Communicating cuneiform: The evolution of a multimedia cuneiform database

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ABSTRACT:

Our paper presents the work of the Cuneiform Digital Forensic Project (CDFP), an interdisciplinary project at The University of Birmingham, concerned with the development of a multimedia database to support scholarly research into cuneiform, wedge-shaped writing imprinted onto clay tablets and indeed the earliest real form of writing. We describe the evolutionary design process and dynamic research and developmental cycles associated with the database.

Unlike traditional publications, the electronic publication of resources offers the possibility of almost continuous revisions with the integration and support of new media and interfaces. However, if on-line resources are to win the favor and confidence of their respective communities there must to be a clear distinction between published and maintainable resources, and, developmental content. Published material should, ideally, be supported via standard web-browser interfaces with fully integrated tools so that users receive a reliable, homogenous and intuitive flow of information and media relevant to their needs.

We discuss the inherent dynamics of the design and publication of our on-line resource, starting with the basic design and maintenance aspects of the electronic database, which includes photographic instances of cuneiform signs, and show how the continuous review process identifies areas for further research and development, for example, the "sign processor" graphical search tool and three-dimensional content, the results of which then feedback into the maintained resource.

I - INTRODUCTION:

During the late fourth millennium BC there was a major technological breakthrough: cuneiform writing was invented. Previously, writing on clay was primarily pictographic, probably done with a pointed implement that executed stylized drawings on the wet clay. Cuneiform writing is much more like letterpress printing: the sharp corner of a triangular-sectioned writing implement was pushed into the clay to make a three-dimensional wedge shape. All of the characters are composed of combinations of these wedge shapes.

The power of cuneiform is in its restriction. The pointed end of a drawing stylus can be freely guided, so drawn pictograms will vary considerably from writer to writer, whereas the triangular end of a cuneiform stylus can only produce wedges, and one wedge is much like another. The power of a writing system is in its versatility, which depends on an agreed stylization, easy differentiation, flexibility and simplicity of the component elements: cuneiform was a great leap forward.

The resulting medium was long-lived and widespread. Cuneiform was, at times, the medium of communication of the whole of the ancient near east, from Egypt to Iran, and was used until the beginning of the Christian era. Great libraries were created, and, since clay is much less fragile than papyrus, vellum, or paper, much of this priceless record is still extant. If you burn a cuneiform library you help to preserve the content.

The first generation of cuneiform scholarship, which accomplished the extraordinary task of finding out how to read this record, depended largely on hand copies of cuneiform tablets for their data: chemical photography is expensive, and publication of chemical photographs much more so. Digital photography, on the other hand, and web publication are virtually free, and this is providing new opportunities as well as posing a new challenge to the present generation of cuneiformists. In order to take advantage of this new technology, the Cuneiform Digital Forensic Project (CDFP) at The University of Birmingham has brought together a team of experts from widely differing disciplines in order to answer questions about cuneiform that had previously been impossible to investigate.

II - EVOLUTIONARY DESIGN:

At its inception three years ago, a fundamental objective of the CDFP was the development of an electronic, on-line cuneiform database for scholarly research. This database system is now fully functional and is accessible via the Internet. It currently contains a sample set of signs which have been used to test and demonstrate the system. Extensive population of the database is envisaged over the next several years.

The design specification of our database evolved during the first 18-24 months of the project as we, a very diverse research team, developed an important common understanding of the basic system requirements. The merging of perspectives involved in this process was essential to the establishment of a shared vocabulary and a fluid design concept. As shown in Figure 1, this resulted in the development of i) a maintainable system, i.e., the working multimedia cuneiform sign database, ii) developmental projects and iii) plans for future research activities for more advanced functionality.

The generation and discussion of various prototypes significantly improved our team's early understandings of the overall requirements. These prototypes took various forms from design drafts such as overview schemas, formal entity diagrams and sketches of user interfaces to real software implementations, and, resulted in a working server implementation with an agreed set of interfaces for data input, search and browsing. These prototypes provided important tangible examples for the team to discuss and test; enabling content, indexing and interaction design and development to occur simultaneously. This dynamic design process also encouraged creative discussion within the team for further extensions to the content and interface. New developmental projects included the “sign processor” for graphical search queries and three-dimension content, while future research was planned for scaleable delivery of content, metadata for object tagging, and personalizable and adaptive interfaces.

