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Development of a Multi-Disciplinary Database of Cuneiform Tablets – an Improvement of 3D Models and Data Re-use

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Abstract

This contribution describes a digitized cuneiform tablet collection based on a complex database architecture that integrates several scientific domains of data obtained from various types of analyses. The system enables creating 3D enhanced digital models, coupling data from science and humanities to pose complex queries. Attention is also paid to the possibilities of re-use of the acquired data.

Introduction

Digitization of collections is a wide-spread trend undertaken by many museums and other 'memory institutions '. The main reason for this activity is a possibility to share unique objects, to democratize the access to the humanity heritage [01]. The driving impulse is an availability of easy to use and the affordable digitization techniques and widespread means of data sharing, e.g. the Internet. Another reason for digitization is a disaster-proofing of collections. From the conservators and curators' perspective the best protection of the artifacts is to show the replicas instead of the originals. Limits of this practice are thoroughly discussed e.g. in [02], while various cases of the visualization of digitized collections are presented in [03]. The new type of research enabled by availability of the vast data accumulated in the databases fits in a more general concept of digital humanities as discussed in [04, 05]. Whether the discipline of digital collection is a fully established scientific field, depends on some fully unknowns. However, the well-known Gartner's 'hype curve' [06] is also applicable for a description of the rise and fall of popular topics in the scientific research. At the present moment it could be only argued at which point of the curve the digitization of collection can be found – a whether it has an aura of panacea, or reaches a deep disenchantment, or has achieved a state of a realistic expectation and steady growth. Among the possible drawbacks of digitization there is so called a digital obsolescence (see e.g. [07]). The digital obsolescence predominantly occurs after a project completion, when no funds are provided, no support helps the keeping the data accessible, and the digital collection is not maintained. Another reason for the obsolescence is the progress in the digitization techniques itself rendering previous results of insufficient quality in comparison to the current state of the art.

In the following text it will be shown how this general framework of opportunities and difficulties applies to the presented project. A collection digitization and the database system development started in 2016 as part of a broader project "Analysis, description and archivation of aggregate information on properties of cultural heritage artifacts and usage of such data in restoration, conservation and research" supported by the program of applied research and development of national and cultural identity (NAKI) of the Ministry of Culture of the Czech Republic. The research team consist of the researches of the three different backgrounds – the museum conservation of collections, the physical and optical methods of 3D documentation and the humanities.

The paper aims to answer questions – 'how to make sure the acquired knowledge will be used?' and 'what are the problems addressable by the available data?' - on demonstrating a use of the multidisciplinary database on selected tasks. To achieve this the paper is organized as follows: The database containing a digitized collection of cuneiform tablets is introduced, the methods applied to acquire data are described, the results presenting queries enabled by data in digitized collection are shown next and finally, the future steps and the conclusions are drawn.

The project and the database

The main aims of the project are described in detail in [08] and [09]. The structure of the presented database was thoroughly described in the paper [10]. Background of linguistic and paleographic research and its requirements on the database was discussed in [11]. Methods used to acquire data were outlined in the paper [12]. The database is not a sole goal of the project - among expected results it will also built a specialized customized version of digitization devices - either creating 3D models or CT (computed tomography) scans at the site of collection.

In short, the database covers multi-disciplinary data concerning the Prague's collection of cuneiform tablets. The system comprises of the three main parts: the first belongs to domain of humanities and covers a paleographic data on signs, transcripts containing linguistic and historic data, translations, and historical data concerning persons and places involved; the 3D digital models based on the Structure form motion (SfM) optical method or CT scans of tablets are the second part of the system's record on each tablet, and the third part is based on data from various physical methods like X-ray fluorescence (XRF) or colorimetry. The goal of the project is to facilitate the new possibilities in the scientific investigation based on the synergy and unification of traditionally separate domains of the knowledge. The main aim is an interdisciplinary approach, yielding new connections, new insights.

The Prague's cuneiform tablets collection

The Prague's collection contains approximately four hundred cuneiform tablets found in 1925 by Professor B. Hrozný during archeological excavation near the contemporary Kültepe in Turkey. The collection of the tablets is a homogeneous as concerns their age – about four thousand years, and as concerns their content – it contains mainly the transaction records and the personal correspondence (more on

Prague's collection can be found in [13, 14]). The collection held in Prague is a small fraction of hundreds of thousands of cuneiform tablets in museum collections worldwide.

The size of the collection that makes it attractive to test feasibility of digitization concepts: on the one hand it can be as a whole managed with a limited human and financial resources, on the other hand it is robust enough to provide an interesting statistics and to enable hypotheses verification.

It is interesting to note that once the text has been written, the tablet was left to dry, seldom fired. So how to explain, that most of the tablet found are fired? The reason lies in a 'document circulation' at that times. Once useless, the clay was left to dissolve in water and re-used. Dried tablets were not meant to last. Fired tablets result mostly from the fire accidents or firing was carried out during excavation in order to preserve the tablet, or directly by conservators in museums [15]. Proof that tablets are unfired can provide XRD (X-ray diffraction), but it is a definitely not a non-destructive method as it requires a material sample, not to mention how equipment and work intensive it is. The point about the firing the tablets is mentioned as another mixed-domain query enabled by the database.

