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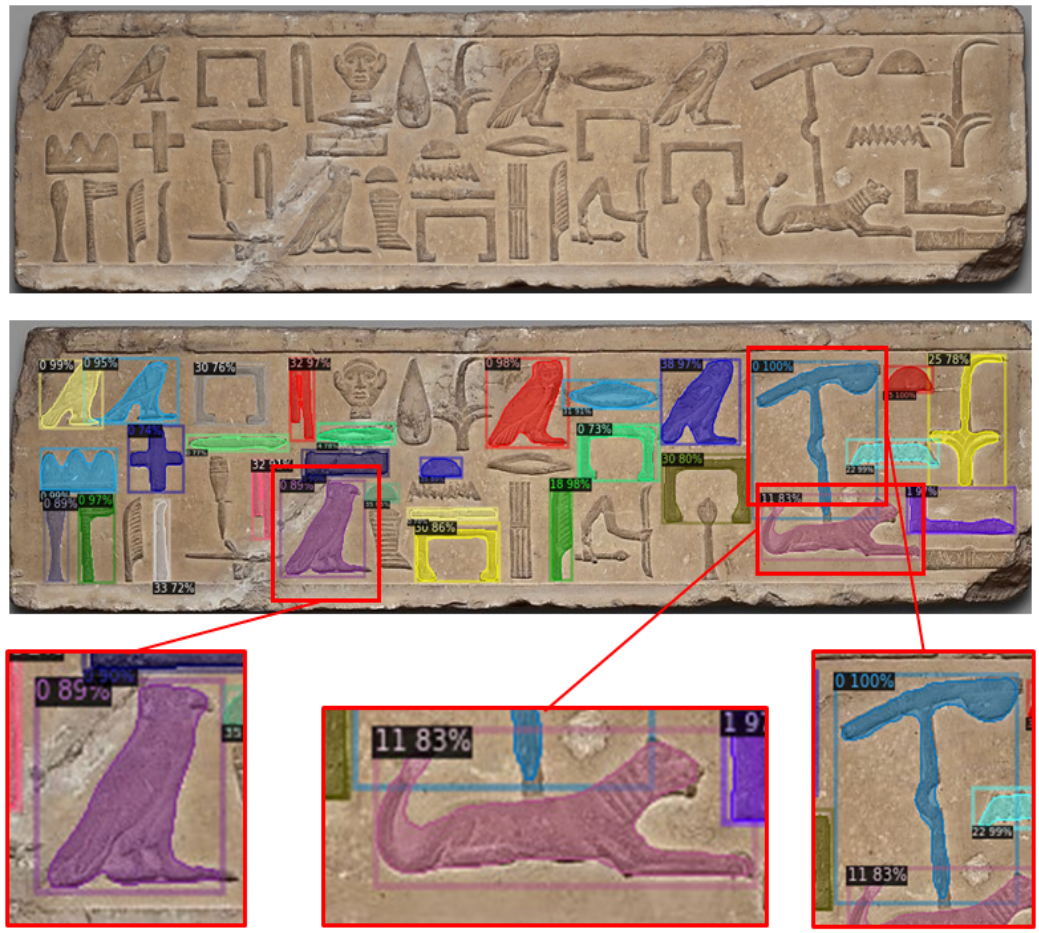

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DISCOVERING THE ANCIENT EGYPTIAN HIEROGLYPHS WITH DEEP LEARNING

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The original image on the cover is part of the collection of the Metropolitan Museum of Art in New York.

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The present work was born from the collaboration among the:

- Institute of Applied Physics "Nello Carrara" (IFAC), Italian National Research Council (CNR), Sesto Fiorentino, 50019 Florence, Italy;
- Department of Information Engineering, University of Florence, 50139 Florence, Italy;
- CAMNES, 50123 Florence, Italy.

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Summary

Preface

Advances in Artificial Intelligence (AI), especially in Machine and in the Deep learning fields, present for the first time an opportunity to build tools to support archeologists to unveil the real complexity of some of the world's most interesting and enigmatic challenges in archeology: the ancient Egyptian hieroglyphs philology. However, the applications of AI in this realm are not restricted to the mere automation of tasks, but it has the power to foster a new paradigmatic view on a collaborative intelligence where human Egyptologist and AI join the forces to generate a deeper and wider knowledge.

This book aims to describe the work developed around the seminal idea to apply Deep Neural Networks to the recognition and segmentation of ancient Egyptian hieroglyphs. This idea was born from conversations between the physicist Andrea Barucci, with and experience in the use of such analysis methods in the field of clinical imaging, and the Egyptologist Massimiliano Franci. Afterwards, thanks to colleagues and friends from different institutions, this interdisciplinary work flourished, synergically mixing the know how in Artificial Intelligence, Applied Physics, Computer Science and Egyptology.

This research explores the feasibility of the use of Deep Convolutional Neural Networks applied to the tasks of recognition and classification of ancient Egyptian hieroglyphs.

In the book, the neural networks used will be introduced and described. Subsequently, their results on artifacts coming from the "Museo Egizio" of Torino (Italy), the MET of New York, the Museo Missionario Etnografico Francescano di Fiesole (Italy) and Museo Archeologico Nazionale di Firenze (Italy) are presented.

Introduction

by
Donatella Lippi
(*University of Florence*)

It is a pleasure for me to write these introductory words to a work that summarizes the results achieved by a working group that deals with the application of AI resources to the Egyptological field. In reality it is also an institutional moment, as a memorandum of understanding called Athena links my Department (Experimental and Clinical Medicine) to the Institutions to which the colleagues involved belong.

In this agreement, the Parties intend to collaborate in a joint research project called ATHENA (ArTificial intelligence applications in ancient egyptian HiEroglyphs aNd archeological, historical and artistic Assets), aimed at research, development and testing of technologies and methodologies developed within Machine Learning and Deep Learning for innovative applications in the field of Cultural Heritage.

The first results of this type of investigation are presented in this volume, which confirms how Artificial Intelligence and Cultural Heritage represent an interesting combination. For several years, this theme has interested scientific and cultural institutions as far as the potential of possible interactions and aggregations between the various actors in an interdisciplinary key are concerned.

As a matter of fact, this volume defines roles and links where research and new technologies can suggest competitive paths and solutions, paving the way for unprecedented developments.

A long time has passed since Jean-François Champollion's detailed analysis of the Rosetta Stone in 1822 first "cracked the code", revealing the secrets of Egyptian hieroglyphs.

Starting from 1890s, the use of photography allowed many more scholars to become involved in further translations, opening a very interesting debate, and challenging the multiple expressions of the Egyptian language, handed down in very different written media: stone, papyrus, ostraca.

It is no coincidence that Hewlett Packard Enterprise named Champollion a super computer, hosted in the HPE Center of Excellence (CoE) in Grenoble (F), which brings together High Performance Computing and purpose-built AI technologies to model and train AI on a large scale: a tribute to the man who managed to decipher a writing considered until then mysterious.

Also in this volume, the field of investigation is the Egyptian writing system, analyzed through the perspective of the Egyptologist and the Physicists and the examples proposed in this research offer encouraging results, which are based on a fruitful synergy of skills.

Champollion isolated the names in the cartouches, compared data and verified his hypotheses. The Author of this research have applied Deep Neural Networks to the recognition and segmentation of ancient Egyptian hieroglyphs, creating a specific dataset and providing tools to support archeologists and promoting a new paradigmatic vision “on a collaborative intelligence where human Egyptologist and AI join the forces to generate a deeper and wider knowledge”.

Chapter 1

LOOKING INTO THE PAST TO OPEN THE FUTURE

by

ANDREA BARUCCI

1.1 – The era of Artificial Intelligence

Artificial Intelligence (AI) is becoming one of the most impacting technologies of our times, with applications in all fields of knowledge. In about 10 years, the world has been revolutionized by its data analysis methods, with algorithms being able to discover patterns in highly complex data and supporting people in many activities such as language translation, natural language processing, assisted driving, medicine and so on and so forth.

One of the keys to the success of this AI-wave are Machine Learning and Deep Learning algorithms, which have the ability to learn from data, improving their performances with experience.

