# The MAAYA Project:
# Multimedia Analysis and Access for Documentation and Decipherment of Maya Epigraphy

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## 1. Introduction

Archaeology and epigraphy have made significant progress to decipher the hieroglyphic writings of the Ancient Maya, which today can be found spread over space (in sites in Mexico and Central America and museums in the US and Europe) and media types (in stone, ceramics, and codices.) While the deciphering goal remains unfinished, technological advances in automatic analysis of digital images and large-scale information management systems are enabling the possibility to analyze, organize, and visualize hieroglyphic data that can ultimately support and accelerate the deciphering challenge.

We present an overview of the MAAYA project (http://www.idiap.ch/project/maaya/), an interdisciplinary effort integrating the work of epigraphists and computer scientists with three goals:
(1) Design and development of computational tools for visual analysis and information management that effectively support the work of Maya hieroglyphic scholars;
(2) Advancement of the state of Maya epigraphy through the coupling of expert knowledge and the use of these tools; and
(3) Design and implementation of an online system that supports search and retrieval, annotation, and visualization tasks.

Our team approaches the above goals acknowledging that work needs to be conducted at multiple levels, including data preparation and modeling; epigraphic analysis; semi-automated and automated pattern analysis of visual and textual data; and information search, discovery, and visualization. In this abstract, we concisely describe three ongoing research threads, namely data sources and epigraphic analysis (Section 2), glyph visual analysis (Section 3), and data access and visualization (Section 4). We provide final remarks in Section 5.

## 2. Data sources and epigraphic analysis

The project focuses on Maya hieroglyphic inscriptions produced within the Yucatan Peninsula, inside the northern Maya lowlands, which encompasses sites within the Mexican states of Yucatan, Campeche, parts of Quintana Roo and a northern-most portion of Belize (see **Fig. 1**). Our research targets the three Maya Books (Codices) produced inside the Yucatan peninsula during the Postclassic period (1000-1521 AD). The first one is the Dresden Codex, housed at the University Library of Dresden, Germany[1]. For this data source, our project relies on published facsimiles (Förstemann, 1880; Codex Dresden, 1962; Codex Dresden, 1989) and on high-resolution, open-access images provided by the SLUB[2]. The Codex Madrid is stored at the *Museo de América* in Madrid, Spain, and for its study, our project relies on published facsimiles and line drawings (Codex Madrid, 1967; Villacorta and Villacorta, 1976). For the Paris Codex,

[1] SLUB: *Sächsischen Landes- und Universitätsbibliothek Dresden*
[2] http://digital.slub-dresden.de/werkansicht/dlf/2967/1/cache.off

the project relies on published facsimiles and images provided online by the *Biblioteque Nationale de France*.[3]


**Figure 1.** Map indicating main archaeological sites under study by our project.

Codex pages were usually divided by red lines or *t'ols* (**Fig. 2**). Each of these *t'ols* is further subdivided in frames relevant to the specific dates, texts and imagery depicted. Frames contain several glyph blocks organized in a grid-like pattern with columns and rows, calendric glyphs, captions, and iconographic motives. Briefly stated, *t'ols* are "segmented" into their main constituent elements (**Fig. 2**). Images are post-processed and from these, high-quality, scale-independent vectorial images of the individual hieroglyphs and iconography are generated in three modes: (a) grayscale/color, (b) binary, and (c) reconstructed forms (marked in blue), which are based on epigraphic comparison of all available similar contexts (**Figs. 3-4**)

[3] http://gallica.bnf.fr/ark:/12148/btv1b8446947j/f1.zoom.r=Codex%20Peresianus.langDE

