also very important for a potential search, since an architect is able to assess structural details with regard to a build project. Furthermore, it should be possible to search for other details of the same project to evaluate the overall implementation of details, as well as a search of details, which belong to a specific architect to compare differences between projects. Therefore, an appropriate description should include each of these three aspects in a computer interpretable version in order to support flexible and detailed search queries and an easy possibility for implementation.

The categorizing of the different aspects led to four major groups.

- Detail Features
- Detail Elements
- Projects
- Persons

The information in these four major groups can be further structured in subgroups, and the subgroups can be composed of other subgroups up to the level of a single information piece. This realization led to the idea to organize all information hierarchically in a way that avoids redundancy. Figure 2 shows a part of the hierarchical structure.

The example address can be used for both, projects and persons, which could have an address. It is a tree, which can
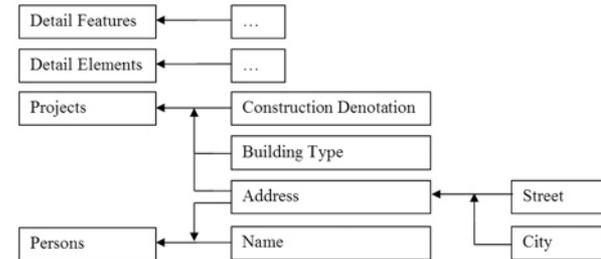

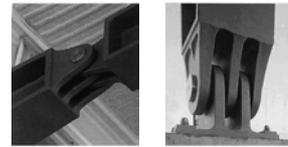**Figure 2: Part of the hierarchical description structure**

Figure 3: Different connections at the same building

have cross connections at different levels. In the following sections we describe briefly our classification:

4.2   Detail-Features
The classification detail-features describes structural and design information, which is based on the complete detail, such as the adjacency of a connection to a wall or a ceiling.

4.2.1. Component Features
Component features describe that the connection is adjacent to a wall, ceiling, roof, or façade. For each component it is possible to specify points like a bottom connection, a middle connection, or a head connection of a façade or a wall, as well as to specify specific points for the roof like a purlin or rafter support. This specific way of description is used to include well known professional language.

4.2.2. Structural Features
The classification structural features is a description of a junction through structural components like frame, arc, truss, cable supported structure, beam, column. It is also possible to specify points like bottom or top of a column.

4.2.3. Stress Features
Structural junctions can also be described by the kind of stress (e.g. tension, or pressure). There are specific terms like tensile bar or tensile rope, which specify indirectly how the junction acts.

4.2.4. Design Features
Design features are very important for the implementation of the final junction. It is the desired visual effect, which gives the architect the possibility to distinguish the specific detail from general solutions to make it more individual. There are often

overlaying design themes, which are for instance used to create similar layouts for junctions in the same building, although the structural needs of each junction are different. In figure 3, there are two junctions of the same building, which could be characterized as accentuated, which is the description of the visual effect of the junction. Often there is a range of descriptions like accentuated, less accentuated, and not accentuated. Another way to distinguish junctions is if the parts are fit together directly (e.g. welded), or if there is another element in-between like the bolt in figure 4.

4.3   Detail-Elements

The second general approach is to look at a detail by describing the elements of which it is made. For instance, in figure 3 left image there are two elements that are connected together. Each element has its own characteristics.

4.3.1. Number and Angular Arrangement

In a first step, it is important to name the elements exactly. Therefore, it is the easiest way to count the connected elements. There are many ways to count and to start counting the elements. After many discussions, our research group decided, referring to a Cartesian coordinate system, to start the counting at the positive x-axis and go counter clock wise beginning with element 1 as seen in figure 4. Angles are also counted in the same way, starting always from the positive x-axis. Since many angles are not exact known, there are 8 different angles we consider for the search [0°, between 0° and 90°, 90°, between 90 and 180°, 180°, between 180° and 270°, 270°, between 270° and 360°]. Thereby between 0° and 90° means an element can be located somewhere between these angles. The major reason for this model is stress, which differs strongly between different angles. For instance, a column (usually oriented vertically) has a quite different load and stress than a beam (usually oriented horizontally), and there is also a difference between a vertical element and an element not just vertically oriented. A second reason is practicality. In order to easily describe the angular properties, it should be easy enough to do (e.g. without a tool). On the other hand there is a loss of exactness, but our tests have shown that the results based on a geometry search are still very good.

