Database of climatic data as a rewarding tool for inclusion of weather observations in computational service life assessments of historical buildings

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Abstract

A climatic database for computational service life assessments of historical buildings is presented. It is suitable for application in most current computational models of heat, moisture and salt transport. The included data were gathered from the authorized institute (CHMI) and the structure is expandable to other sources of weather observations, even in-situ measurements. Therefore, it can be used in designs aimed at the renovation of historical buildings on the territory of Czech Republic. The database is devised as an open system so that it can be extended in an arbitrary way, e.g., more sophisticated statistics or converting tool can be added. It also provides an easy-accessible and user-friendly interface for raw climatic data or long-time collected data important for service life assessments.
Keywords: climatic database, historical buildings, computational assessment.

1 Introduction

The reconstruction of a historical building is always a question of two contradictory attitudes – to preserve the object in its original form and keep exactly its appearance (and historical value) or replace its defected parts in order to preserve its functionality (and sometimes even the existence itself). The decision of the more or less significant change in the building's character is supported by both the technical, cultural and design nature of a problem. Therefore, it is rather important to assess the durability of used materials and the

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whole construction in the particular climatic conditions of a historical building in its geographical location.

Most currently used computational models of heat, moisture and salt transport can be considered appropriate for predicting hygric and thermal conditions in the envelopes of historical buildings and making the service life assessments. However, every model can provide reliable information as long as the input data corresponds with the reality, concerning both the inner material properties and the outer climatic conditions. Nowadays, research institutes are usually well provided with collection of material data gathered either from their own experiments or from collaborative projects. Yet the weather data are still hard to implement in computational models since there is a plenty of different formats from different sources to be found and one cannot always easily get the data for desired geographic location.

In order to run contributing simulations, two types of data must be provided – material parameters of the construction system and the environmental conditions. The latter one is in focus of this paper, which aims to provide a new tool for gathering, storage and utilization of climatic data for localities in the Czech Republic. The need for a single climatic data source and manipulation tool was recognized both in the branch of computations proving a new material or structure design and in the branch of verification or redesign when handling historical building's preservations. As the restoration of an existing structure is a project of significant importance and delicate treatment, as many influences must be taken into account as possible.

A suitable computational tool is already accessible, because much computational software (either commercial or institutional) can be approached, but the source of exact data is a crucial part of this process. Therefore, we present a user-friendly and easy-approachable source of weather data in the Czech Republic. The demand of gathering, viewing and distributing such data is satisfied by a complex database-application system. The safety, flexibility, expandability and approachability were the main attributes to be satisfied, so the modern computer tools and programming methods were called in.

Similar database-based software for climatic data storage and distribution is described by Yang *et al.* [1], in the field of medical informatics the database system is studied by Martin *et al.* [2]. The Czech Republic is in focus of the climatic data study by Cahynová and Huth [3]. It is desirable to store the representative data in the form of the typical meteorological year, which is the subject of studies by David *et al.* [4] or Salonvaara *et al.* [5].

This paper describes an online PHP application approachable via internet with MySQL database storage and utilities for data export or conversion.

2 Database model and user interface

The application has succeeded in primary testing and currently is operating in beta-testing mode. Database is languageless; the application is available in English and Czech [6].

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2.1 Primary data

All of the acquired data were measured and processed by CHMI [7], but the storage is fully expandable for other possible sources (each source has its own table in database which also affects the structure of such table).

The database currently includes five localities (see Table 1) for which the Reference Climatic Year (RCY) and daily downfall values were acquired. All of the available hourly quantities are listed in Table 2. The map of available localities is given further in this paper.

Table 1: Climatic data stations.

Name of station	Latitude [°]	Longitude [°]	Elevation [m.a.s.l.]	Station code	Note
Most – Kopisty	50.5442	13.6233	240	U1KOPI01	The north
Šumperk – Šerák	50.1875	17.1086	1423	O1SERA01	Highlands
Přerov	49.4239	17.4064	212	O3PRER01	Lowlands
České Budějovice	48.9519	14.4714	385	C2CBUD01	The south
Praha – Karlov	50.0694	14.4278	232	P1PKAR01	The capital

Table 2: Available hourly weather data.