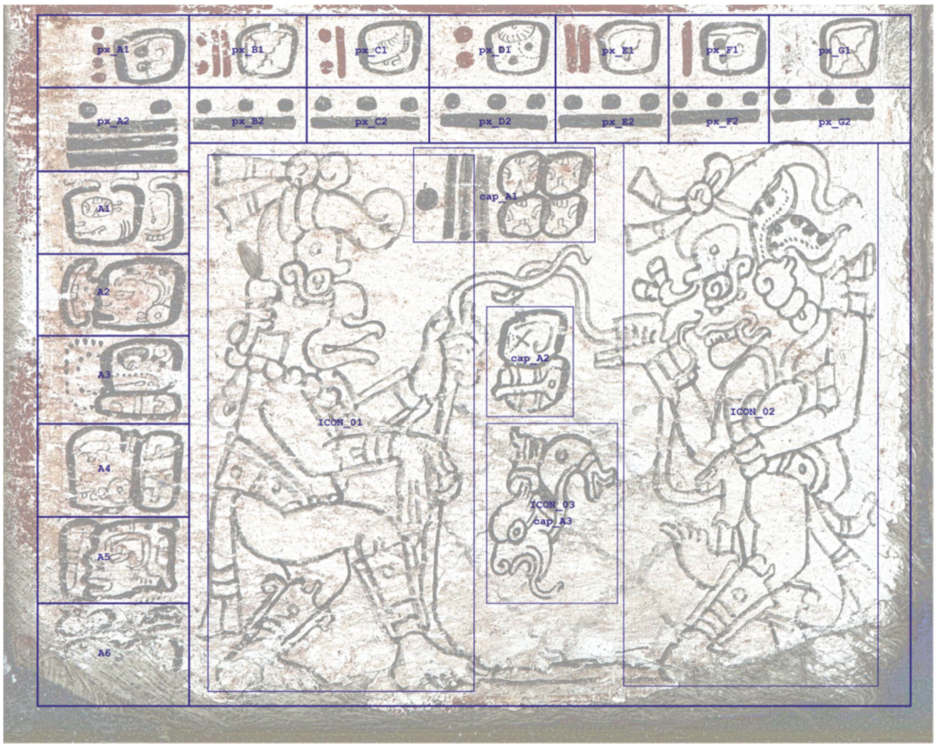


**Figure 2.** Page 47c (44c) of the Dresden Codex framing main individual constituent elements (by Carlos Pallán based on SLUB online[4] open source image)

The process of annotating the Codices entails an analysis comprising the following steps: (a) identification of individual signs on (Thompson, 1964) catalog, i.e. T0588:0181; (b) identification of individual signs on (Macri and Vail, 2008) catalog, i.e. SSL:ZU1; (c) identification of individual signs on (Evrenov et al., 1961) catalog, i.e. 400-010-030; (d) identification of signs on (Zimmermann, 1956) catalog, i.e., Z0702-0060; (e) transcription, specifying phonetic values for individual signs as syllables (lowercase bold) or logograms (uppercase bold), i.e. **K'UH-OK-ki**; (f) transliteration, conveying reconstructed Classic Maya speech (words) formed by the combination of individual signs, i.e. *k'uhul ook*); (g) morphological segmentation, a division into morphemes for later linguistic analysis), i.e. *k'uh-ul Ok*; (h) morphological analysis, assigning each of the previous segments to a definite linguistic category, i.e. god-ADJ step(s)/foot; (i) English translation: "Divine step(s)/foot". Taken together, the processing steps within this workflow provide the ground for more advanced multimedia analyses (**Fig. 5**).

[4] http://digital.slub-dresden.de/werkansicht/cache.off?id=5363&tx_dlf%5Bid%5D=2967&tx_dlf%5Bpage%5D=47


**Figure 3.** Process to generate vectorial representations of the Dresden Codex: a)color/grayscale; b) binary; c) reconstructed (blue) forms (by Carlos Pallán based on SLUB online[5] open source images)

[5] http://digital.slub-dresden.de/werkansicht/cache.off?id=5363&tx_dlf%5Bid%5D=2967&tx_dlf%5Bpage%5D=47