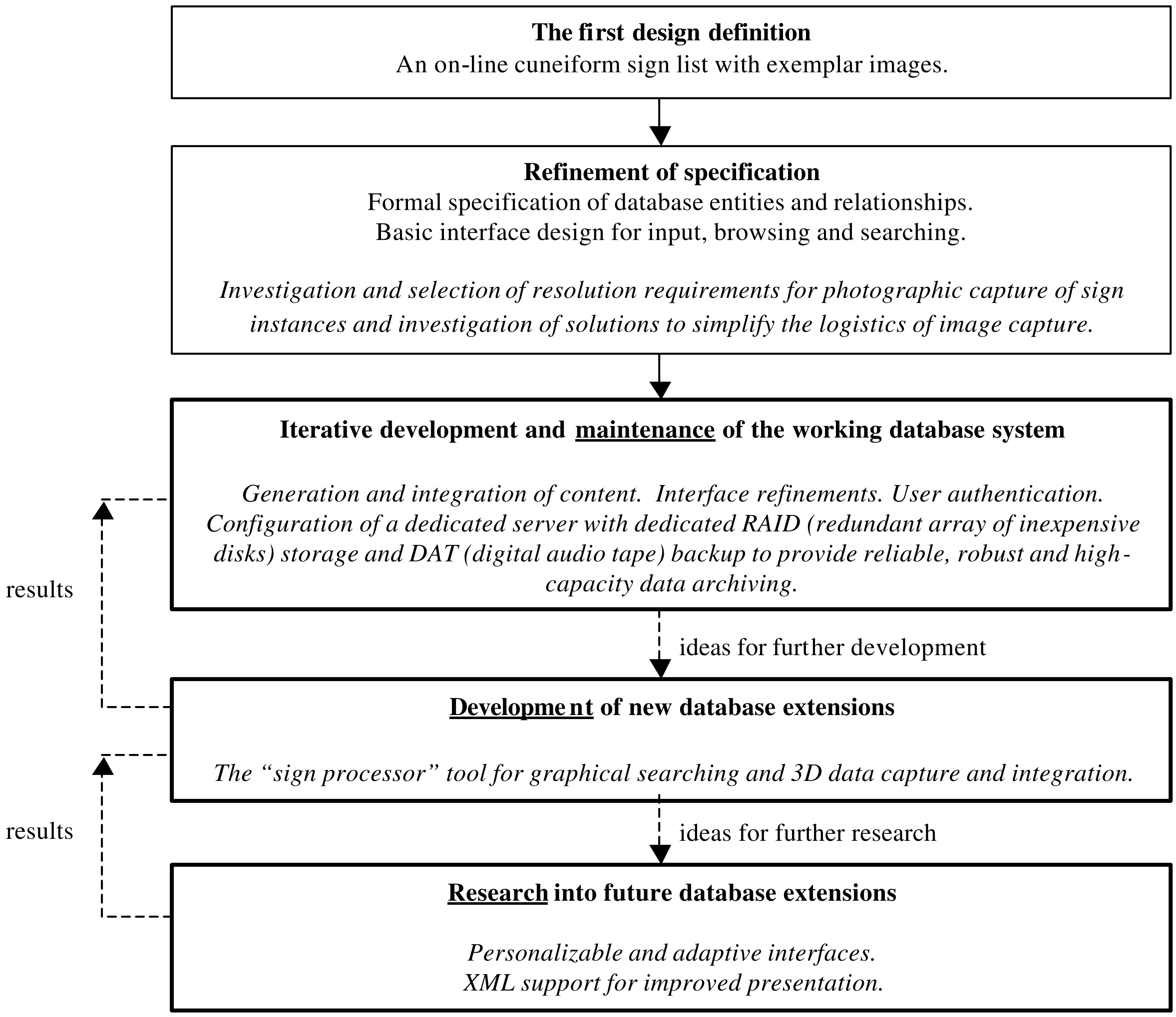

Figure 1: An overview of the design evolution and the establishment of three broad activities i) maintenance of the working system, ii) development of new systems and iii) research into future systems. Examples of each are shown in *italics*.

III – DATABASE DESIGN AND CONFIGURATION:

The levels at which a cuneiform sign can be classified provide the main structure of the database. We defined three levels : the *sign*, *allograph* and *instance*, which are summarised in Figure 2 and described in detail in [1].

The top level of our hierarchy is the *sign* represented by the *grapheme*, a label that uniquely identifies the sign.

The intermediate level contains a set of *allographs*, consisting of each one of the valid representations of the grapheme. These are simple graphics that represent the variations in sign construction, for example, variations across historical periods.

The *instance* represents the bottom level of our hierarchy, i.e. actual realisations of the sign in the clay. Instances are currently represented by digital pictures.