Deep Learning in particular, based on the famous Neural Networks (NNs), shows a great adaptability to all kind of problems, without the need to define complex (and hard to find) "hand-crafted features", which have been the foundation of Computer Vision systems for many years.

Neural Networks, despite the general structure based on layers of artificial neurons, can be found in many different architectures, with structure and features that tend to adapt to specific task, such as Convolutional NNs (CNNs) for images analysis, Recurrent NNs (or more recently Transformers) for signals or Graph Neural Networks for drug design. There are so many architectures and applications today, that it is literally impossible to give a complete view. Moreover, many architectures can be used jointly, mixed together and there is not a real separation between the realm of application of a specific architecture. For example, CNNs were born to process images but they can be applied to time-signal analysis too, just by transforming the input data: an audio waveform (1-dimensional) can be transformed using the spectrogram in an image.

In Computer Vision, the application of Convolutional Neural Networks, has been revolutionizing the field. Tasks related to classification of image, recognition and segmentation of objects in an image, are today the realm of CNNs, with astonishing results.

Some details can be found in [1]–[3].

1.2 – The aim of this work

In this work we aim to show how some very famous Deep Convolutional Neural Networks architectures can be used in the field of ancient Egyptian Hieroglyphs recognition and segmentation.

Starting from a simpler scenario, where just a hieroglyph is present in the image, we will show the power of such methods, arriving to develop a specific CNN for this application, named Glyphnet [4]. Then we will move to the more interesting and real scenario of a picture with many Hieroglyphs inside, above all considering the possibility of disturbance in the data coming from damages that time can do on artifacts dating back at least 2000 years.

Applications on real pictures taken from Museum around the world will be shown and results discussed. Very promising and very poor results will give us the opportunity to outline the potential and the limitations we encountered on the application of CNNs in this field.

It is worth noting how the results we obtained must be considered not as the best one achievable, but just an example of the power of the Convolutional NNs. Our idea is to foster the application of Deep Learning in the field of Cultural Heritage [5] and Archaeology, in this case focusing on the ancient Egyptian writing systems. Many of the results obtained can surely be improved and we hope that this work, along with the other articles we published [4], [6], [7], could be a starting point for all people interested.

1.3 – Looking into the future, a perspective

Since the beginning, I was astonished by the power of these algorithms to face different problems starting from the same general structure, such as using the same CNN architecture to find a cat in a phone snapshot or to detect a lesion in a computed tomography image, just changing the training dataset or leveraging on the Transfer Learning paradigm.

In my experience I have had the opportunity to apply this idea in many fields, in particular in Radiomics, forensic anthropology [8], cultural heritage [5] and Biophotonics [9], and I hope to extend this list in the near future.

Concluding, to summarize my efforts for the future I would like to rephrase the famous quote from Star Trek into "*to boldly go where no algorithm has gone before*".

This is exactly the view I'm trying to embrace in the world of Artificial Intelligence.

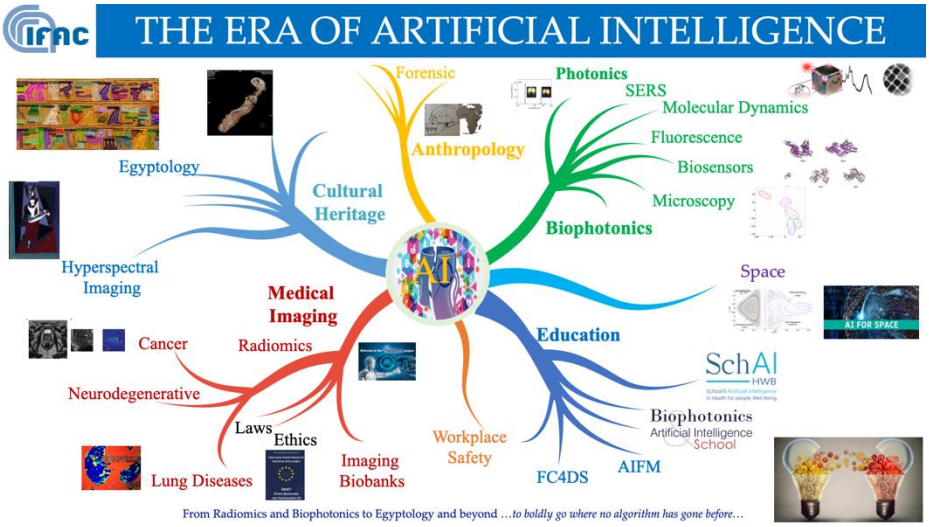


Figure 1.1: Mind map of the first author current applications leveraging on AI.

Chapter 2

THE ANCIENT EGYPTIAN WRITING SYSTEMS AND AI

by

MASSIMILIANO FRANCI

In recent years, the relationship between artificial intelligence and the ancient Egyptian language has become ever closer. Many studies now go beyond the mere digitization of the text and deal with problems and solutions on different topics: coding of hieroglyphic signs [10],[11]; recognition and transliteration of signs [12], [13], [14], [15], [16]; recognition of determinatives and their semantic field [17]; transliteration and translation of the signs inside the cartouches [18]; how the single hieroglyphic signs are combined to form words [19]; translation and analysis of the hieroglyphic text [13,19-21].

This field of investigation creates interest by itself; it is clearly fruitful and must be examined from different points of view ranging from Egyptology to Computer Science, Neural networking engineering, computational analysis, given the complexity of the Egyptian language in all its components and the usefulness of integrating the tools used for its analysis. Moreover, it is in this direction that it seems profitable to move by developing an integrated system of analysis for every part of the problem: recognition and coding of signs, automatic text editing and recognition of the function of the sign, transliteration, and analysis of texts. The results and advantages of such an instrument are numerous [22] both at the synchronic level, both at the diachronic level and at the regional level: the analysis of words, the recognition of variants, the graphic evolutions, lexical changes, the calculation of the logographic, syllabic and alphabetic percentage of hieroglyphic writing system, to name a few. To better understand the application possibilities of AI to hieroglyphic writing and the Egyptian language, it is significant to describe both.

2.1 - The Egyptian Language phases

The Egyptian language family can be divided into two major periods[1] :

1) Earlier Egyptian, covering a phase between 3000 BCE and 1300 BCE, attested in some religious texts until the 3rd century A.D.
2) Later Egyptian, attested between 1300 B.C. until 1300 A.D.

Within these two macro phases, we have the following breakdown:

1.1) Ancient Egyptian attested between 3000 and 2000 BC, the language of the Old Kingdom (2686-2160 BCE) and the First Intermediate Period (2160-2055 BCE). In the Old Kingdom, there is a process of partial standardization in the writing system with the selection of phonetic signs and auxiliary elements, including **phonetic complements**, due to formative choices, such as the exclusion of the vowel connotation. These processes may have undeniably influenced the same script of phonemes that in some cases could had particular and different graphemes. In this perspective, one must understand the phonetic reduction and the graphic abbreviation of this period when writing and language tended to coincide. It is however good to keep in mind that precisely these particularities may have produced a certain aura of ambiguity in phoneme-grapheme relations, as it can be found in the Egypto-Semitic lexical comparison.[2] It is paradigmatic the examples of the sibilants phonemes *z* and *s* shift.

[1] See A. Loprieno, *Ancient Egyptian. A Linguistics Introduction*, Cambridge 1995, pp. 5-10 [23].
[2] M. Franci, "Considerazioni sulla storia della comparazione egitto-semitica", in *Quaderni del Dipartimento di Linguistica di Firenze* 16 (2006), pp. 113-134 [24].

Figure 2.1 - Old Kingdom hieroglyphs example: The Pyramid Texts[3]

In the Old Kingdom, it is recorded randomly from the reign of Sesostris (Middle Kingdom) though it is consolidated, and the choice of one sign depends only on an aesthetic idea or mere space problems. On language level, there were many "popular" expressions with within them the seeds for those linguistic developments of the later periods.[4] As far as hieratic writing (more cursive style of writing) is concerned, it is still, at this stage, a simplification of the hieroglyphic one, to which it remains linked.