4.3.2. Element-Type, Cross-Section Type, Materials, Stress, Connection-Information

Since we have defined a way to name each element of a structural junction it is possible to describe each element in a detailed manner. In many cases the specific purpose of elements can be extracted by their element-type name, like column or beam

   A second classification is the cross section type. Figure 5 summarizes some of the most popular types. The last icon [Figure 5, bottom left] symbolizes a free form, where it is not
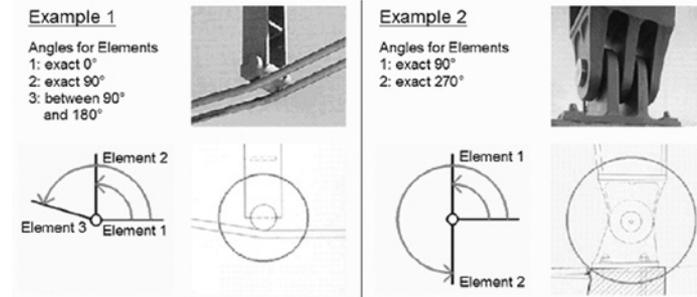

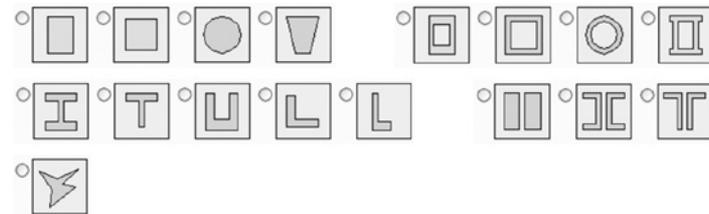**Figure 4: Counting and angular arrangement of elements.**

Figure 5: Most popular cross section types.

possible or not easy to specify a cross-section type.

   Each element is made of one or more materials; thereby the building-material has to be another classification.
The stress of each element can be defined as pressure, tension, bending moment, or a combination of these. So, each element—not only the complete junction—can be classified using stress. It is also esthetically and structurally important how each element is connected to the joint. First, we can look at the static information: bending resistant or pin-jointed. And second, it is possible to define the way a specific junction is joined (e. g. welded joint or a bolt etc.).

4.4   Projects

Another criterion, which specifies a structural junction, is the building or the buildings where it is used. This information is interesting because different junctions of the same building often have overarching visual layout. Sometimes junctions are designed specifically for one building. It should be possible to describe all junctions of the same building, and therefore projects are a classification.

   Sub classifications of projects for instance are the denotation, address, and the building type such as stadium, school, or theater.

4.5   Persons

Many structural junctions can be related to the architect or engineer who developed the joints. Architects often tend to create their own "hand writing" in design. For instance, many buildings of Richard Meyer or Frank O. Gehry are interrelated through design singularities such as white tiles or amorphous

metal structures. If one searches for a specific design type, it can be really useful to consider structural junctions of the same architect.

4.6 Complete description – a combination of classifications

Each of the given classifications can be combined to describe the complete structural detail. The description can be increased gradually depending on how much information for a structural detail is available.
Example:
- 3 Elements
- Element 1 = Steel
- Element 1 = between 0° and 90°
- Element 1 = T-Beam
- Element 2 = Steel
- ….

Such a very detailed description is necessary, specifically if one wants to search for an example of a structural junction based on a drawing (see section 5.3).