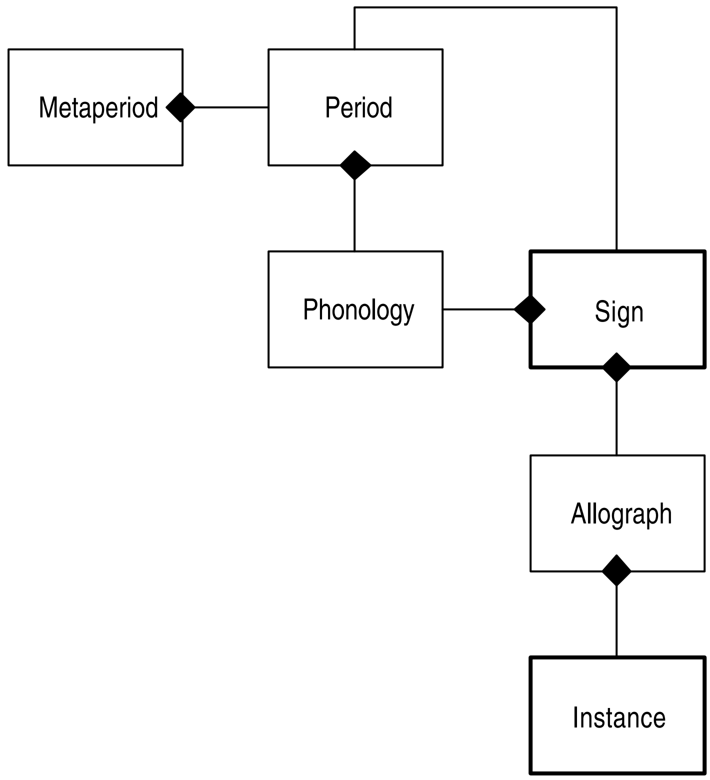

Figure 2: A simplified entity relationship diagram of the cuneiform database

Each sign can have several allographs and each allograph can have many instances. Allographs are classified by periods which can be selected by the user. Figures 3 and 4 show example screen captures from the current database for the symbol *babû*.

Having agreed the basic specification and discussed the future life-cycle of the cuneiform database, it became clear that the serving system required a robust and high-capacity long-term archiving ability, capable of delivering high-bandwidth content. Since extensive population of the database is planned over the next several years, an independent web server was configured with its own disk storage facility and backup mechanisms. The database server currently employs JavaServerlet technology and presents data to Internet users via standard web-browser interfaces.