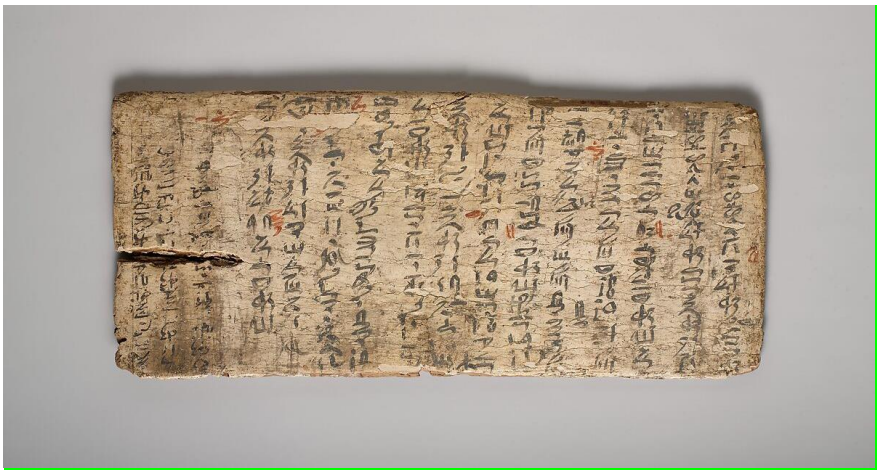


Figure 2.2 - Hieratic writing system example [5].

[3] https://commons.wikimedia.org/wiki/File:Cartouches_of_Pepi_I_and_Pyramid_Texts._Limestone_block_fragment_from_the_debris_of_the_north_wall_of_the_antechamber_within_the_pyramid_of_Pepi_I_at_Saqqara._Petrie_Museum.jpg
[4] M. Franci, "Considerazioni sulla fonetica egiziana", in *Quaderni del Dipartimento di Linguistica di Firenze* 17 (2007), pp. 233-249 [25].
[5] https://www.metmuseum.org/art/collection/search/544319?searchField=All&sortBy=Relevance&where=Egypt&ft=painting&offset=40&rpp=20%amp;pos=46

2.1.1 - Middle Egyptian

Middle Egyptian or Classical Egyptian, attested between 2000 and 1300 BCE, approximately towards the end of the XVIIIth Dynasty. There is no real break between Ancient Egyptian and Middle Egyptian, as in all the following stages, but the Egyptians themselves still perceived a change. The high official Mentuweser, under the reign of Sesostri I (1970-1928 BCE), in his autobiography emphasizes: "I am one who speaks in the official way, free to not use the paw (the article)"; that is a man who does not use articles because they were not part of the official language.[6]

The final part of the ancient period seems to be characterized by a cultural impoverishment. The documents, even before the end of the Old Kingdom, show an extreme simplicity and expressive limitation, and the first Middle Egyptian linguistic characteristics. In the Middle Kingdom (2055-1650 BCE) we arrive at the formation of a graphic canon, of a spelling, which respects the traditional graphic fixity, adding phonetic/semantic notations (paradigmatic is the high abstraction and systematic of the determinatives) to get closer to the actual pronunciation.[7]

It presupposes the ideation of school activities with the aim of promoting the diffusion, the ordering, and the control (in particular of the graphic and linguistic variations) of the new linguistic code: *r3 nj km.t* "the Egyptian language".

The Middle Egyptian is preserved in a fixed way until the 18th Dynasty, due to a guided development of the Egyptian language as an instrument of a state, as result of a conscious and deliberate intervention to forge a highly perfected instrument of communication; when by now the spoken language was the Neo-Egyptian. This was the product of a clear scholastic intention, due both to the great importance assumed by literature and writing in general, and to the need to restrict the graphic and linguistic variations.

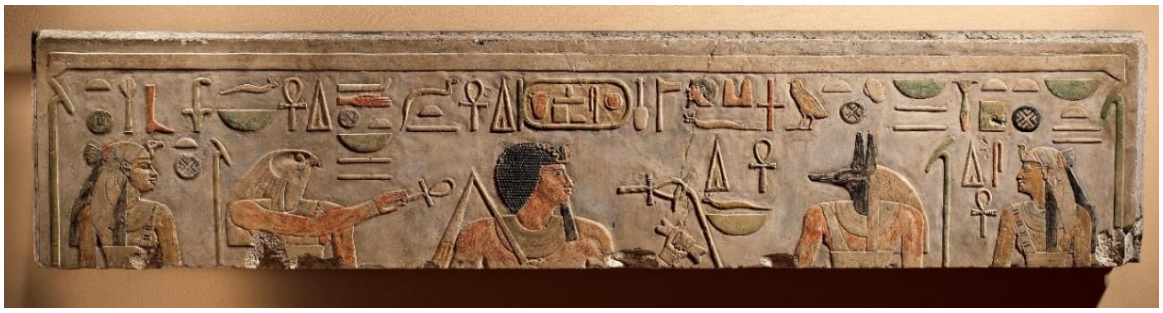


Figure 2.3 - Middle Egyptian example: Lintel of Amenemhat[8]

Two phenomena emerged in this step: a) the formation of a linguistic dualism caused by the persistence of a rigid literary language, and b) the conquest by the hieratic writing system of substantial autonomy, probably involving notations closer to the spoken language than the fixity of hieroglyphic writing. However, in the second millennium BCE, when communication between Egypt and the Ancient near East world reached a new peak, a clearly identified linguistic form emerged, the Neo-Egyptian. We, therefore, feel a dichotomy between Middle Egyptian as liturgical language, linked to the temple, and later also and above all literary, gravitating on the court, and Neo-Egyptian as a conscious expression of a popular culture; which has a greater refinement of the phonetic reality rather than graphic of the word, as a logical consequence. We thus see the contrast between the "court" language and the "popular" language accentuated, in such a way as to be the productive thrust of those phenomena that will assume dialectal function related to the geographical distribution in Coptic.

[6] A. Loprieno, *Linguistic variety and Egyptian literature*, in A. Loprieno (ed.), *Ancient Egyptian Literature. History and Forms*, Leiden 1996, p. 519 [26].
[7] A. Roccati, *Note di ortografia egizia*, OrNs 44 (1975), pp. 190-191 [27].
[8] https://www.metmuseum.org/art/collection/search/544141?ft=pyramid+texts&offset=0&rpp=40&pos=13

2.1.2 - Late Middle Egyptian

Late Middle Egyptian, also called *égyptien de tradition*, attested by the New Kingdom (1550-1069 BCE) at the end of Egyptian history, in diglossia with the Late Egyptian phase.

2.1.3 - Late Egyptian

Late Egyptian attested from 1300 to 700 BCE. In the passage between the two macro-phases are distinguished a) those elements that continue the ancient linguistic heritage; b) the archaisms resurrected by the research of imitation of earlier literature; c) the Neo Egyptian attestations of ancient elements not resulting in previous documentation; d) Semitic loans in Egyptian during the New Kingdom.[9] Cautiously we can see in these a partial fracture, as two strands will continue in diglossia ratio. However, it is right to specify that the Neo-Egyptian was not an innovation, but the emergence of different elements and in some cases the preservation of ancient, compared to the previous phase. The same transition phase can be divided into different stages, in which there are relationships that require an attempt at an interpretation. We can see in it a strictly internal phenomenon to the Neo-Egyptian.[10] The first evidences are attested during the occupation Hyksos (1650-1550 BCE): a funerary stele of Edfu, the stele of Kamose, the Carnarvon Tablet I, and the Westcar Papyrus. With the beginning of the New Kingdom the documentation shows the difference between spoken and written language: the inscription of the tomb of Paheri in El Kab, under the reign of Thutmose I, together with the aforementioned Tablet Carnarvon I, points out how the Neo-Egyptian expressions are spoken by workers.

