CULTURAL HERITAGE AND FLOOD

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Summary

Floods impose a significant risk to buildings sustainability. Due to climate changes this issue becomes a topic for more and more areas. Among various categories, cultural heritage is especially vulnerable because its assets cannot be reproduced. This contribution discusses some results of the ongoing research project focused on protection of cultural heritage from flood danger. One of the crucial goals of the project is the design and development of a methodology and supporting software application for analysing building and materials vulnerability to floods. During the research several experts from various areas of materials engineering contributed to an extensive knowledge base covering the most important materials related to immovable constructs, and movable objects. The database is based on a knowledge engineering of crucial vulnerability aspects. It has been designed with the goal to be transformed to a formalised computer model that enables development of a knowledge system. Such a system has been prototyped and it is now being finalised for end users. It offers the users to perform customised analysis of their building consisting of general aspects of the building and location together with sophisticated details of inner building constructions and movable objects. The output of the application offers prioritised actions, procedures and hints to avoid and mitigate flood risks and aftermath based on user's inputs being consulted with the inner knowledge base.

Keywords: flood risk, risk mitigation, knowledge software, knowledge map, cultural heritage

1 Introduction

Owners and administrators of the cultural heritage need an effective ways of protecting the values from floods, preventive measures and effective remedial work need a profound knowledge of the mechanical, chemical and biological reaction to the flood stress. This knowledge is usually not possessed by the stewards in the sufficient rate. This is probably not even possible, because it encompasses knowledge of various building branches from the view of hydrology, physics, biology, chemistry, geology and others. Objects of cultural heritage require special sensitive approach otherwise it may lead to applying precautions and acts that may even make the damage more severe. This is why expert's knowledge is very necessary. Getting and expert assessment is however not easy, because

- There is a limited number of experts capable of complex flood risk assessment. This comes from what was already explained: such an expert needs a relatively broad inter-disciplinary knowledge, which is not common.
- The assessment by an expert is usually expensive – this comes from the previous point.

These facts were a motivation for building an application that would contain necessary expert knowledge that may be used to assess the risk of flood for typical constructions, materials and movable objects that are present in cultural heritage objects such as chateaus, churches, old houses, museums, old factories, etc. This knowledge base should be able to answer the most common questions the stewards ask related to the flood risk:

- What I need to know about the flood risk?
- What I need to know about my object to be able to protect it effectively?
- What reaction and what damages may I expect for constructions and movable objects according to their material composition?
- What are the secondary risks that may occur?
- What are suitable procedures for saving the impacted object? What are the time limits?
- What is recommended for final remedy and restoration of the saved objects?

With those questions in mind, we gathered a team of various experts and formulated a goal. Our team consists mainly of experts having the following expertise:

- construction stability,
- moisture in constructions,
- biological degradation,
- geology and hydrogeology,
- hydrology,
- drying and restoration of movable cultural heritage,
- cultural heritage protection.

This core team is then supported by a team having an expertise in:

- knowledge formalisation,
- software engineering,
- web applications development.

2 Methodology

The solution consisted of several key steps:

1. Collecting the necessary expert knowledge. This was much simplified by the fact that the core team already possessed most of the needed knowledge, however, it was necessary to do some additional research and analysis. It was also necessary to align, merge and interconnect differing aspects of the individual knowledge fields.
2. Ontological analysis of the problem domain [3]. The team needed to define and merge the terminology and specify key inputs and outputs and their relations.
3. Analysis, design and implementation of the knowledge base software application based on the ontology requirements from the previous step.
4. Filling the knowledge base with the expert data.
5. Testing and debugging the application.

The above steps were performed in an incremental iterative way [4].

3 Results

3.1 Ontological analysis of the problem domain

The knowledge consists of two parts:

- Knowledge about the general characteristics, behaviour and recommendations regarding the building as a whole, its surrounding and character of the flood.
- Knowledge about individual construction element-material combinations and movable objects type-material combinations.

Both of these parts are affected by specific conditions and aspects. As was already presented in section 2, the ontological analysis was based on designing a simple semantic network [7] using the similar approaches as discussed in [5] and [8]. The key term in the network is risk analysis. This term denotes a concrete knowledge of the second group listed above. The knowledge base is filled mostly by these risk analyses in an attempt to cover all most common situations and inputs. The sample of the network is showed in Fig. 1.