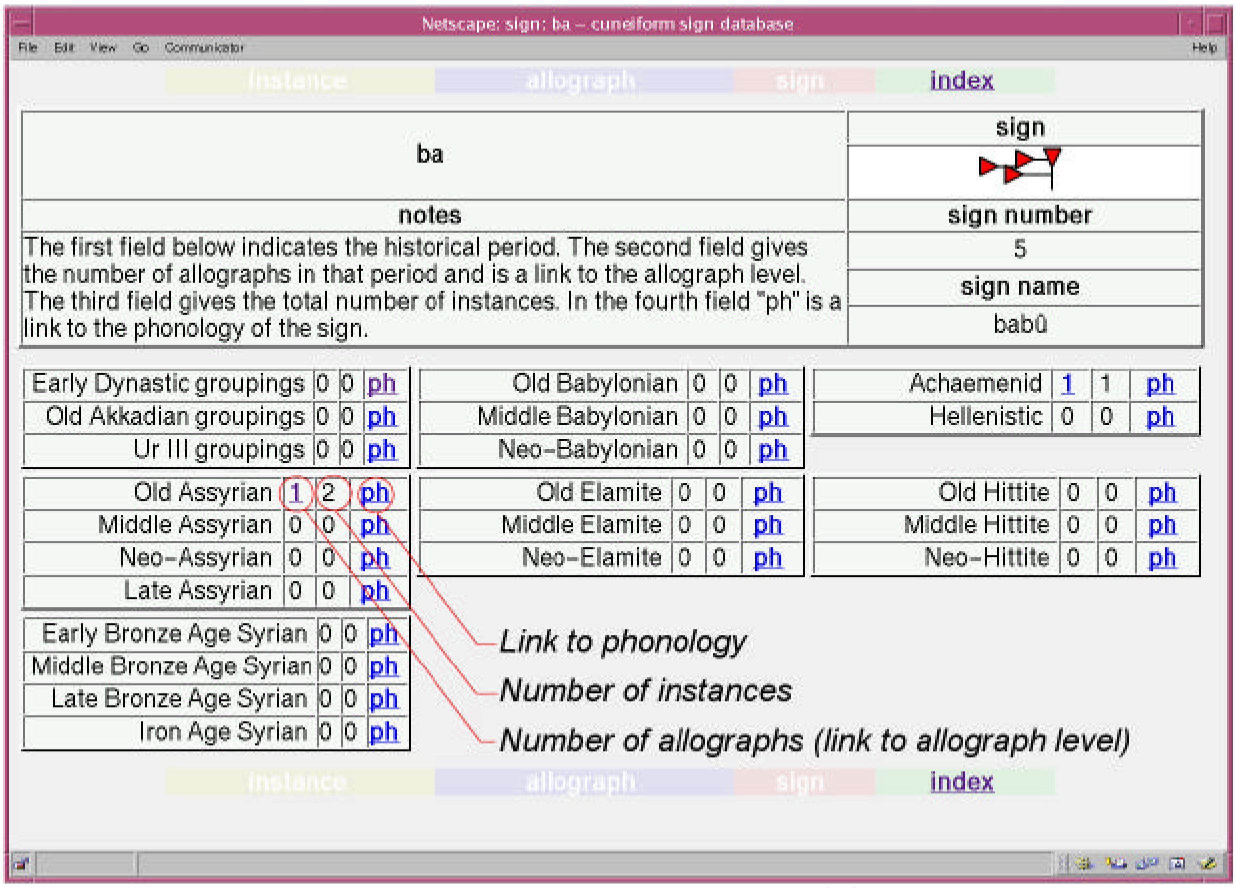

Figure 3: The database entry for the sign *babû*

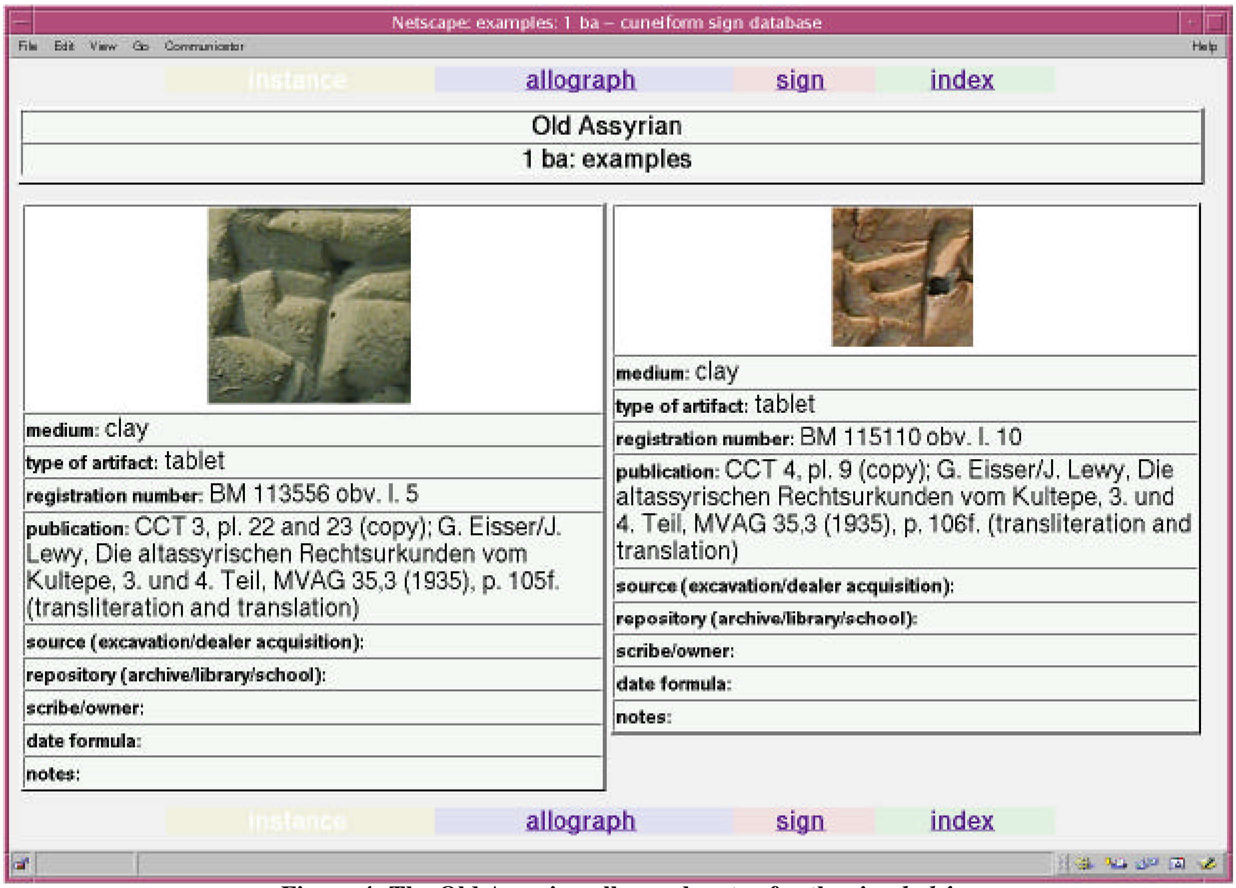

Figure 4: The Old Assyrian allograph entry for the sign *babû*

IV - THE SIGN PROCESSOR:

Any reference collection, particularly one as large as a cuneiform sign database, needs an index: a search tool. It is of course easy to search lists of signs by their conventional names, and then work downwards in the hierarchy from name to sign to allograph to instance, but that kind of search is only useful if the name of the sign is known. The student of cuneiform is often in the position of looking at an instance of a sign on a tablet and not knowing which sign it is. He or she therefore needs a means of moving upwards through the hierarchy: from (unrecognised) instance to allograph to sign. No conventional search technique will allow that, because what is unknown is an unidentified graphic shape, and there are no purely graphic search engines. Therefore one had to be invented. The "sign processor" is an extension to the original database design which will enable graphical search queries. As can be seen in Figure 5, the sign processor allows users to draw instances of signs, taking advantage of the highly stylised nature of cuneiform: any sign consists of groups of very few basic elements, which are combined in very simple ways.

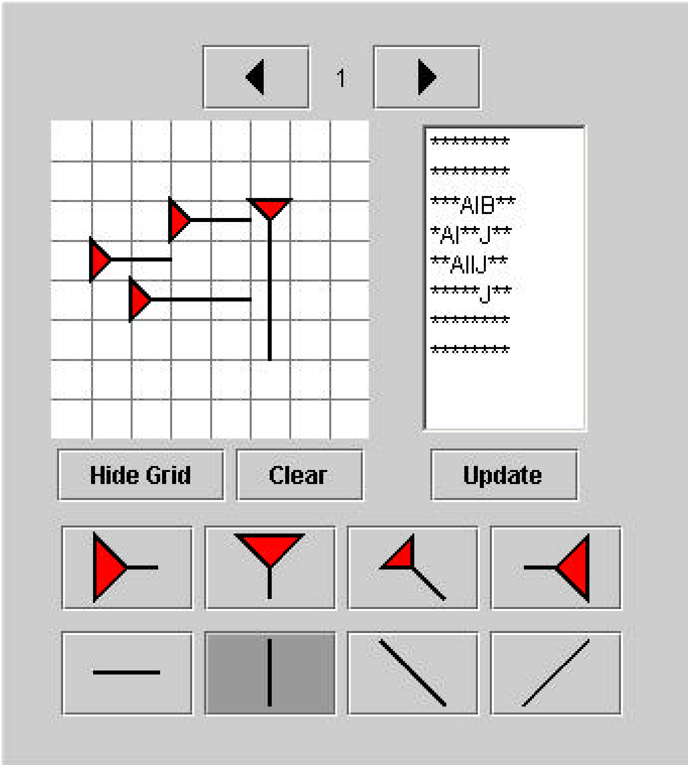

Figure 5: The sign processor showing a graphical entry mode where the user has sketched the *babû* symbol

The user employs the simple tools and a point and click interface to produce a stylised representation of the unknown sign on a grid. During this drawing process the computer creates an alphabetic representation of the resulting drawing (seen on the right of the image). All allographs in the sign list will have been drawn using the sign processor and the alphabetic representation stored as part of the data for that allograph. It thus becomes possible for the user to search for matches of the unknown instance. We are developing loose or fuzzy search methods to assist this process. What is particularly useful is that a user of cuneiform will often be working with broken tablets, and therefore fragments of signs; the sign processor will allow the input of partial signs and search for partial matches.

V - PHOTOGRAPHIC AND 3D REPRESENTATIONS OF CUNEIFORM TABLETS AND SIGN INSTANCES:

a- Photographic data capture: Our analysis of the tablets established a resolution requirement of approximately 0.025mm to support forensic study of sign instances sufficient to distinguish between different scribal hands. However, we anticipated that users may, more often, be interested in the general shape and size of the tablets, and a simple, low-resolution image may suffice. Other scholars may be interested in reading the symbols and would therefore require more intelligible, higher resolution renditions, but not at the same high resolution required by forensic analysis.