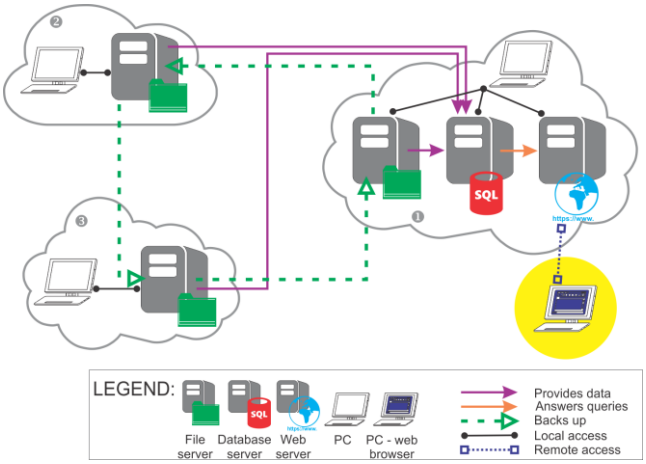

***Figure 1**. A schematic drawing of dependencies and data flow in a multidisciplinary database system*

The digitized Prague's cuneiform tablet collection is not unique, because it contains 3D digital models of the tablets: for example, a similar digital data can be found in [16]. Neither it is unique because it contains data on the elemental composition obtained by the XRF measurement as the works on this topic were already published in [17, 18]. Lastly, neither it is unique from the point of view of humanities, the most important resource for paleographic, linguistic and textual information on cuneiform tablets is CDLI database (where the Prague's collection is already included) and ICE (Initiative for Cuneiform Encoding) – see [19] and [20].

The main contribution of the digitized collection consists in availability of these results at the same time.

The methods and the devices used

Web interface to the database is in the development, it will provide users with the access to data, and to digital the models of the tablets. The interface will unite all domains of research and their respective data on one page. In the course of system development open, freely available data formats were preferred, as well as the web browser as a lean client means a reduction of a necessity to install specialized software packages and the independence on the operating system. The servers of partners' institutions mutually back their data up on each other as seen on schematic figure 1.

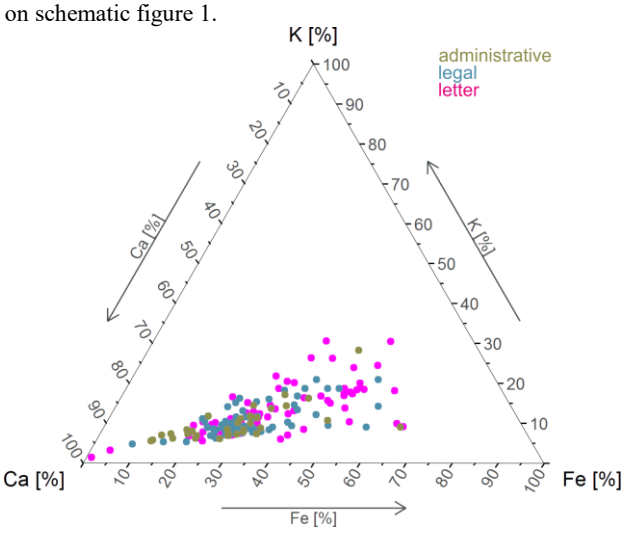

***Figure 2**. Ternary diagram of cuneiform tablets' composition in relation to the content of the tablet's text*

The database is planned to be open to the interested users, therefore it is necessary to outline several categories of users in order to provide every category with an appropriate rights and ensure a smooth operation of the whole system at the same time. At the basic level open access to basic descriptions of objects and their documentation will be allowed, for a group of registered power users - generally interested researchers working on this subject - downloads of the large datasets would be allowed. Naturally, all access rights would be given to the users creating and managing the content.

CT is still an expensive, data and labor-intensive method. Therefore it would be applied on a representative subset of the tablets. A knowledge of the tablets' inner structure reveals pores and cracks and therefore, contributes to the conservation efforts. The scans also expose the process of material preparation, show the distinct layers indicated by a rough core and smooth fine-grained surface layer. The method is also uniquely capable of the scanning of the tablets enclosed in the unbroken envelopes. On the other hand, the optical 3D methods are important for study of tablets' scripture, as it allows shadows to be cast upon tablet. In the future, a development data merging between CT and optical SfM method is planned as it is desirable to combine the true surface appearance and the colors of tablets with its inner structure.

Other physical methods – like XRF - provide information on the spectra and the atomic composition of the clay, which is helpful in a provenience studies. The colorimetry helps in sorting out the collection of the tablets.

An identification of the scribes can help in the paleographic investigation of the sign variants. The identification can be done purely based on the scripture, but as data on the materiality of the tablet are available, relations can also be inferred from the composition similarity. Also other indicia can be utilized – a technique for the clay preparation, the preferred material source, the same processing technique. In some cases, truly forensic methods can be used as there are the scribe's fingerprints left on the surface of the tablets.

