Cultural Heritage and Floods
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1. Introduction
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 to floods and usually requires unique and individual approach because its assets cannot be reproduced in contrast to ordinary buildings and objects. This contribution would like to present some results of the ongoing research project focused on protection of cultural heritage from flood danger.

2. Preliminary analysis
Starting point and motivation for the project was experience from last floods in 1996, 2002 and 2010 that influenced gradually whole area of the Czech Republic. Team of experts from different institutions was gathered and analysis of the main problems that occurred during and after the disastrous flooding was done. Here are the main points that emerged from it:
- insufficient foreknowledge of owners and stakeholders about value of cultural heritage objects and necessity of special approach during remedial works, especially in heritage reservations and zones,
- inaccessibility of practical experience from floods in past years,
- lack of effective instructions for owners and administrators,
- lack of experience and methodic guidelines for local government in unusual situation happening on cultural heritage site,
- inappropriate use of materials during renovations,
- importance of proper maintenance and good technical condition of buildings,
- importance of preventive measures,
- absence of guidelines for flood protection planning on outstanding cultural heritage sites,
- need of transparency in legislative and processes of flood protection planning to achieve maximal efficiency and sensitivity,
- underestimated role of historical water works.

3. Structure of the project
According to this experience project "Methodology of Protection and Rescue of Cultural Heritage against Flood" was formed. Whole project sustains of following five parts:
Phase 1 - Risk analysis of cultural heritage monuments and buildings
One of the preconditions for successful planning is to estimate the risk of flood damage with regard to the construction resilience and constituent materials of historical objects. The output of this phase is software application and methodology for classifying the rate risk of specific materials and a reasonable estimate of risk diversification in different parts of the building. A special attention
is paid to prevention and tends to recommend suitable measures for different situations.

Phase 2 - Guidelines for liquidation of floods consequences
This part follows up the phase 1 and should give specific recommendations for liquidation of floods consequences - restoration of flooded buildings and artefacts. According to construction and material type the specific recommendation is given for remediation of damage of monuments (e.g. mural paintings, stucco, different types of stone, ...). Development of methods for remediation of damage of collection items with regard to specific material properties (paper, wood, leather, metals, entomological collections, ...) is also included. The output is addition to the previous software tool and methodology with the summary of appropriate remediation facilities and equipment, identification of the requirements for disinfectant agents (antibacterial, antifungal) with regard to possible damage to the concrete materials.

Phase 3 - Guidelines for flood protection system planning in historical urban sites
The aim of this part of the project is methodology development for suitable flood prevention measures design (FPM) which will serve to protect historical structures and their integration to the landscape and urban planning. Project will be also focused on improving of the cooperation among partial subject in the planning process. The output of this phase is methodology (guidelines) for planning and assessing FPM and software that will be able to track the whole process from the very beginning to the actual realization of the specific construction.

Phase 4 - Risk preparedness plans for historic buildings and sites
This phase should stress the crucial part of risk preparedness and importance of flood and risk preparedness plans on any level (urban site - individual building). The output is methodology development of risk preparedness plans for historic sites, buildings and collections, and historic buildings, including the collections stored in them. It includes method of negotiating the plan, defining responsibilities, structure of the plan, its linking to a central emergency system
and the local government.

**Phase 5 - Role of historical waterworks in current flood protection systems**
There are plenty of historical water works in the Czech Republic which belong to the industrial heritage. Project is aimed to evaluate their role in current flood protection systems. Specialized map of cultural heritage and historical water works with regards to flood risk will be prepared. Next output is also a methodology of historical water works safety improving.

**4. Results**
Nowadays methodology and software for the Phase 1 is finished. Guidelines and supporting software application for analysing building and materials vulnerability to floods was invented. 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. The aim is to bring expert knowledge of flood risk and best practices of mitigation of the damages as well as removal of aftermaths to broad audience. We focus on owners and administrators of the cultural heritage that lack information about effective ways of protecting the historical and cultural values from floods.

**4.1. Guidelines for risk analysis**
The main role of the guidelines is to bring out the crucial questions that are necessary to address when dealing with cultural heritage flood risks.

- **What kind of flood might hit the property?**
  This question encompasses all possible information about previous flooding in your area - dynamics of the flood, season when it appears, repetition, duration, water height.

- **What is the cultural and historical value of the property?**
  It is crucial to know what kind of values the property represents.

- **How is the property situated (in landscape, position towards other buildings, hydrogeological conditions etc.)?**
  This information refers to how the water can get to the building, as water may come not only from the river.

- **What is the technical state of the property?**
  Buildings that are neglected are much more vulnerable than the one well kept. It is necessary to be aware of already existing damages.

- **What are the types of constructions and used materials?**
  Some constructions and materials are more resistant to flood influence than others. It is important to have a precise knowledge of the building composition to be able to predict the risk. Some constructions and materials may even have secondary impacts on others.

- **Other aspects that either worsen or mitigate the risks.**
  For each of the questions, we formulated textual description of its importance in risk analysis and also what are the possible sources of required data or where to get the professional help. The core of the knowledge then lies in quanti-
fied measures and relations between the various cross-domain aspects. This knowledge provides a source of detailed information for owners and administrators about the possible risk of their property. We would like to stress that good risk analysis brings more possibilities for effective preventive measures.

4.2. Supporting software tools

Formalized experts’ knowledge is not directly usable by broad audience. Thus we developed supporting software tools that would hide the complexity of the knowledge and provide simple, comprehensible and user-friendly device how to work with this knowledge.

The tools 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. These are the questions it is able to give answer for.

• 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 possible preventive measures if any?
• What are suitable procedures for saving the impacted object? What are the time limits?

These answers are based on acquaintance of experts from different fields of knowledge, on experiences from previous floods and results from other research projects dealing with this topic. We find it very important to gather all this knowledge in one place and make available for wider audience as we experienced that applying impropriate precautions and acts may even make the damage more severe. The system is open so it may be updated and new information may be added.

The application was developed using standard software engineering approach as discussed by Beck in [Beck K., 1998.] and it was inspired by Agile methodologies [Beck K., 2004]. 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 [Holovaty A., Kaplan-Moss A., 2009]. Persistence is managed by a PostgreSQL database. The whole solution is hosted on Ubuntu Server machine.

The solution consists of two applications:

- **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 owners, 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. As such, it will provide a primary interface for buildings' administrators.

5. Conclusion
Flood protection is a very hot topic nowadays though cultural heritage still lies on its outskirt. There is great need of interdisciplinary approach in planning of flood protection systems where not only technical but also cultural, esthetical and historical point of view would go into account. We have to have in mind that each field of knowledge has only limited point of view but urban areas
especially with cultural heritage on site are very complex systems that require also a complex approach to solve the flood problem. We are at the beginning of the project but so far it was proved that cooperation between experts from different domains has to be established to achieve the required outcome. Opening up for solving the problem from different points of view seems to be necessary if we want to be effective and successful, particularly in the case of flood protection of cultural heritage. The resulting knowledge software applications and methodology guidelines are definitely not perfect nor complete however it proved that our approach has a potential to bring expert knowledge of flood risk to broad audience.

References