For our photographic experiments we used a 3.34 megapixel digital camera (the Nikon CoolPix 990) at The British Museum, using a four-light bed with adjustable camera height and with tablets mounted on a sand tray to stabilize their orientation. The photography of cuneiform tablets poses several challenges due to the densely compacted inscriptions on both sides, with text running over rounded edges and frequently continuing along each side edge. This makes the complete photographic capture of tablet signs problematic even with many exposures from different angles. Lighting proved problematic, not least because of repeated burns from the directional spotlights. The depth of the impressions also made the selection of correct lighting both difficult and time-consuming. Other challenges included the development of systems to preserve scale information and enable the correct attachment of catalogue and context information.

b- Three-dimensional data capture: The problem with photographs is that the lighting and shadows are fixed and cannot be manipulated by the viewer. When reading real tablets, experts tend to rotate them constantly: grossly in order to present all the signs to inspection, but also subtly, in order to use light and shadow to bring out the indentations clearly. In order to duplicate the 'viewing experience' on a computer, we investigated the provision of three-dimensional models of signs and tablets as an extension to the database design [2].

There are a number of different techniques for capturing three-dimensional models of real objects, each offering different scanning areas and resolutions. The Digital Michelangelo Project at Stanford University [3] involved scanning larger objects, e.g., Michael Angelo's statue of David, at a resolution of up to 0.25mm using laser triangulation rangefinding. The 3D-Matic project [4] at the Turing Institute and The University of Glasgow used 'photogrammetry' to give a resolution of 0.5mm.

Our stringent forensic resolution requirement of 0.025mm resolution over the entire surface of a cuneiform tablet (typical size 50mm by 70mm by 20mm) was achieved using the Breuckmann OptoTOP scanner [5]. With the assistance of Scientifica [6] (a distributor of the Breuckmann system) we obtained high-resolution scans of some cuneiform tablets held at The British Museum. Figure 6 a. shows the scanning operation in progress at the museum and Figure 6 b. shows an example of a captured tablet. The tablet depicted belongs to a category of tablets known as "buns". This one measures about nine centimetres across and is about three centimetres thick. The inscription is an invocation for a long life addressed to the Babylonian king Samsuiluna, who reigned from 1749 to 1712 BC, and who was the son and successor of the famous Babylonian king Hammurabi, best known for his code of laws. This bun is from an ancient scribal school. The master would write on the inscription on one side and the pupil would have to memorize it and write it on the other side without peeking.

Figure 6: a.) (left) Three-dimensional capture of tablets in The British Museum archive and b.) (left) an example of a rendered three-dimensional scan of a cuneiform tablet with a resolution of 0.005mm.

Our high-resolution three-dimensional scans contain all the information required to fully represent a cuneiform tablet. However, the resulting file sizes are typically over 100MBytes. Files of this size are extremely difficult to manipulate in real-time and are unsuited to communication over the Internet, for example, even at the maximum transfer rate, a 28.8k*bits*/second modem connection (i.e., 3.6k*Bytes*/second) would require almost *8 hours* to download a small tablet. This would be a very inefficient means of delivery and wasteful of network bandwidth particularly for users only requiring a low-resolution model. In order to satisfy the needs of various users, scalable delivery is desirable. A typical scenario would be this: the user first obtains a model of the entire tablet at a low resolution. Then, if the user chooses to zoom in on a specific region, additional information is transferred to increase the resolution of the area of interest. The important difference between this technique and standard delivery mechanisms is that the user would not need to download an entire high-resolution model in order to zoom in on a small area.

c- Three-dimensional visualization and manipulation: Standard three-dimensional viewers download complete datasets rendering them on the screen depending on the user's chosen viewpoint. When used as a mechanism to view three-dimensional models such as cuneiform tablets, the user can select which part of the tablet to look at, zoom in and out, and rotate the tablet in all three axes. Examples of our scanned bun tablet are shown in different viewers in Figures 7 and 8.