Name	Database codename	Unit
Air temperature	Tep	°C
Air relative humidity	RV	%
Water vapor pressure	Nap	hPa
Dew point temperature	Td	°C
Air absolute humidity	Avl	g/m^3
Global radiation intensity, hourly average	Glb	W/m^2
Diffuse radiation intensity, hourly average	Dif	W/m^2
Insolation	Insol	W/m^2
Wind speed	Rychvet	m/s
Wind direction	Smervetru	°
Air pressure for current elevation	Tlakvzduchu	hPa
Vertical rain flow density	Est1	$mm/m^2.h$

2.2 MySQL database model

The chosen database domain is MySQL [8] in order to ensure universal data accessibility via internet, easy data management (importing, administration and

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backup) via PHP application, separation from user interfaces and exportability of data in several formats (image, *.csv* file, text file) as an input for computational software. The character encoding is *utf8-czech-ci* and the data storage type is *MyISAM* (with such a relatively small amount of data it is more efficient in speed than *InnoDB* storage).

It was designed as a Relation Model Database (RMD) [9] with two application processes (*adminSite* and *userSite*) and basic integrity restrictions. In order to use the storage safely and efficiently, we need to secure that only the safe and purposeful data will come in and none of them is lost. On the side of input data format, the safety and integrity of data is well guaranteed by CHMI [7] and their data format (*.xls* tables). Conversion is accomplished separately from the general access route (via *phpMyadmin* [10] and *adminSite*) with internal programmed restrictions securing reference integrity. Active reference integrity is defined in the code of application, so in the case of its violation, the importing/deleting process will not be executed, user will be prompted and the integrity will remain unharmed. Lifetime of the data is ensured by regular back-ups of the whole database.

Normalized form of tables is used, with the contents divided into two minor tables (*stations*, *users* and *static variables*) and one major table (*climatic data*). All together it contains approximately 50,000 data rows, which is approximately 2.7 MB of data.

The *insert* operations are presumed to be only occasional comparing to the *select* operations (view or export of the data) and the multi-user approach (multithread) is also expected to be rare considering quite small scale of users in the Czech Republic.

To optimize the speed and memory demands of the queries, the columns in tables were retyped to reflect its factual contents (shortens the size of the database on the server) and the special indexes (*primary key* and *unique*) were added where suitable (fastens the response of database). We call this *Level 1 optimization*.

2.3 Database-interface model

On the beginning, the net database was created and administrated via *phpMyadmin* online application [10]. But the intent is to restrict any outer direct access to the data or its structure so that even for the administration of the database the specialised application was programmed (we call it *adminSite* hereafter). To enable users to view and download the data, the user interface was programmed (we call it *userSite* hereafter). This means that only a certain group of users is privileged to interact with the database as it is shown in Table 3.

From the programming point of view, the online application (*adminSite* and *userSite*) is written as the mixture of *PHP*, *JavaScript* and *HTML* code with the Nette PHP Framework [11] as the basic engine. The Model-view-presenter concept (MVP) [12] was chosen to utilize both database and framework capabilities, simplify the development and later expandability and ensure clarity of the code. On the other hand, the Nette Framework [11] provides many advantages for both programmers (for example compact programming, easier

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bug tuning, testing methods, database tools, session and cookie management, security, error logging, or statistics about the application or database loads) and users (for example the cashing functionality or secure enrolment).

Table 3: User access hierarchy.

User	Application access	Permissions
Superadministrator	phpMyadmin, adminSite, userSite	Edit database structure, edit/delete/view/export data, edit/privilege users
Administrator	adminSite, userSite	Edit/delete/view/export data
User	userSite	View/export data
Visitor	userSite (only view)	View data

Fig. 1 illustrates the basic principle of the application design. Here, the Integration layer stands for the administrative part (*adminSite* and *phpMyadmin*) and the Interpretation layer stands for the access part (*userSite*). With such a mechanism, no data can be changed or harmed by improvident user behaviour and even the administrators are strictly guided to manage the database in bounds of its integrity.

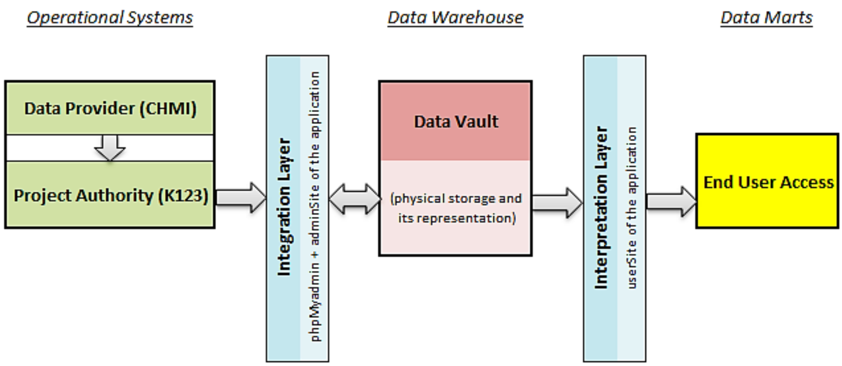

Figure 1: Scheme of the whole system of database, administration and user interfaces.