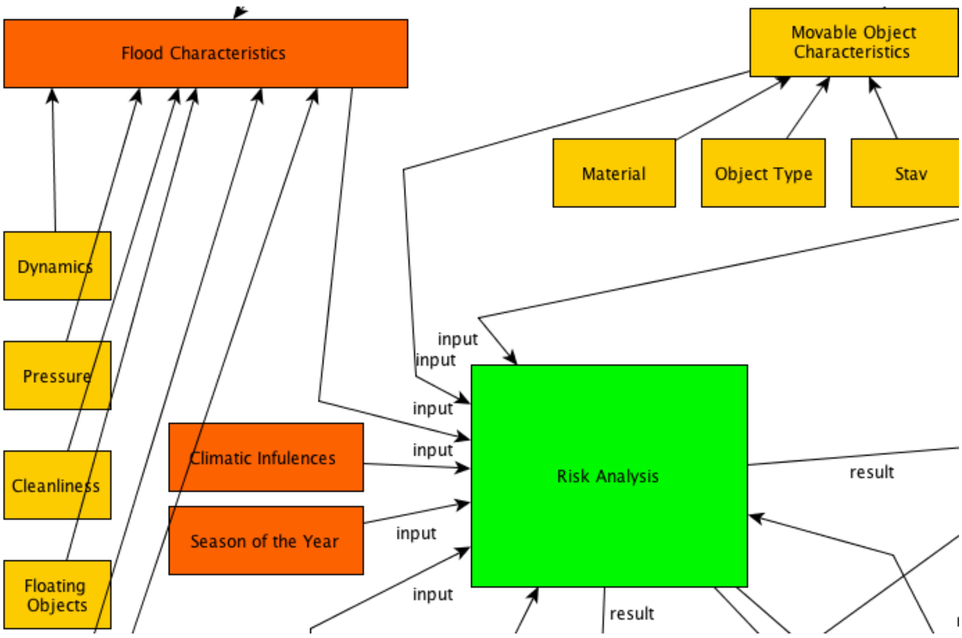

Fig. 1 *Sample of flood risk knowledge map*

The whole knowledge framework is then captured in the overall knowledge map in the form of Buzan's Mind Map [4]. This map contains not only the structure, but also the hierarchy of concrete constructions and materials. The sample of the map is showed in Fig. 2.

These two knowledge maps serve for development of the "Methodology for protection of cultural heritage from floods" as well as a structured input to analysis, design and implementation of the knowledge base application.