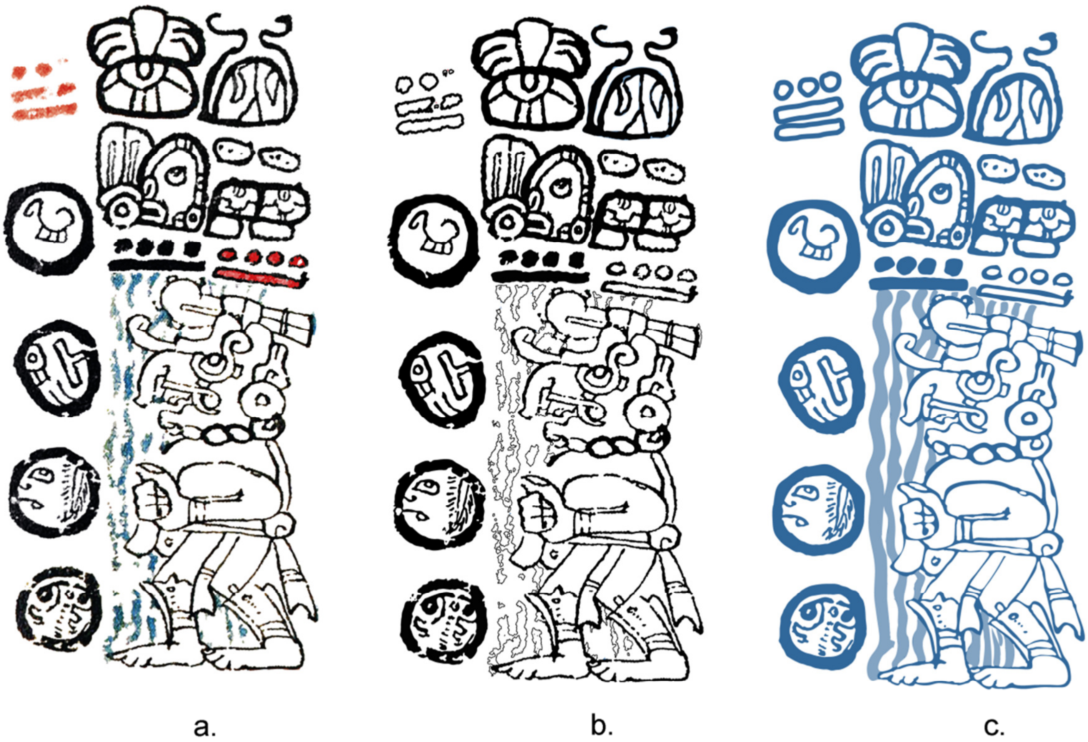


**Figure 4.** Vectorial representations of the Madrid Codex, Page (T'ol) 10b, Frame 1: a) color/grayscale; b) binary; c) reconstructed (blue) forms (by Guido Krempel based on (Codex Madrid, 1967))

| **DRE** | Page/T'ol 47c | | | | | |
|---|---|---|---|---|---|---|
| **Frame** | 1 | 1 | 1 | 1 | 1 | 1 |
| **Read. Order** | 01 | 02 | 03 | 04 | 05 | 06 |
| **Collocation** | A1 | B1 | A2 | B2 | A3 | B3 |
| **Glyph Date(s):** | | | | | | |
| **Glyph-block** |  |  |  |  |  |  |
| **Members (a, b, c...)** | a, b | a, b | a, b, c | a, b | a, b | a, b, c |
| **Members Ranking a, b, c, d, e....** | 3, 3 | 3, 3 | 3, 3, 3 | 3, 3 | 3, 3 | 2, 1, 1 |
| **Thompson** | T0400-0010-0030 | T0048.1037 | T0033.0765b:0102 | T0668.0102 | T0024.1006b | T0162:*0506.*0501 |
| **Macri/Looper** | SSL.ZU1 | PC4 | AMC.AP5:1B2 | MZ9.1B2 | 1M2.PE8 | 32P:*XH4.*XE2 |
| **Evrenov *et al.* 1961** | 400-010-030 | 025-262 | 040-323-112 | 530-112 | 111-255 | 574-*515-*212 |
| **Zimmermann 1956** | Z0702-0060 | Z...-0130 | Z0030-0707-0061 | Z0169-0061 | Z0080-0126 | Z0139-*1324-*1321 |
| **Transcription** | **WA'-ja** | **NAAH** | **K'UH-OK-ki** | **cha-ki** | **LEM?-NAL** | **TI'-WAJ*.HA'*** |
| **Transliteration** | *wa'aj?/ wa'[hl]aj?* | *naah[al]* | *k'uh(ul) ok* | *Chaa[h]k* | *Lem? Nal* | *ti' waaj* (ti') ha'** |
| **Segmentation** | *wa'-aj / wal?-aj* | *naahal* | *k'uh-ul ok* | *Chaahk* | *Lem? Nal* | *ti' waaj ti' ha'* |
| **Morph. Analysis** | stand.up-PAS | north | god-ADJ step(s)/foot | rain.god | resplendent? maize.god | mouthful tamale (mouth |
| **Translation** | "(he) raised/stood | (at) north, | "the holy-step(s) Rain God" | | "the resplendent(?) maiz | "abundance of sustenan |

**Figure 5.** Multivariable fields used to annotate textual contents of Dresden Page (T'ol) 47c (44c) (by Carlos Pallán)

## 3. Visual analysis of glyphs

Modeling Maya glyph shape is challenging due to the complexity and high intra-class variability of glyphs. We are developing methods to characterize glyphs for visual matching and retrieval tasks. In previous work, we proposed a shape descriptor based on visual bags-of-words (HOOSC: Histogram-of-Orientations-Shape Context) and used it for isolated glyph retrieval (Roman-Rangel, 2011). We are pursuing two research lines to extend our current capabilities.