Figure 2.4 - New Kingdom hieroglyphs example: Fragment of a Doorjamb from the Tomb of Djehutynefer[11]

In the Deir al Bahari temple's inscriptions, the soldiers spoke Neo-Egyptian as in the annals of Thutmose III the king, officers, and soldiers. The Amarnian period (1352-1336 BCE) can indicate a transitional phase from which many Neo-Egyptian elements emerge, due to extra-linguistic factors: the

[9] Cfr. A. Roccati, *Conservatività dell'egiziano*, in F. A. Pennacchietti – A. Roccati (eds.), Atti della terza giornata di Studi camito-semitici e indoeuropei, Roma 1984, pp. 78-110 [28].
[10] P. Vernus, *Les inscriptions de S°-Mwt surnommé Kyhy*, RdE 30 (1978), pp. 137-142 [29].
[11] https://www.metmuseum.org/art/collection/search/544784?searchField=All&sortBy=Relevance&when=2000-1000+B.C.&where=Egypt&ft=painting&offset=80&rpp=20&pos=86

reform of Amenhotep IV and its socio-cultural consequences on the country and the language spoken. Thus, we are witnessing a "linguistic crisis", also due to the increase in the exchange of words with the Syro-Palestinian Semitic area, during which, through texts such as the Hymn to the Aton, an attempt to maintain the Middle Egyptian as a literary language it was made. The considerable amount of neo-Egyptian elements present in the post-amarnian letters and documents show how the Neo-Egyptian was becoming the official and literary language of the new dynasty (the oldest papyrus in Neo-Egyptian is the Harris 500 dated to the beginning of the 19th dynasty), beginning to replace the Middle Egyptian. With the Ramesside age (1295-1069 BCE) the Neo-Egyptian became a literary and administrative language, a new means of expression and communication for a new state, indicated by the 19th Dynasty as *mdw T3 km.t* "the Egyptian".

The Middle Kingdom (obviously also the Old Kingdom, since evidently the division between two previous linguistic phases was not easily perceived) is mythologized especially in the literary field. So in the schools it is promoted, copied, and transmitted the "classical" literature through the *égyptien de tradition* (or the late Middle Egyptian),[12] but the official literary language is the neo-Egyptian.
The documentation from the workers village of Deir el Medina is paradigmatic: the texts are not yet "translated" in Neo-Egyptian, but are accompanied by glosses, paraphrases, and stylistic exercises. It emphasizes again how the control of spelling to create a literary language, has a logical consequence to "classify" both. Can we provide for further division? Yes, if we also take into account the consequences of the great effort to reconnect hieratic and hieroglyphic writing. Therefore, we see the birth of a new dichotomy, graphic this time, between the hieroglyphic writing, used by narrow environments especially to connote the "classical" language, and the Demotic system, a true means of expression of the spoken language.

But not only that. Some linguistic evolutionary traits are documented already at the end of the New Kingdom, while a large majority were at the beginning of the Third Intermediate Period (1069-664 BCE).
The Egyptian world enters in the Saitic Renaissance. It was a period of flourishing of ancient values and not sterile repetition of a glorious past. On one hand, they emphasize the refinement of an archaic linguistic purism, which aims to clean the ideological texts from any influence "popular" imitating the ancient Egyptian as faithfully as possible. On the other hand, the administrative use of Demotic language is established.

2.1.4 - Demotic from the 7th century BCE to the 5th century CE.

The Demotic language does not represent only a linguistic variant, but also of the writing. It has origin from a new graphical vision, differentiating from the hieratic writing system supplanting the "hieratic abnormal", based on simplified versions of groups of signs, abandoning the iconic immediacy of hieroglyphs, renouncing the logographic principle that allowed to understand the lexical value without the vowel connotation. At the linguistic level, it is an evolved stage of the Noe-Egyptian.

It was taking the path of the dissociation principle between sound and meaning, creating an instrument of expression that could be used to write other languages (see for example the Amherst Papyrus 63 in Aramaic language but written in Demotic). However, it also allows conceiving the writing of the Egyptian language in different handwriting, for example, the Greek.

However, hieroglyphic and the classical language remain in use, at least in the Temple of Philae, and until 24 August 394 CE, the date of the last document in hieroglyph. The last text dated is from 452 CE. Therefore, something had broken. Hieroglyphic writing system remains at the mercy of scholars and scholars, who develop personal solutions transforming it into a game of intelligence. Within the Demotic are recognized subdivisions, in writing, vocabulary, morphology and even syntax, depending on the areas of the country. It is usually divided into three phases, which seem to reflect both the

[12] Cfr. M. Malaise - J. Winand, *Grammaire raisonnée de l'égyptien classique*, Liège 1999, p. 10: "*...le recours à cette langue mimétique est « une marque sacralisante » ; comme l'emploi de l'écriture hiéroglyphique, il s'applique à des réalitées qui n'appartiennent pas au monde de la communication quotidienne...*" [30].

language and the writing: 1) Ancient Demotic; 2) Ptolemaic Demotic; 3) Roman Demotic. Demotic dialectology is still under discussion: if two dialects, North and Theban, are to be considered as existing and functional, the former would have supplanted the latter in use.

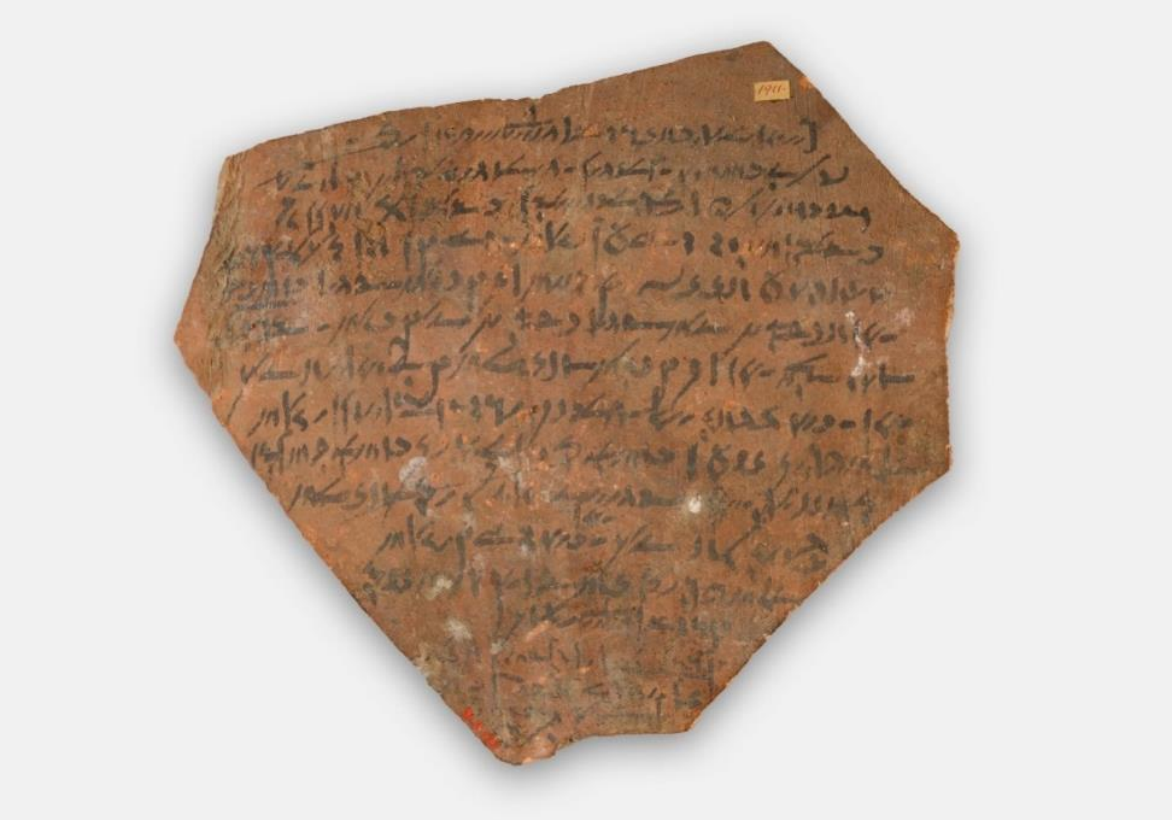


Figure 2.5 - Demotic writing system and language: Demotic Temple Oath[13]

2.1.5 - Coptic language(s)

Coptic is the last stage of the Egyptian language that finds documentation in the Christian period up to the last records of the 9th century of our era. It is important to note the part of the Greek in its genesis: the alphabet with some characters derived from the Demotic writing system, part of the lexicon, and of the syntax. The classical linguistic view describes the Coptic language simply as the later stage of the Egyptian language. At a certain time, it is transcribed through the Greek graphic system, with the addition of a series of characters derived from the Demotic script, to indicate the characteristic Egyptian sounds not present in the phonetic inventory of the Greek language. The use of Greek letters also allowed for the first time to highlight the vowel connotation.