4.7 Vagueness and Misinterpretation

Since there are often many terms for the same information or one term which can have different meanings, the idea comes up to standardize the language of the different professionals. For our project such an approach was far too difficult. We decided to try a different approach. For a specific criterion (e.g. material), we can determine which information (e.g. steel, wood etc.) is used in the database. For querying a specific criterion only the available data is displayed either in a list box or as an image. Thereby it can be easily determined which term was used to describe a specific detail, and so the search query is much easier. A future version of the descriptions could also include a thesaurus to enable different terms with the same meaning to have the same search results.

Another problem can be the mirroring of a structural junction. Our description (specifically numbering and angles) starts always from the same side, but usually a structural connection can be used also in a mirrored version. We decided to leave that problem as is and to rely on the judgment of the user to understand this issue. We will consider integrating a mirroring of search criteria for a future version.

5 User Interface

In order to find a user interface which is easy to handle, different possibilities were tested. As a result, both internet based queries and input could always be divided into three steps. Primarily, the criterion to be edited has to be chosen. Secondly, information is attributed to this criterion. In the final step, the issue is illustrated for examination.

The interface of each part of the program is discussed succinctly in this paragraph.

5.1 Data Input

In order to enter records into the database, the user has to authenticate in the input area, typing in his username and password. Then it is possible to start the input on a specific internet page.

The system implementation separates groups of information, such as projects, elements, materials, etc., and objects (the actual structural junctions). If one wants to give certain information to an object, this information is only assigned through a pointer. That guarantees that information is not redundant and simplifies the process of inputing the data, because e.g. information about an architectural project is only typed once and can be assigned as often as necessary.

An object being filled with information is illustrated in figure 6, inside the green border. The input of data takes place in the three main areas starting from the left side. First, a branch of criteria is specified on the left side [Figure 6, blue border]. All sub criteria will now appear in the second area [Figure 6, middle]. These are information pieces, which can be attached to an object and which later will allow the search for a specific object. For each criterion a list box turns up, offering all acceptable entries. By selecting appropriate entries of the list boxes and clicking "save" the selected information is attached to the object and shows up on the right side [Figure 6, red frame].

In the case that desired information fails to appear in the list box, a respective input field is provided, available by clicking on the sub criterion that is created as a link. Besides, in the opening window, existing entries can be deleted [Figure 7, red frame], or can be modified and completed [Figure 7, blue frame]. Modified data is automatically updated for all references.

When editing is finished, the window can be closed; all necessary data will be updated automatically. On the right side of the main entry page [Figure 6, violet frame], the complete data that is available for a certain object will appear self-controlled. The X [Figure 7, red frame] is used to deallocate. With the described procedure, any information can be collected to an object, whereby a single junction is regarded as an object. Such an object will only be free for querying after assigning presentation data to it. This can only be done by storing suitable images and texts in the database, assigning them to a certain detail, and completing the procedure by reassigning them in the presentation area of the input page. Henceforth, the detail will be ready for querying.

5.2 Search over the Internet

The start page, which appears via Internet whenever DeTra is started http://detra.architektur.uni-siegen.de, is the query interface. At this place the user gains the possibility to search for details that suit his personal requirements. Again, the procedure is divided into three sections. First, a relevant criterion is chosen from the criteria tree in the left field [Figure 8, blue frame]. Depending on that selection, he either can input search values, or, when the database is already able to determine possible

Figure 6: The form to allocate information to an object

Figure 7: The form to enter information

Figure 8: Search form

values, choose from a list of records [Figure 8, middle field]. Depending on the requirements, selections will be displayed either in a list of text information or in a list of small diagrams. The element number, referring to a single element that is meeting the queried junction, can optionally be given, generating a relation between the search criterion and the specified element.

Whenever search criteria are chosen, they are listed on the lower part in the middle of the screen. Simultaneously, a query is performed generating a list of result-records in the right field [Figure 8, violet frame]. The list of criteria is linked as an AND-conjunction. By clicking on the respective trash button, a criterion can be removed from the criteria list [Figure 8, red frame].