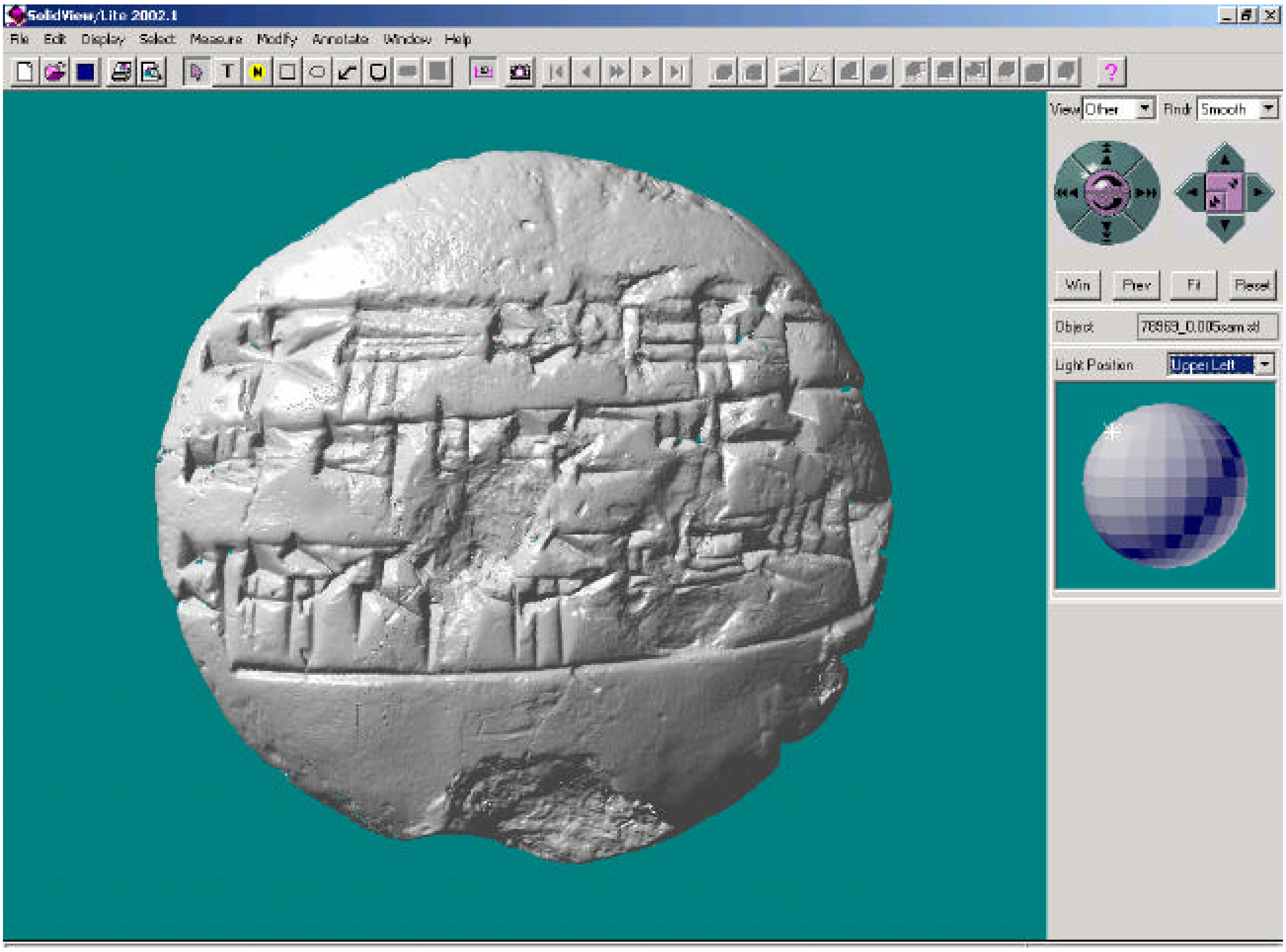

Figure 7: The bun tablet at the highest scan resolution of 0.005mm shown is the Solidview Lite 3D viewer. This freeware viewer allows manipulation of the tablet and a single light source (the controls for rotation, translation and zoom, and, light positioning are shown on the right-hand-side).