2.4 Database administration

The client side of the application-database system can be viewed from two different access points depending on the granted privilege for a user. First and more sophisticated is the administration web (*adminSite*), which is a part not visible for common users. The other part is the user interface (*userSite*) visible to both users and administrators. The verification is run within the log-in process (Fig. 2) as well as the language options.

Administrators are allowed to import new data sets (both station information and weather data) from *.xls* files of a specific format, delete existing station (with its data), edit static variables, user privileges and do the basic MySQL maintenance as illustrated in Fig. 3. Information about the number of current database size, dates of last update and last import is also provided.

The decision about static variables being stored separately was the result of a *Level 2* optimization. As some of the queries or computations are run over the unchanged data, it is not necessary to execute it every time the page is loaded, so it is stored as a static variable, which is being updated on an occasional import of new data. As the database will grow and the number of users as well, the *Level 1* and *Level 2* optimization will be carried out again.

Administrators are allowed to access also the whole *userSite* contents (as it is described further).

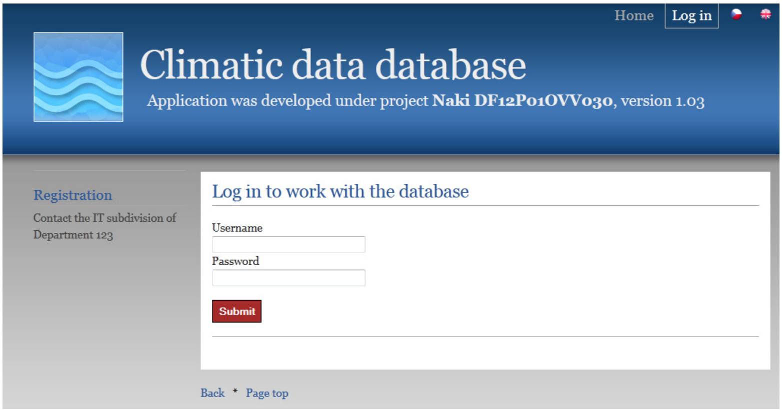

Figure 2: Log in page of the application.

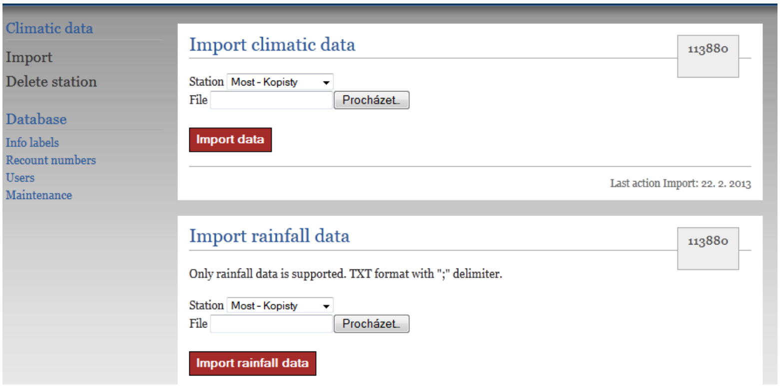

Figure 3: The administration pages – *adminSite.*

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2.5 User interface

The main purpose of this kind of online weather data storage is to provide it to users for utilization in computational simulations or other types of designs dependent on climatic conditions. Therefore the user can search, view and download desired data in several formats (.png image, .csv table, .cli text file). Fig. 4 shows the table view of stations in the database; Fig. 5 a map view. The quantities available for each station are shown in Table 2 above, any of it viewable or downloadable for the whole RCY or a single month as illustrated in Fig. 6.

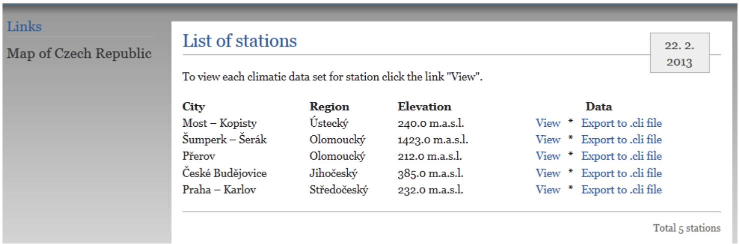

Figure 4: Stations view, userSite and adminSite.