Through this, unlike the Pharaonic period emerged a series of dialects reflecting the natural regional diversity. The Christian message, which arrived and was handed down in the early centuries through the Greek language, is thus transmitted through Coptic to the Egyptian population, which did not include Greek. Coptic writing thus seemed to be used for the dissemination of Egyptian Christian, Gnostic, Manichean, and Orthodox literature; partly for administration and in epistolary relations between distant communities. In recent years, this traditional vision has been called into question. To imply that the biblical texts were written in Coptic for precisely that part of the population who, not understanding Greek, could not participate in the Gospel message, it is in itself a misleading vision, given the illiteracy of the peasant classes. In fact, the simplest and most effective method of transmitting Christian doctrine, arrived in Greek in a different linguistic environment and composed of illiterate

[13] https://www.metmuseum.org/art/collection/search/569661?ft=demotic&offset=0&rpp=40&pos=1

people, is that of oral translation/transmission. [14] Moreover, anyone who was not, even at an auditory level, familiar with Greek could not understand a Coptic text; in whose vocabulary we find a large number of Greek lexicons, whose use goes beyond a mere use as a specialized lexicon (for religious concepts).

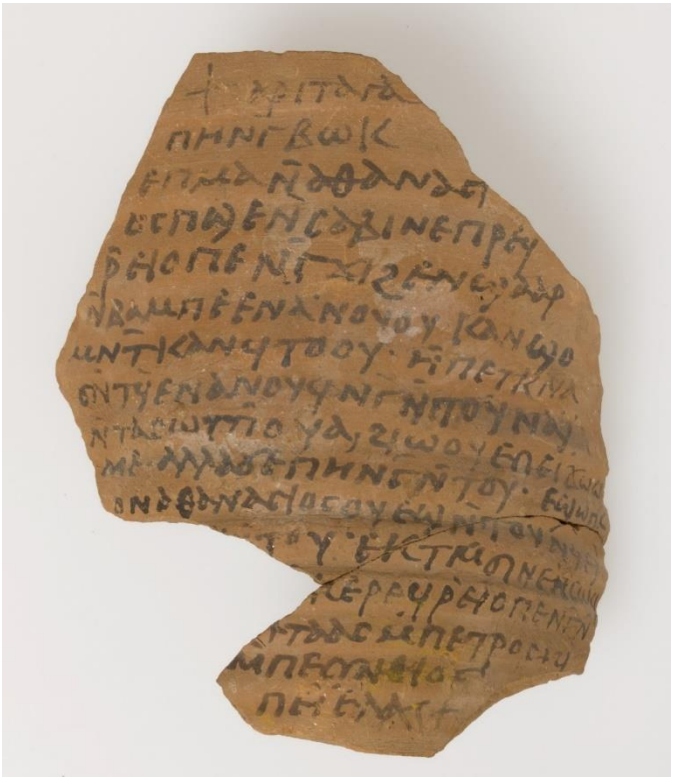


Figure 2.6 - Coptic writing system and language: Ostrakon with a Letter from Pesynthius to Peter [15]

The Egyptian dialectological study is by definition complex, since we put a working hypothesis on a dead language. Of this, we know in an imperfect way the pronunciation, because of the peculiarity of the hieroglyphic graphic system to have remained substantially fixed for three millennia not foreseeing the vowel connotation. However, it is common opinion that already in the Proto-Dynastic era (3200 BC, but probably even earlier) local linguistic diversity had developed, with different exogenous and endogenous influences, depending on geographical location. In the Delta the greatest linguistic contacts took place with the Semitic environment; west of the middle Nile valley with the Libyan environment; in the Theban area a linguistic island had probably been created; and finally in the area of cataracts (south of Aswan) with the Kushitic and Nile-Saharan environment.

2.2 - The basic principles of hieroglyphic writing

The hieroglyphic writing system is a hybrid system consisting of signs with an ideographic significance representing an idea or a word, and/or phonetic regardless of their ideographic value.
The signs represent concrete objects although in a standardized form, understandable to the cultural environment that has chosen them but in some cases not clear for us.

[14] Orlandi 1997:47-48 [31].
[15] https://www.metmuseum.org/art/collection/search/473400?ft=coptic&offset=0&rpp=40&pos=7

Figure 2.7 - Egyptian hieroglyphs: Relief of Nebhepetre Mentuhotep II and the Goddess Hathor[16]

Nevertheless, a system limited to ideograms alone could not express abstract concepts or logical processes. Some alternative methods were developed to develop further meanings. The most productive was to abstract, according to the rebus method, sound from ideograms by creating phonograms to write other homophonic words, especially abstract concepts; also in combination with other signs that specified the pronunciation of the word. In this way were created not iconic words compared to those related to ideograms: the individual signs were iconic but not their combination. A word written in this way expressed a high arbitrariness that implied the need to learn the code that, overcoming the only iconic character of the ideogram, allowed from that moment to give expression to an infinite series of contents and to deposit the knowledge they express and to transmit it from one generation to another[17].

In some cases, we have examples of polyvalence that is signs with more than one phonetic reading that generated new meanings. The impasse of the meaning of a thing in relation to one by one with the sign that represents it had been overcome.

[16] https://www.metmuseum.org/art/collection/search/548212?ft=egyptian+relief&offset=0&rpp=40&pos=27
[17] Simone: 40-41 [32].

These innovations were important. However, they made the understanding of the writing system complex, due to the removal of the meaning of a sign from the original form and value. On the other hand it was possible to express in writing abstract concepts, grammatical elements that were not actual logograms but rather elements that indicated the syntactic relations between sentences, and move to indicate purely phonetic values; Fundamental stage for future alphabetic writing through a series of cognitive and social changes. Writing your own language for the first time also meant describing it, allowing you to see what was only heard until then, giving rise to different forms of abstraction and new types of connections.[18]

It was a participatory process, whose social character allowed as a linguistic act to make use of sounds that interacting with others evoking a wider world made so by the indessical properties of the words themselves consenting a connection to the socio-cultural context.

The word is the unit of analysis par excellence. The Egyptian word is a linguistic sign with *signifier* and *signified* in the Sausserian conception. The first component represents the external aspect, merely graphic, that can be composed of one or more hieroglyphics; while the second represents the internal structure, essentially phonetic, derived from the name of the object according to the principle of the rebus: an idea that it evokes with a phonetic value, or, metaphonally, only the sound.

The Egyptian hieroglyph is further composed of two elements: a semagram (or ideogram) and phonogram. The semagram is a graphic symbol representing an idea in relation to it. Our modern culture is literally surrounded by semagrams, just think of the road signs, the logos of many brands, or the social networks emoticons. The phonogram is the phonetic value of the sign.

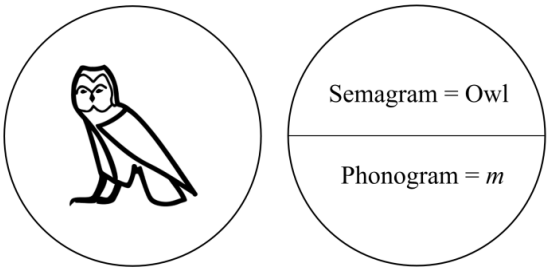


Figure 2.8 - The two parts of an Egyptian Hieroglyphs

2.2.1 - The "semagram"

The "semagram" element can have two different values, depending on its function in the word:

a) *The real* semagram, in this case it refers and means the object represented, and it indicates directly a word (it is a non-interruptible element, with a meaning).

b) *The determinative*,[19] a sign with a purely semantic and no phonetic value (it is not read and on the phonetic level it is essentially mute), whose function is to express the lexical field, i.e. the group of meanings to which the word belongs, facilitating the reading and the meaning of the word. Unlike the function of normal semagrams, the determinative does not directly indicate the word to which it is associated, but it specifies the semantic field to which a certain sequence of sounds refers. Its function avoids the confusion in the reading of homophones (words with the same sound, or at least the same consonant skeleton), well attested in Egyptian.[20]

[18] A. Duranti, *Antropologia del linguaggio*, Milano 2000: 117 [33].
[19] This topics is has been investigated in Goldwasser-Harel-Nikolaev 2019 [17].
[20] Franci 2004: 361-369 [34].