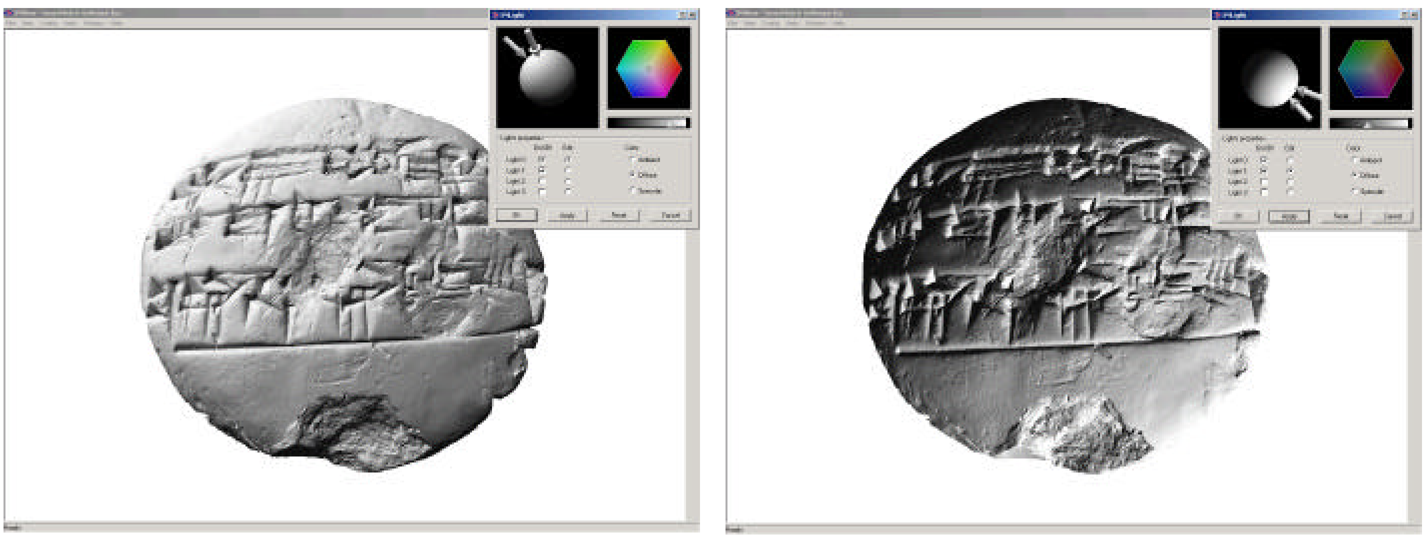

Figure 8: The bun tablet at a scanned resolution of 0.01mm shown in the Polyworks 3D viewer. This viewer allows manipulation of the tablet and up to four light source (ambient, diffuse or spectral). The lights can be easily manipulated with the mouse - two different settings of north-west vs. south east illumination are shown left and right, respectively.

Some three-dimensional viewer interfaces can be confusing, particularly to novice users. If, for example, left-right movement of the input device produces rotation of the tablet, when the user may have been expecting a lateral movement in the viewing window. An additional complexity is added when illumination is taken into account; for correct viewing of the cuneiform tablets the user must be able to alter the position of one or more light sources to create the shadows to provide the necessary depth information. However, our simple experiments with high-resolution scans clearly demonstrated the benefit of three-dimensional models over photographic representations of instances and we plan to continue working on methods to integrate three-dimensional instances with the image data of the sign list database.

VI - FURTHER RESEARCH AND FUTURE DEVELOPMENTS:

In addition to developmental activities, the team have identified several areas which would benefit from further research. Any results from these activities could, after development, be integrated into the maintained database system. The items of further research of particular relevance to electronic publishing are summarized below.

It is very important that the three-dimensional datasets are traceable throughout the entire capture, storage, delivery and manipulation process. There are several pieces of information associated with the electronic representation of each tablet, for example the catalogue number, physical dimensions, excavation details, storage location, ownership, etc. This “data about data” is called “metadata” and needs to be robustly connected, or “tagged”, to the data it describes. As the user manipulates the data and zooms in, metadata referring to, for example, the physical size and location of the selected subset should be available.

Support of the new XML (extensible markup language) cuneiform standard is also considered important for future web publications [7][8]. Issues of copyright also require consideration when making high-resolution electronic scans of copyrighted artifacts. It may be necessary to provide mechanisms to scale delivery of scanned models based on user privileges. For example, public access could be given to low-resolution data, and access to the high-resolution models limited to authorized experts. To prevent copyright infringement, it is important that this information is also closely coupled to the data itself. Techniques such as digital watermarking could be used, although there are no standards at present.

An interesting area of new research in interface design involves the personalization and adaptation of interface settings and behaviors based on user models. We plan to investigate the potential for intelligent and adaptive interfaces to support user requirements and preferences.

SUMMARY:

We have presented a summary of the maintenance, development and research aspects of our database, highlighting three separate activities whose interactions form an evolutionary development path for the database. An important limitation of these interactions is that new functions are researched and developed independently of the maintained system prior to integration, so that untested experimental content or functions are never presented to the database user.

A notable project in on-line cuneiform publication, which may be of interest to readers, is The Cuneiform Digital Library Initiative (CDLI), a joint project between UCLA and The Max Planck Institute for the History of Science, (online at http://early-cuneiform.humnet.ucla.edu). The aim of the project is to develop an electronic resource making 3rd millennium B.C. cuneiform tablets available on the internet. Full image data sets of the Hermitage, with its substantial archives of pre-Sargonic Lagash (ca. 2400-2350 B.C.) and Ur III (ca. 2050-2000 B.C.) administrative documents, and of all collections of tablets deriving from the period of proto-cuneiform (ca. 3200-3000 B.C.) are in the process of being made available on the CDLI pages. The pages also provide links to many useful resources.

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