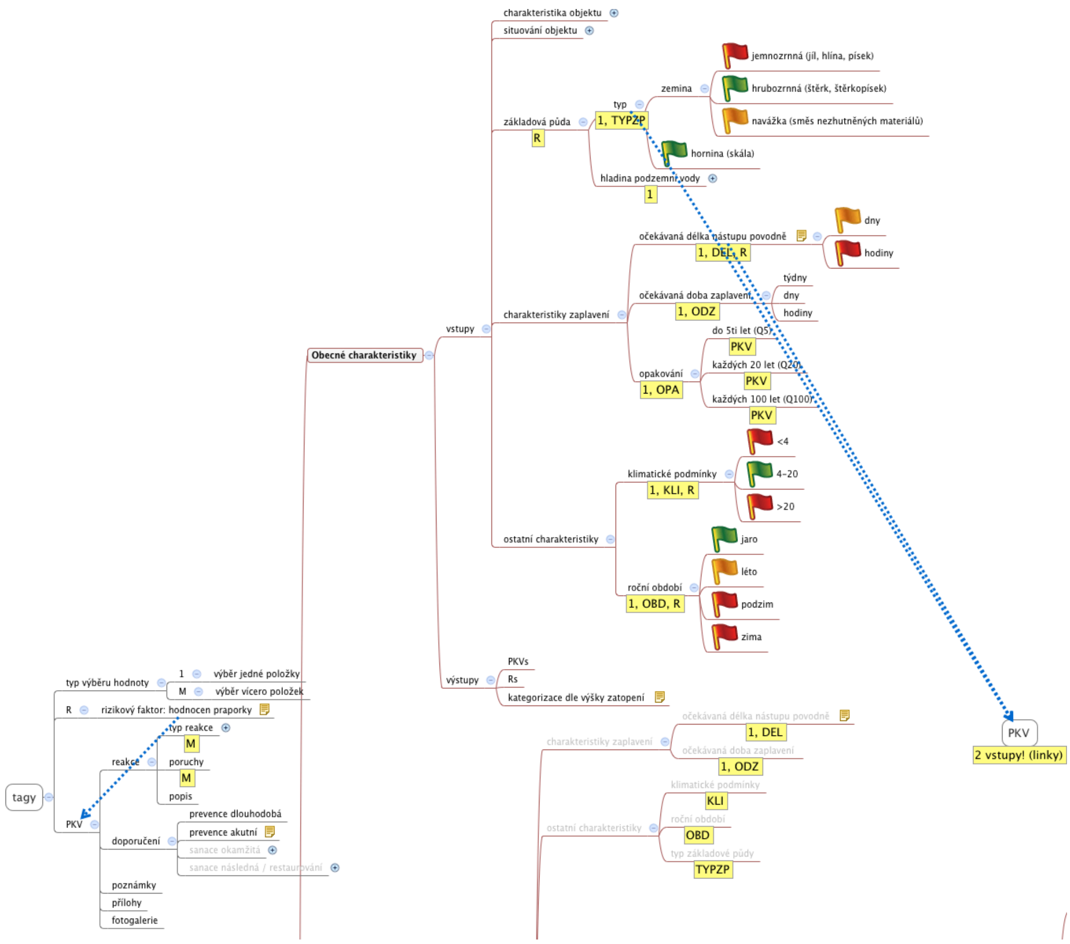

Fig. 2 *Mind map of the flood risk knowledge base*

3.2 The software application

The application was developed using standard software engineering approach as discussed by Beck in [3] and it was inspired by Agile methodologies [4]. The architecture is client–server: the target client application platform is a standard web browser. The server part is developed in the Django web development framework [6]. The database runs on PostgreSQL 0. The whole solution is hosted on Ubuntu Server machine.

The application consists of two components:

- **Experts' component.** It is a closed-access web application that is designed for experts to directly interact with the knowledge base. Its key features (depending on the rights assigned) are:
  - Listing the knowledge base contents.
  - Adding new risk analysis items.
  - Modifying existing risk analysis items.
  - Searching the knowledge base.
  - The experts' component may be also used directly by the stewards, however, it assumes a certain level of orientation in the area.
- **Users' component.** This component is dedicated to a broad audience that would like to leverage the knowledge base in a read-only mode in a fancy wizard-style web application.

The Expert's Component is based on standard Django admin sites [7]. It consists of the following main databases:

- Analyses of risks of constructions.
- Analyses of risks of movable objects.
- Lists of tabular values of inputs and outputs used in analyses.

The core databases are the first two. For each item in the list, several main characteristics are shown together with the author of the item and creation and last modified timestamps (Fig. 3).