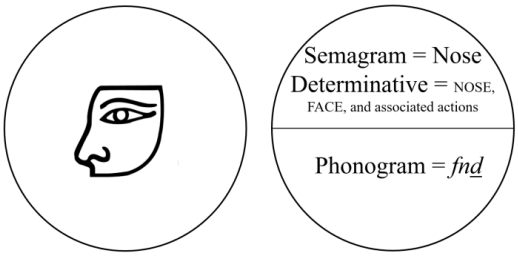


Figure 2.9 - Example of the double function of a Semagram

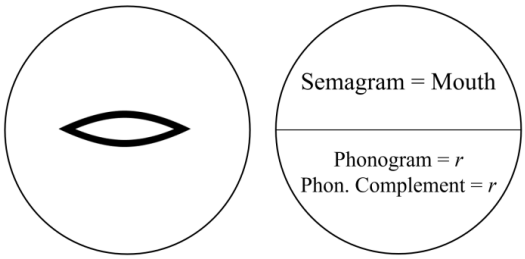


Figure 2.10 - Example of the double function of a Phonogram.

2.2.2 - The "phonogram"

The "phonogram" may also have two different roles:

c) *The real phonogram*, that can indicate the phonetic value of the sign to which it is associated. Metaphonically, it can also indicate the sound (or phonetic sequence) only, deriving it from the object name according to the rebus principle (a representation of a word or syllable through the drawing of an object, whose name resembles the word or syllable in sound, and may represent a phonetic sequence of one, two or three consonants).

d) *The phonetic complement*, i.e. a specific series of signs that expresses in a redundant way the sound of the sign to which they are accompanied. Their usefulness is commonly seen in reminding the correct phonetic reading of the multi-consonant signs. This redundancy allows us to define a phonetic complement essentially mute at the phonetic level, as for determinatives.

However, not all the hieroglyphic signs have all these functions, as showed in the following table.

Sign	Semagram function	Determinative function	Phonogram function	Phonetic Complement function
	1	0	0	0
	1	1	0	0
	0	1	0	0
	0	0	1	0
	1	0	1	0
	0	1	1	0
	1	1	1	0
	1	0	1	1
	1	0	1	1

2.3 - The neural network for the recognition of the Egyptian hieroglyphics complexity

It is in this different possibility of using the sign, semagram or phonogram and their variations, the key of the hieroglyphic writing system. For these reasons, the recognition of a hieroglyphic sign should not be limited to the identification of a single sign without taking into account its context, that is, what other signs surround it. A hieroglyphic sign is not just a world in itself with a single meaning, or a fixed reading, but precisely in the interaction with the accompanying signs, it finds its function.

For example, concerning the indicated phonetic complements, some scholars are considering whether sometimes, especially in the III millennium B.C. such signs also had a function of vocal integration.[21] In this case, the neural network would provide interesting data.

2.4 - AI and multispectral imaging analysis

The Egyptian civilization is a civilization of images, with a meaning such as brands, social emoticons, photographs and our contemporary society. Symbols such as pyramids, gods with animal head and human body, faces in profile, marked eyes, identify at first glance what is Egyptian. This immediacy is given by the idea of making a beautiful work of art (according to a taste different from ours), symbolic (tells who or what are the characters and objects) and functional (in a magical and ritual sense). Three elements that convey a fundamental vision of the Egyptians: each work was as alive and real as the original subject was. The invitation is to observe differently.

Paintings and sculptures are completed by hieroglyphics. Next to the scenes of agricultural works or religious ceremonies, there is the caption that describes them. Near the faces of the characters, the name and words they are saying, like a cartoon. The hieroglyph is a small work of art. Its simple form allows you to recognize what it reproduces. In writing it the scribe follows the choices of the representation: the eye is seen of prospect, the living beings of profile, the scarab and the lizard from above. As "words of God", they are alive: when they identify demonic entities they are mutilated to avoid negative influences.

The AI and multispectral imaging techniques (MIT) could have many outcomes in the world of Egyptian artefacts. Exploring the bulk, microscopic and surfaces properties of artefacts, they allow the identification of pigments, binders, and materials used in the original artworks. Revealing details not visible to the human eye and/or hidden, they identify materials and explore production technologies and techniques, giving more information and data on the existence of *sinopia*, grids, retouches, binding medium used (egg tempera, gums, resins), colorants used and their spatial distribution to facilitate comparisons between objects.[22]

The information given by the multispectral analysis can go deeper. As the examples above show, each Egyptian text or painting was first written in red ink and then rewritten in black in the final version. This method would make it possible to detect errors of audition that were then recurred, both in the school textbooks, where the teachers' corrections were present, but especially when the scribes worked on texts whose linguistic register was archaic compared to the current language, retrieving information related to Egyptian grammar. In addition, the acquisition of such precise images would facilitate the same reading of hieroglyphic signs in cases where they have been reworked or intentionally abrasive, as in the following example.

[21] Roccati 2008:57 [35].

[22] Further, the MIT acquisition and post-processing methods could provide preliminary indications of the status of the object, giving information for its monitoring process. The high definition of the digital "copy" (2D and 3D) of the artefact digitization eliminates the need to handle a fragile object. Such "remote" access (digital archive) will increase access to the artefact, for an interdisciplinary study (both for educational and research reasons, or just to create Virtual exhibitions), promoting the sharing of the knowledge.

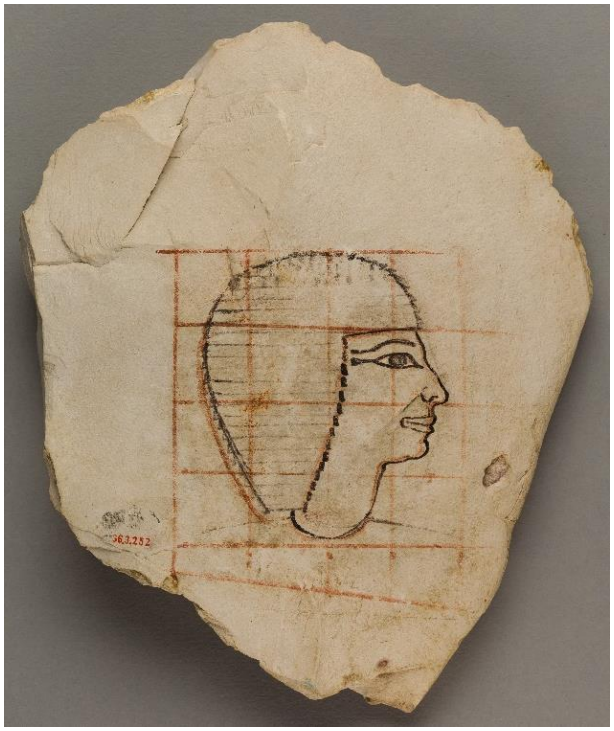


Figure 2.11: Grid example[23]