**Improved shape representations.** Three directions are being considered: (1) the improvement of bag representations to retrieve syllabic glyphs. In particular, we developed a method to detect visual stop-words (Roman-Rangel, 2013a), and a statistical approach to construct robust bag-of-phrases (Roman-Rangel, 2013b); (2) the use of neural-network architectures like auto-encoders (Ngiam, 2011) that automatically build representations from training data. These approaches represent an alternative to handcrafted descriptors like the HOOSC, and provide a principled way to quickly adapt representations to different data sources (codex vs. monument glyphs); (3) the use of representations based on the decomposition of glyphs into graphs of segments, from which shape primitives can be extracted. This representation might be more suitable than histogram-based descriptors like HOOSC at identifying which strokes of a shape are discriminative, potentially allowing comparisons with so-called diagnostic features provided by epigraphers (**Fig. 6**).

**Figure 6**. Three glyph instances of the same sign. Right: one diagnostic features and variant.

**Co-occurrence modeling**. We are exploring ways to exploit the fact that glyphs do not occur in isolation within inscriptions but in ordered groups (glyph-blocks) (**Fig. 2**). To this end, we are studying options to build models relying on glyph co-occurrence statistics or further accounting for the glyph spatial position within the blocks. We plan to investigate how such information can be used in a retrieval system to improve performance and to help scholars deal with unknown or damaged glyphs. This has several dimensions like query types (e.g. single glyphs with known identity of other glyphs within the block), and contextual combination of shape similarity with text metadata.

## 4. Data access and visualization

Our work in this direction focuses on visualization of and effective access to image databases with archaeological value. We are developing a repository that will serve further goals within the project. This database stores visual elements of the Madrid, Dresden, and Paris codices. It is complemented with an online system, shown in **Fig. 7**, which allows for capturing and annotation of codices. More specifically, the repository contains relevant information regarding the composition of the codices, such as hierarchical relations between components and bounding boxes of glyphs. Therefore, it allows to query visual elements at different levels of semantic structure, i.e., page, t'ol, glyph-block, individual glyph, etc. The repository will also allow to query and study statistics of the Mayan writing system, e.g., hieroglyph co-occurrences.

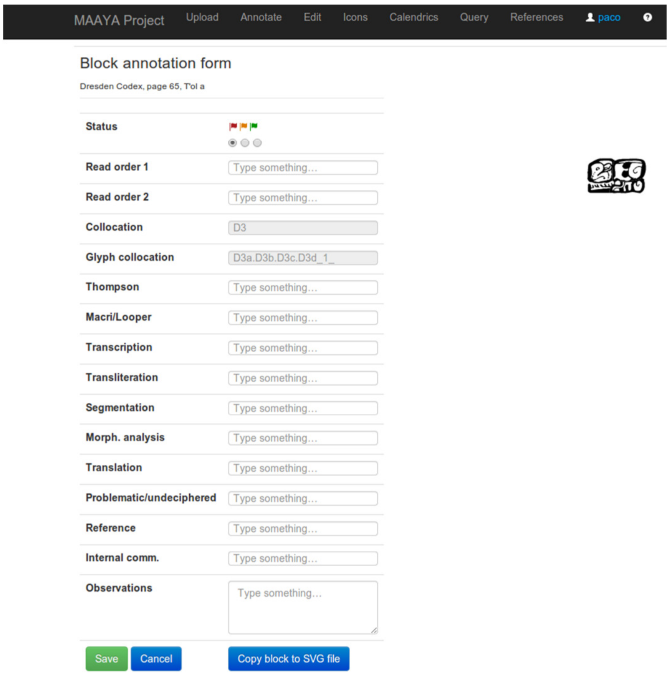


**Figure 7.** Snapshot of the online tool that feeds the database with imagery data and its corresponding annotations, i.e., codex name, t'ol, glyph-block reference, Thompson and Macri and Looper catalogs.

The second research line is the advancement of visualization techniques, and more precisely, the development of techniques that will allow exploring the feature space of a number of visual shape descriptors used to represent Mayan hieroglyphs for retrieval purposes. By relying on these visualization methods, our goals are detecting, understanding, and interactively overcoming some of the drawbacks associated with the shape descriptors currently in use (Vondrick, 2013).

## 5. Conclusions

We presented an overview of the MAAYA project's work-in-progress on epigraphic analysis, automatic visual analysis, and data access and visualization. Our close integration of work in computing and epigraphy is producing initial steps towards the design of computing methods tailored for epigraphy work; and can create opportunities to revisit findings in Maya epigraphy under the light of what computer-based methods can reveal (e.g., data-driven analyses of glyph diagnostic features.) At the same time, several of our machine learning, computer vision, and information retrieval methods are applicable to other problems in digital humanities. We would be interested in investigating applications of these methodologies to other sources of Cultural Heritage materials.

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