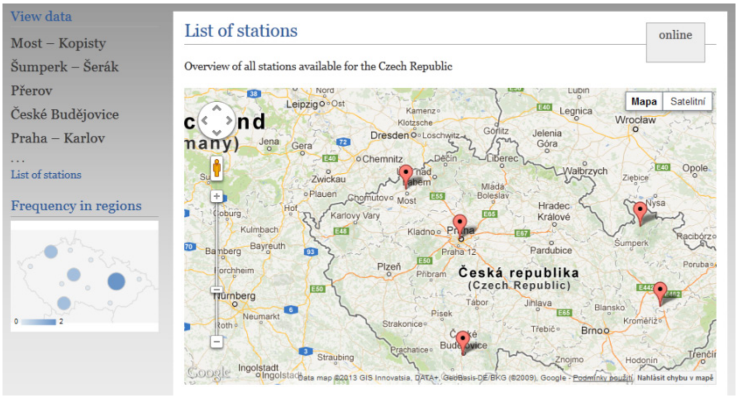

Figure 5: Map view, userSite and adminSite.

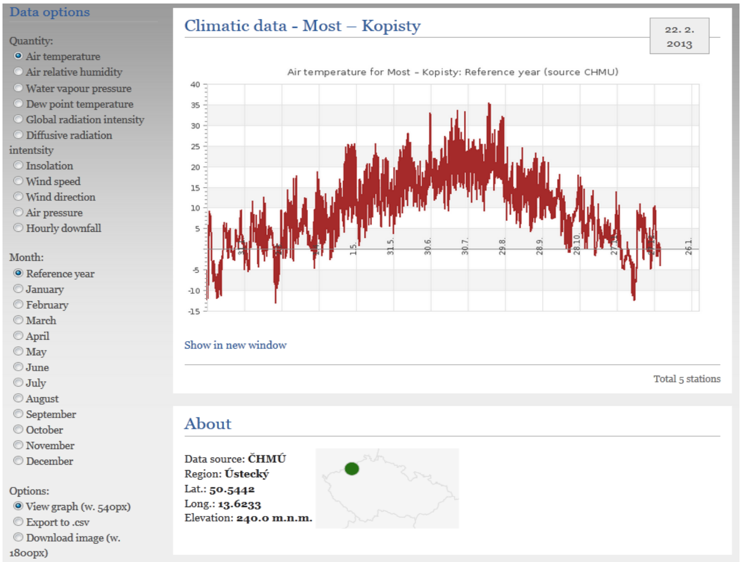

Figure 6: Data view – graph, userSite and adminSite.

3 Application

3.1 Set up of an example

A simple 1D problem was solved to illustrate the value of the climatic database. The chosen historical masonry was provided with lime-pozzolana plasters (Table 4, material parameters can be found in [13]). Table 4 also contains initial conditions of the construction (relative humidity and temperature).

Table 4: Dimensions, materials and initial conditions of simulated construction.

Layer	Material	Thickness	Initial conditions (RH, T)
Outer plaster	Pozzolana plaster	10 mm	60%, 16°C
Brick	Historical masonry	300 mm	60%, 16°C
Inner plaster	Pozzolana plaster	10 mm	60%, 16°C

On the interior side, the constant boundary condition was set (50% relative humidity and temperature of 21°C). The exterior side was subjected to climatic conditions downloaded from the database [6] for two localities – Přerov (warm lowlands) and Šerák (cold highlands with higher precipitation (see Table 1)).

Numerical computations were carried out using Künzel's mathematical model [14] implemented in Finite Element Method (FEM) software with the timeframe of five years.

3.2 Results

The temperature and relative humidity in the last year of simulation at the outer plaster-brick interface for two localities are presented in Figures 7 and 8.

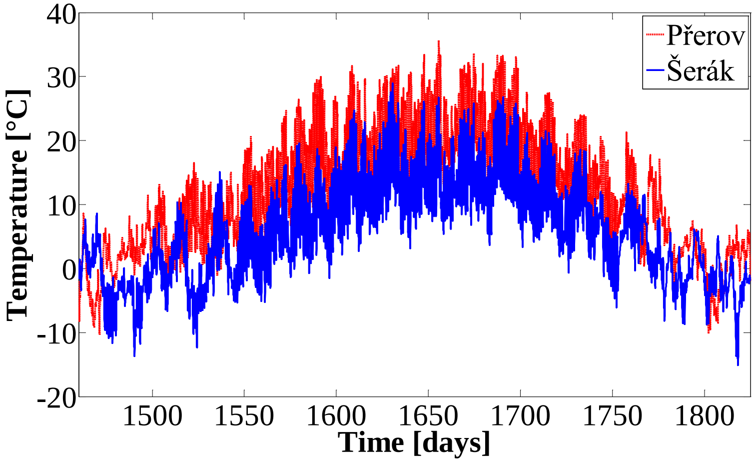

Figure 7: Temperature distribution for studied locations.