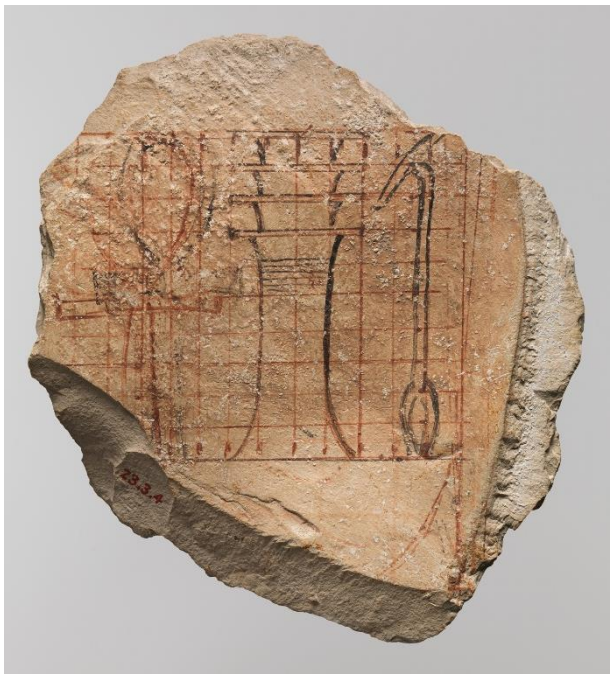
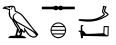


Figure 2.12: Grid example[24]

2.5 - The extra-graphic information

In the ancient Egyptian culture, word and image are closely related. The text integrates the accompanying figurative structure and vice versa. For example, it is often pointed out that the pronoun of a singular first person is often omitted in a text. Nevertheless, when it accompanies the scene where the owner of the tomb harvests the barley, this image indicates the subject or the action indicates the

[23] https://commons.wikimedia.org/wiki/File:Artist%27s_Scaled_Drawing_of_Hieroglyphs_MET_DP280353.jpg
[24] https://it.m.wikipedia.org/wiki/File:Artist%27s_Gridded_Sketch_of_Senenmut_MET_36.3.252_EGDP013666.jpg

verb, replacing respectively the sign of the pronoun and the verbal form. In the tomb of Sennedjem, he is represented while he is harvesting using a sickle with his wife. His action represents the infinitive of the verb  *ꜣzḫ* "to reap" in an infinitival form where the subject or agent is introduced by the preposition *jn* "by"  .

It is not enough to read and understand the text, but to decipher and understand the images and the mutual relationships.

The same hieroglyphic signs can be further differentiated one from the other through the chromatic rendering: each sign has a well-defined shape and a precise chromium, as it represents reality, being drawn from it. The guidelines of this choice are both far and close from the modern sense: you do not give importance to the hue (light/dark): the sky is blue, the green plants, the black indicates the wavy lines, the blue objects in clay.[25]

Figure 2.13: horned viper sign (Gardiner I.19) variants

Figure 2.14: similar signs variants and their variants: the Sun disk (Gardiner N.5), the sign H (Gardiner Aa1), and the walled city (Gardiner O.49).

Unfortunately, through the millennia the Egyptian artefacts have partially (or totally) lost their chromatic information that can be investigated with the AI and MIT, highlighting traces, type of colour, letting the scholar to reconstruct the expressive value of it, both in its graphic functionality, and in its possible symbolic component.

[25] Hornung 2002: 21-22 [36].

All of this information can help AI understand and develop a different view of hieroglyphs, defining also new types of interactions between humans and machine learning algorithms in a continuous active learning process where also the human is involved. It is a god examples the case of Toposyntax. This "New" discipline is emerging between the scholars that are studying AI application to the Hieroglyphs, especially in performing a way to communicate the ancient Egyptian linguistic information to the machine.

The Toposyntaxis can be defined as that part of linguistics that deals with the rules and principles that in writing, hieroglyphs in this case, overseeing the connection and relations between signs, the way they combine in words and/or phrases. Relationships can be considered not only in relation to the phonetic sequence but also in relation to the meaning, form, dimension and position assumed. If syntactic functions are expressed by morphological variations, the level of analysis will be morphosyntactic. Having a meaning for each sign, we can say that we study how they combine to form a higher-level unit.

This vision is the result of human machine interaction and in the open mental approach that sees AI as a means of getting deeper and deeper into the mind of ancient man. Therefore, through the past you had better focus on the future.

Chapter 3

DEEP LEARNING
THE POWER TO DISCOVER PATTERNS IN DATA:
FROM MEDICAL IMAGING TO PICTURES CONTAINING ANCIENT EGYPTIAN HIEROGLYPHS

The aim of this Chapter is to foster the ability of Deep Learning to explore patterns in any field of human knowledge, encouraging colleagues from different sectors to embrace this view. This path is just at the beginning and there is a Universe of discoveries in front of us. Here we started from the experience of one of the authors to analyze clinical images, making a comparison with similar tasks in the field of Egyptian writing systems.

3.1 – Patterns in Nature

Looking at nature, a reflection comes to mind: "Are there some similarities in the patterns observed in different phenomena?"

Starting from this thought, we asked: " What does a common medical image, such as a Computed Tomography or Magnetic Resonance Imaging, have in common with a picture of an ancient Egyptian hieroglyph?"

The question can be tricky, but the answer could be extremely interesting. Indeed, in our perspective, the answer is two-fold: everything and nothing.

Medical images and picture of ancient hieroglyphs are obviously expressions of completely distinct processes, containing very distant information, the first originating from the human body's nature and the latter as a product of the human mind.

However, they share more things than what we expect. They evidently contain information, some clearly visible and others hidden. We like to define this information as patterns.

These patterns show and share both an intrinsic complexity and a multi- scale nature. Clinical images, as it is known, are a representation of phenomena acting at different scales, from atomic, molecular and cell levels up to tissues and organ levels. Such kind of images should be seen as a source of knowledge, incorporating information coming from all these multi-scales. Indeed, pathological tissues should always be regarded as the expression of micro-systems which affect the macro-system. However, these features, quantifying the behavior of this system can be of two kinds, clearly seen or hidden behind what human-eye can perceive.

It is likewise for the Egyptian hieroglyphs, which show the same multiscale complexity. Simple shapes are connected to build symbols, which bring an intrinsic meaning. Symbols are combined together to give birth to different words, which give rise to sentences, tales and then thoughts.

So again, we ask:" What features do a medical image and an ancient Egyptian hieroglyph share?"

Now, we can try to answer:" They both show an intrinsic multi-scale complexity, which can be represented by humans as features. They show patterns. And today we know how we can deal with patterns in data or in this case in images."

3.2 – Patterns and Artificial Intelligence

Today, we are aware that Artificial Intelligence (AI) is one of the best approaches to studying patterns in all the fields of human knowledge, from fundamental physics [37] to drug discovery, language translation and archaeology [4], [6].

AI is one of the most powerful tools across different disciplines.

Between the many sub-fields of Artificial intelligence, Deep Learning [1] is probably nowadays one of the most important and widespread expression of this technology. With an intrinsic ability to explore data and images, learning to discover complex patterns, Deep Learning is the perfect tool for studying any kind of patterns, extracting hidden information.

At its base, a neural network tries to mimic the human behavior, learning from examples, improving with practice, and at the end trying to deal with any new problems it's facing, using previous knowledge (previously learned schemes).

This is exactly what the eyes of the medical radiologist and of the Egyptologist are doing when examining their images. They are essentially performing the same operation, extracting patterns from images, exploring all the scales reachable by human eyes and the human mind, recomposing the information into something to be understood by our mind and used in practice.

In the vast field of Deep Learning, Convolutional Neural Networks [2], [3] represents one of the best architectures to explore visual information, thanks to their ability to define a hierarchical view of an image. This kind of hierarchy is exactly what we need to explore medical images, aiming to uncover hidden processes. In Deep-Radiomics [38], where features representing visible and invisible patterns are learned by the network structure made by convolutional filters, features related to pixel colors distribution, textures and shapes are recovered and self-defined, in a hierarchic way, empowering the ability of the network to characterize the task at hand.

For ancient Egyptian hieroglyphs it is the same. Basic shapes give origin to the symbol, which represent the first visual information, while at same time textural features highlighted by convectional neural networks, carry with them information about the process the glyph was done, the inks used, the background material up to the "hand of the writer".