By clicking on the title or thumbnail of a search result in the right frame [Figure 8, blue frame], a new window opens with a detailed description of the corresponding record. The detail is presented in the context of the respective project, accompanied with images and explanation texts. This presentation complies with the presentation area in the data input section. Additionally, an outright view with all accessible information can be obtained.

5.3   Search with Structural Information of a Graphical-Static Software

In order to simplify the input of search criteria, a procedure has been developed, allowing direct data assignment from a example-static program to DeTra. This program has been created as an LISP application in AutoCAD, and has been expanded with respective program modules. First, a sketch of the structural system is drawn, and values are assigned to material, profiles, support, and load [Figure 9]. By hitting the command button "Search connection examples," all information is read and sent to DeTra, and the query is performed immediately. The data transfer is achieved by sending the data from Auto-LISP via command line to the Internet Explorer to the respective web page, which prepares the received data and forwards it to the actual query [Figure 10]. In the help menu, the functionality of querying is accurately described on the basis of examples. As already mentioned, the current prototype allows adjusting the list of criteria, even with a filled database. To relieve future decisions upon suitable criteria, each query is logged in an anonymous hit list.

6   Implementation

At the time being, the Internet offers one of the easiest ways to distribute information. In order to provide a widely spread accesibility for students, the research group decided early to use standardized hard- and software and, regarding issues of access and of updating the database, implement a centralized version of the system (Client-Server Principle).

For storing and searching the structural details we use the mySQL database, available for Windows, UNIX and Macintosh; PHP scripting language is used to prepare the data for distribution in HTML format—both free available for our prefered
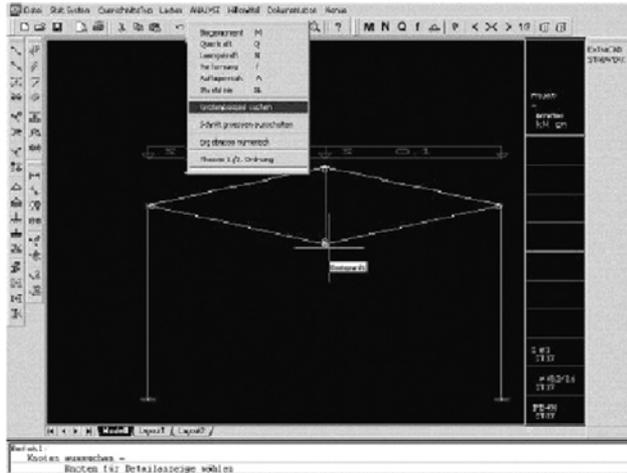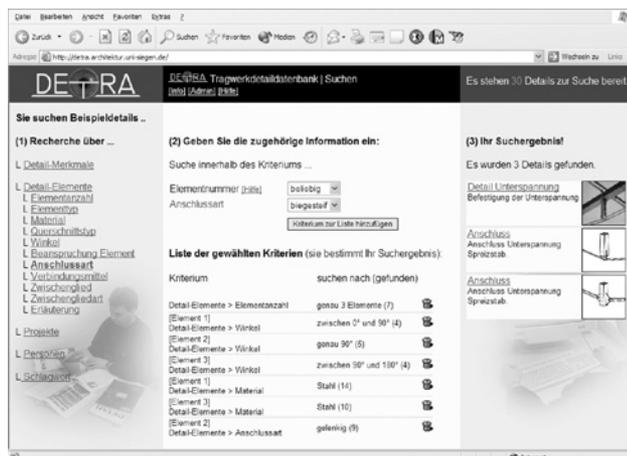
Figure 9: Example of a graphical query.