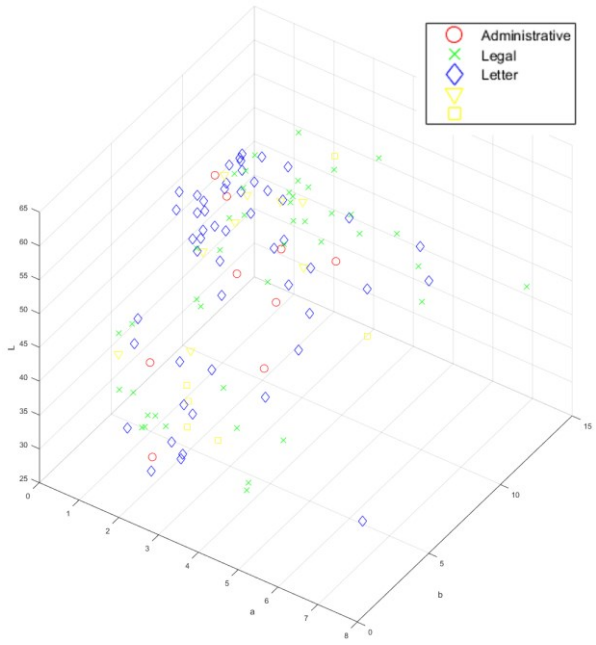

***Figure 3**. Relation between the tablet's content (as point marker) and prevailing color of the tablet depicted as Lab color space coordinates.*

Results

Interest in the provenience studies of the cuneiform tablet can be traced in scientific literature for a long time. Paper [18] classifies studied Assyrian tablets based on principal component analysis. Tablets are divided into four groups related to important excavation sites and centers in Assyrian history. It was of the interest to verify this division in the case of Prague's collection. According to [14] some forgeries are likely included into Hrozný's collection. There is a great opportunity to test this claim by XRF methods combining the humanities and the physics domains. Preliminary study [Polák unpublished work] confirms properties of studied tablets fit in the expected group and some of the suspected forgeries were by the composition indistinguishable from the rest of the collection. Testing the forgeries hypothesis is made possible by coupling humanities and physical knowledge. The humanities contributed by the identification of the subset of tablet and physical data provided verifiable answer.

It was already mentioned that Prague's collection is contained in CDLI, where every tablet is classified according to its content as 'administrative', 'legal', 'correspondence', etc. The relation between the content and physical composition and appearance can be then studied. This rather naïve query is not of the practical importance, but well illustrates the possibilities of the database. In the figure 2 it plots a composition to type of tablet's content relation. As expected, there is none. Similarly, on figure 3 the color of tablet depicted in Lab color space coordinates is shown for the studied tablets. The markers of the point indicate the content of the tablet. Also no relation, but without the database it would not be possible to answer the question.

3D models of tablets as well as information on its color and composition will be made accessible not only to the users of the database, but it is planned to use it for enhancement of authentic cuneiform tablet, to accompany real objects on the exhibition. In the exhibition only a limited amount of known information can be displayed alongside with a basic info – an opportunity to enable users/museumgoers to choose what interests them. Data will be presented using techniques of mixed, virtual and augmented reality. VR+AR in exhibition will give a feedback in comparison of attraction between real historical objects and enhanced virtual objects. Visitor would also see excavation site and compare it to its nowadays appearance.

There is also a possibility for 3D printed replicas of tablets. The replicas should not be necessarily in the same scale as original. For educational purposes, it is advantageous to enlarge the whole object for features demonstration, to enable visually impaired to enjoy hands-on experience of the object usually confined behind glass of showcase as seen of Fig. 4. It can be also used as a mold for souvenirs or to sensually enhance exhibition by touching the objects. For replicas we plan to use a material dissimilar to the original in order to avoid temptation to sale them in antiquities auctions and markets as genuine one.

Conclusions and future work

The main aim of the presented database is an inter-disciplinary approach, enabling the discovery of new relations within the collection. In addition to these new investigations, the data is also to be used for the purposes of a planned exhibition displaying 3D digital models of tablets in virtual and augmented reality, as well as creating their 3D printed replicas.

Data reuse will also take place in preventive collection care - surface alternations in the course of time can be traced this way and proper adjustment to environment can be enforced.

***Figure 4**. Three times to scale enlarged replica of cuneiform tablet for a 'touch experience' on final project's exhibition.*

The database of cuneiform tablet collection combines data from several domains - science and humanities. In many cases once project is completed, there are no resources and motivation for further development and maintenance. In order to avoid obsolescence, acquired data has to be used. To prolong a lifespan of the digitization project it is always advisable to follow standards not relying on proprietary data formats, data ontologies, metadata and other semantic tools to make the data discoverable and machine understandable [21] and also join

some large scale initiatives and projects like CDLI [19] or Europeana [22].

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Authors Biographies

Jaroslav Valach has a background in materials science and physics, and works in application of optical and physical methods in the study of cultural heritage objects.

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Ladislav Polák obtained MSc. in geology from Faculty of Natural sciences of the Charles University in Prague. At the Czech National Museum concentrates on collections documentation and carrying out physical analyses, mainly XRF.