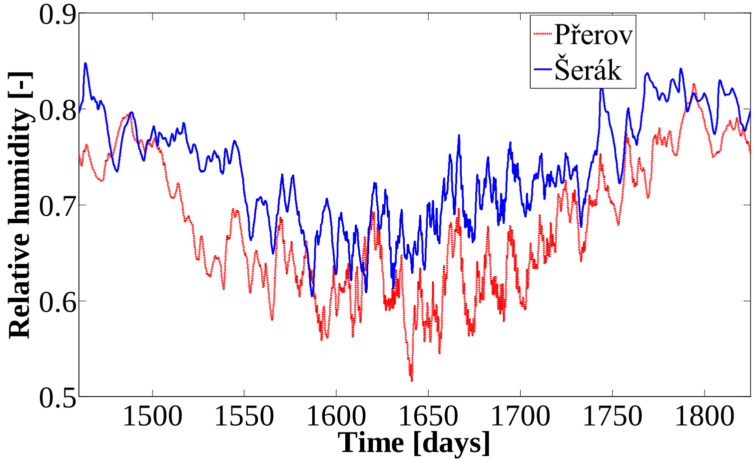

Figure 8: Relative humidity distribution for studied locations.

4 Discussion

In Figures 7 and 8 one can see the differing values of both temperature and relative humidity on the interface of plaster and brick caused by diverse weather conditions. The other parameters (material properties, initial conditions and computation setting) were exactly the same for both simulations. The variance of temperature reached approximately 10~20°C for some extreme days, for the relative humidity it was approximately 10% (absolute). It surely is caused by different climatic conditions in selected localities. Such a difference will be reflected by eminent rise or fall of both variables throughout the whole construction. In other words, the location is a very significant input parameter for any simulation when one tends to obtain numerical results replicating the real behaviour.

The weather data (both historical and reference) are already provided online on several websites (for example [7]), but usually not all of the quantities listed above (Table 2) are given at one place or for free. Moreover, those mostly view-only data charts enable minimum or none usage by a computational application. Our database system is primarily designed to assist to numerical simulations; thus the conversion from any format to a usable data file is another advantage. Compared with Windows-based applications (for example [15]), our web-based database system avoids the need of individual user installation and update. It provides up-to-date collections of weather data accessible any time from any place and on any system platform (only the internet browser is needed). The user is also allowed to store only the data he is interested in with no need to have the whole database installed.

Compared with the database system studied in [1], our system is not so rich for different data sources, usage purposes or software tools, thus does not provide as detailed and highly integrated data. On the other hand, the simplicity of our database ensures the fast and easy way to purchase the requested data for a specialised user.

There is one notable imperfection of the current database system – the small number of localities being provided. As the project is of early age, not all of the geographically important stations in the Czech Republic are available at this moment. But this will be changed soon as the purchase of the data for the biggest and county cities is already planned.

The system is also intended to be improved in terms of statistical information (description of stored data), more sophisticated search tools, visual data comparing and better (automated) backup management.

5 Conclusions

In this paper, a database system of weather observations was described and explained. The climatic data is an important input parameter for any numerical simulations, in particular for the historical-buildings performance assessment. The database reflects the parameters of specific localities in the Czech Republic and provides the data collections suitable for processing in computations.

The web-based application was designed as a package of an MVP programme with RM MySQL database and data conversion or interpretation tools. From the programming point of view, the *Model* scripts interact with the database, the *Presenter* scripts process the responses of both *Model* and user and the *View* scripts provide the representation of the data and query results in a suitable form.

From the access point of view, the application enables *administrators* to store and edit the data and *users* to only view or download it. All of the RCY data currently available is purchased from the national institute CHMI (temperature, humidity, wind, solar energy, and rain quantities).

An illustrative example showed the practical importance of such data vault. The prospective of further development was outlined as well, including a brief comparison with other available weather database tools.

Acknowledgement

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