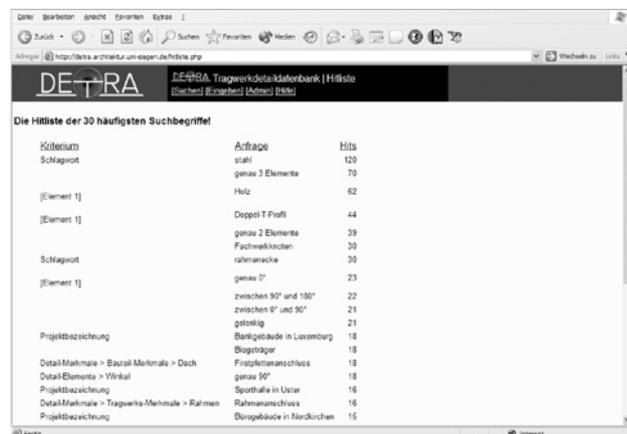**Figure 10: Query results.**

Figure 11: Hit list of the queries.

computer platforms.

Of the many possible web-server-combinations we chose a Windows 2000 Server—Internet Information Server 5.0 and a RedHat Linux 7.1—Apache 1.32 combination. Clients too can choose between several operating systems and browsers, like Linux/MacOS/Windows and InternetExplorer/Netscape/Mosaic; due to the lack of time we tested only the Internet Explorer for search queries.

As our example-static-program is an AutoCAD-application (see section 5.3). Windows-environment is needed for its use.

7 Evaluation
Evaluating DeTra was a difficult and time-consuming task—and it has not yet come to its end.

In a first step, the research team presented the language and its structure to professional architects, teachers, and lots of students. Due to this process, an efficient way to select appropriate and graspable criteria was found. In the second step, professionals and students tested different versions of the user interface. Here, a multi page oriented version, where criteria and the results appeared on different web pages, was discarded in favor of a single page version where criteria and search results appear on the same web page. We learned that starting the search at any odd search criterion is more flexible, but at the same time more difficult, than a guided approach over many web pages. There seems to be a trade off between search-flexibility and ease of use.

Finally, we decided on the more flexible solution. The current version allows the listing and the manipulation of search criteria generated through this automatic process.

Very interesting information for evaluation is gathered by maintaining a hit list of the most often searched criteria [Figure 11]. This hit list allows analyzing which criteria were selected properly and which approach for searching the data base is preferred by the users. This enables the optimization of search criteria.

Another approach to evaluation was made by asking students to acquire and input more structural junctions for the search. In their seminar, the students had the task to choose buildings and to analyze and describe structural junctions from different perspectives such as structure, construction, and design. The results of this experiment were that the needed abilities to understand the structural implications, as well as the professional language were not adequate to the detailed needs of the data input. Thereby a member of the research team had to review all given details to verify the appropriate description. We came to the conclusion that for a final version a specifically trained professional should input the data.

8   Limitations and Outlook

The research at hand is the approach of the authors to handle a complex database system. Due to the high flexibility of the system, there is a leak in query, since it needs a lot of queries to determine the correct result with a high number of restrictions to the structural detail search. The intended solution to this problem is a completely different search algorithm, which is subject for further implementation, leading to very high search speeds even with a large amount of users at the same time.

Already within the development phase of the project, ideas for supplementary functions occurred. For example, the situation may appear that a certain search criterion in the keyword query will not lead to any results because the database uses a synonym. So it would be an excellent upgrade to check the full-text search word based criteria with a thesaurus.

Another difficulty resulting from the query is geometry. The current version is not able to find mirrored details, although usually it is possible to use the same detail in a mirrored version. A possible future development is the transition from 2D to 3D geometry. In view of the great complexity of such a development, a new research application would be necessary. It is also very difficult to realize an input module that is easy to use and still can handle the full 3D information.

9   Conclusions

The online structural detail database DeTra is an approach to create a tool which is able to find example junctions for architectural and structural design using different and flexible ways for the description of the anticipated detail. The authors explored different ways of describing structural details, as well as the effectiveness of different search methods and result visualizations. DeTra is designed to work over the internet and has the ability to adapt quite flexibly to future conditions.

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