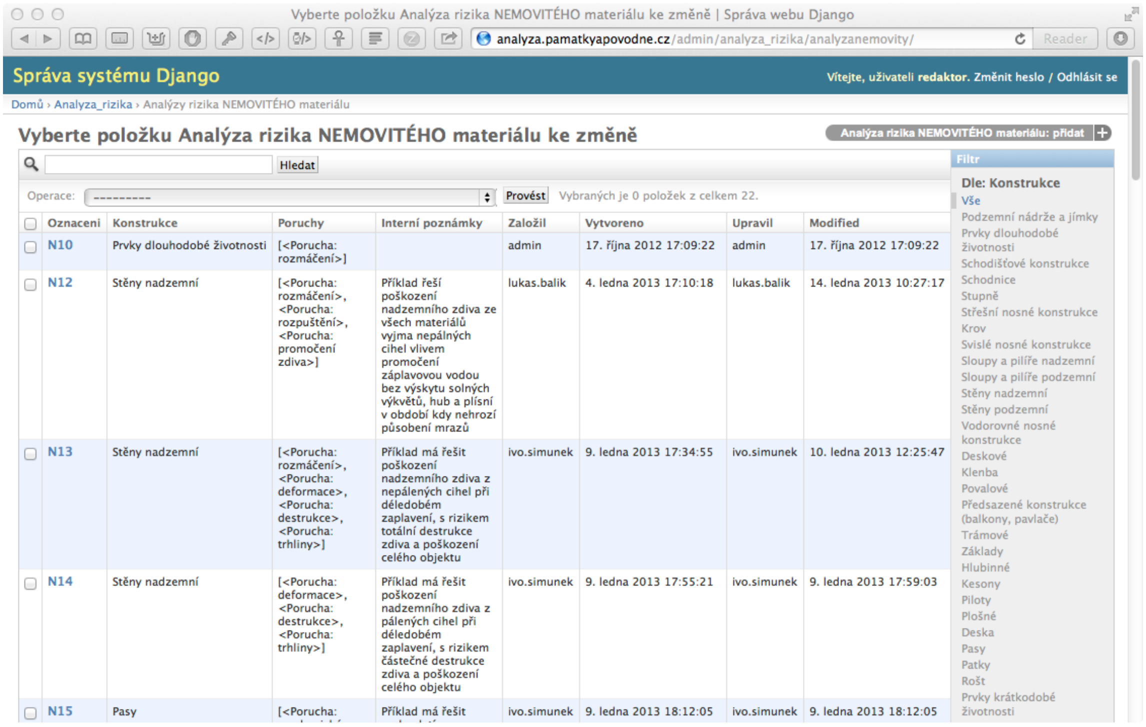

Fig. 3 *Knowledge base items in the experts' web application*

As for item editing, the author may select various input characteristics as defined by the ontological analysis in subsection 3.1. For the combination of the selected characteristics, the outputs are specified, mainly the reaction and recommendations, again according to the ontological analysis. Authors may attach illustrative photos and internal comments may be applied. These comments are not considered to be a part of the knowledge base and serve as meta-data. The sample part of the input screen is in Fig. 4.

The knowledge base is now filled with expertise gathered during the project (as mentioned in section 2). These data cover the most frequent situations and they are still being improved and added, as the project will continue up to the end of 2015. External experts are most welcome to join the efforts to fill the knowledge base with new data and review and comment the data present.

Users' Component is now under construction. So far, the analysis and design has been performed and the implementation has started. The sample of the graphic design is in Fig. 5.

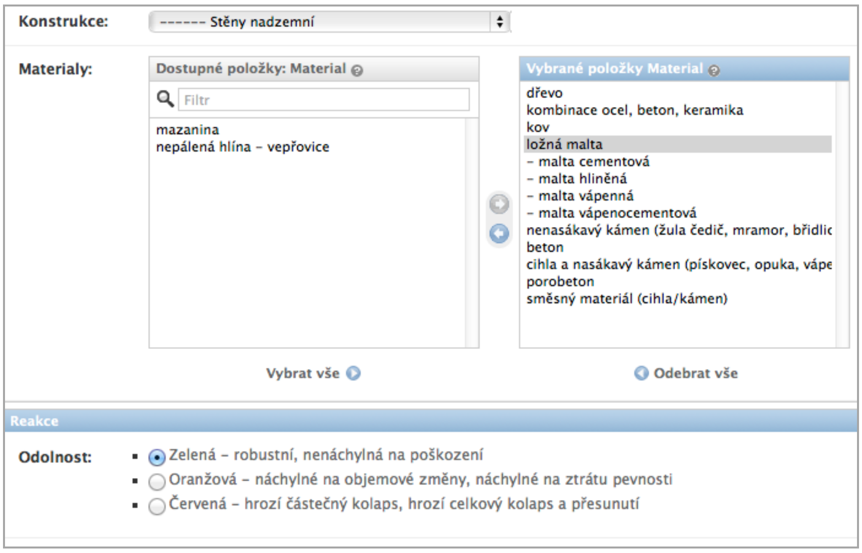

Fig. 4   Part of sample knowledge item input screen

Fig. 5   Design of the users' web application

The application will provide a fancy wizard that will guide the user through the key aspects of flood risk analysis. As such, it will provide a primary interface for administrators. The complete analysis will consist of:

- Analysis of the building as a whole.
- Individual analyses of constructions in the building.

Based on the provided inputs concerning the building and the characteristics of the expected flood, the report for the user will be generated using the knowledge base. In this report, the risks and recommendations will be presented as described in the Experts' Component. Additional comments and recommendations will be provided, too. The user will be also presented with a well-arranged indication of the risk categories in the form of "semaphore lights" and also a brief schedule of necessary rescue procedures.

4 Conclusions

Flood impose great risk on cultural heritage. It is necessary to use modern information technologies due to cross discipline character of the problem. Great challenge was to find the structured way of combining knowledge of relevant disciplines to be able to implement the knowledge base. This gave great leverage in understanding complex mechanisms of the flood risk. Many of the concepts needed to be simplified to gain practical result (use). Great benefit was utilization of iterative agile development. Together with flexible development technologies we were able to specify, implement, test, review the whole solution partially in several steps. The resulting knowledge software application is definitely not perfect nor complete however it proved that our approach has a potential to bring expert knowledge of flood risk to broad audience. Further development lies in connecting the knowledge base with other information systems like flood maps and generating valuable statistical information from the specific analyses from users.

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