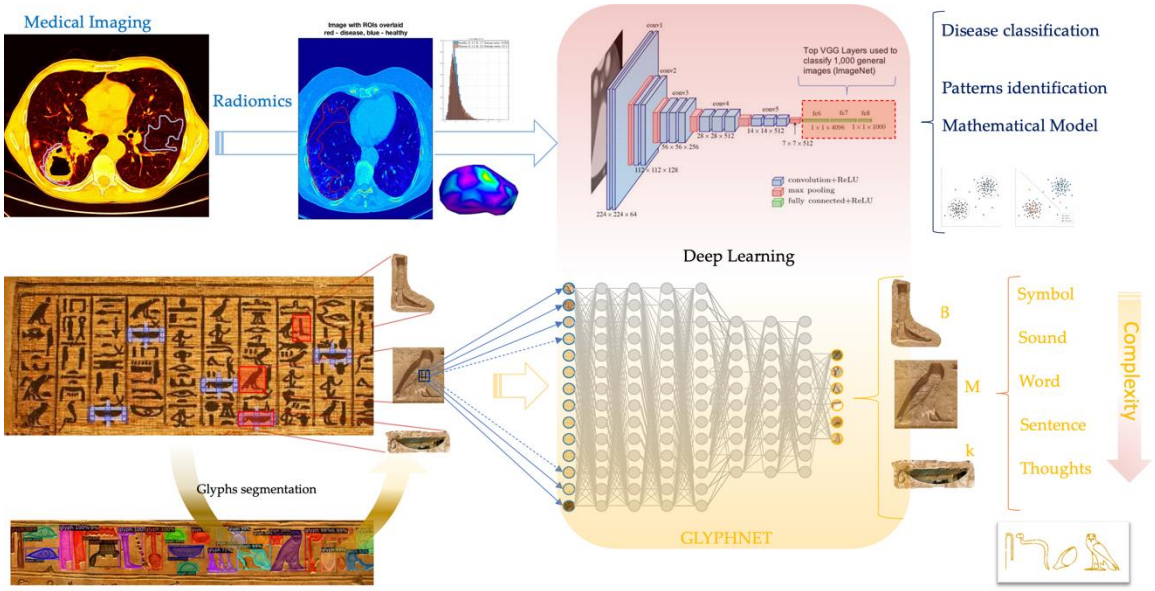


Figure 3.1: A similarity between Convolutional Neural Networks application in the field of Deep Radiomics (i.e. clinical imaging) and in the field of ancient Egyptian writing system Hieroglyphs recognition and segmentation.

Chapter 4

DEEP CONVOLUTIONAL NEURAL NETWORKS APPLICATIONS TO HIEROGLYPHS CLASSIFICATION AND SEGMENTATION

4.1 – The idea

Starting from the experience using Convolutional Neural Networks in Radiomics, we moved on to an (apparently) different problem.
We decided to explore the ability of CNNs to segment and classify ancient Egyptian hieroglyphs.

Figure 4.1: A sketch showing our seminal idea to apply CNN to the recognition of ancient Egyptian Hieroglyphs. We started developing Glyphnet, our first CNN to classify image with just one hieroglyph inside. Thanks to G. Guarducci from CAMNES (Center for Ancient Mediterranean and Near Eastern Studies – Florence (Italy)) for this graphic.

4.1.2 – A complex task

At the beginning we didn't know the complexity of the problem at hand.
Moreover, we had to face the problem to find datasets for training.
So, we split the problem into two steps:

1. Classification of a picture with a single hieroglyph;

2. Segmentation and classification of hieroglyphs in an image with multiple instances.

The first task was obtained thanks to Glyphnet, a CNN we developed starting from very famous CNN architectures such as ResNet, Inception-v3 and Xception.
The second task was achieved thanks to the Detectron2 framework.
All these steps were obtained thanks to the thesis work in engineering of 4 students: Marco Loschiavo, who developed Glyphnet; Tommaso Guidi, Matteo Forasassi and Lorenzo Python, who trained and tested the Detectron2 framework in this context.

4.1.3 – Classification and Segmentation tasks

Before discussing the results, it is worth to give a definition of what we mean by classification and segmentation tasks when we refer to an image.

- Classification Task: prediction of the class to which the image belongs out of many different categories/classes;
- Classification and Localization: in addition to the previous task, here the CNN has to show exactly where the object is in the image;
- Object Detection task: the difference from the Classification task is that now we have multiple classes that exist simultaneously in the image and the CNN has to classify and localize each of these objects;
- Instance Segmentation: the CNN identifies the exact contour of the object.

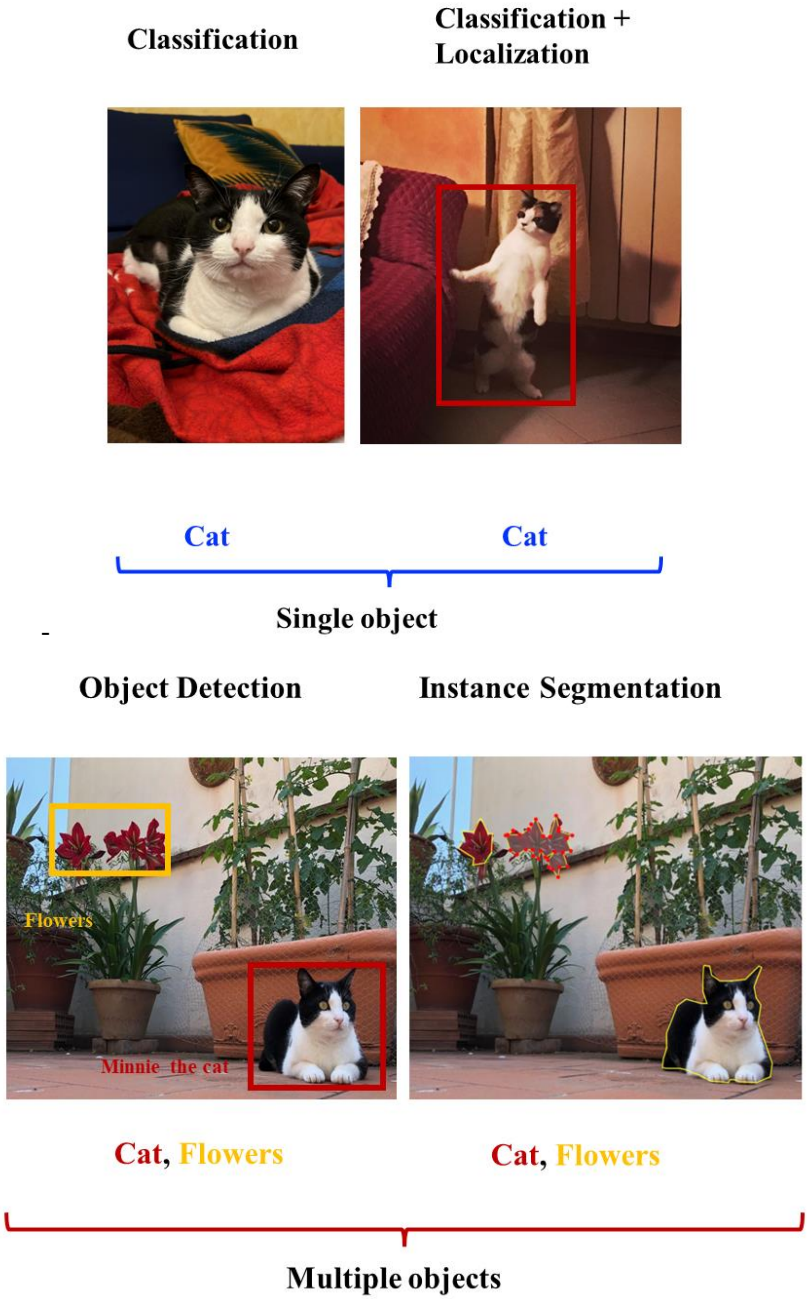


Figure 4.2: Example of image Classification and Segmentation tasks. The top image shows the Classification + Localization of a single object. The bottom image represents the segmentation task of multiple objects.

4.2 - Glyphnet

The first CNN we developed in order to face the problem of ancient Egyptian Classification of image with single hieroglyphs classification was Glyphnet [4], which is a modified version of Xception [39].

Glyphnet was trained in a specific created dataset and reaches 97.6% of accuracy in classification. The main limitations are that Glyphnet works with grayscale images containing just one single hieroglyph inside, which is not suitable in real applications.[1]

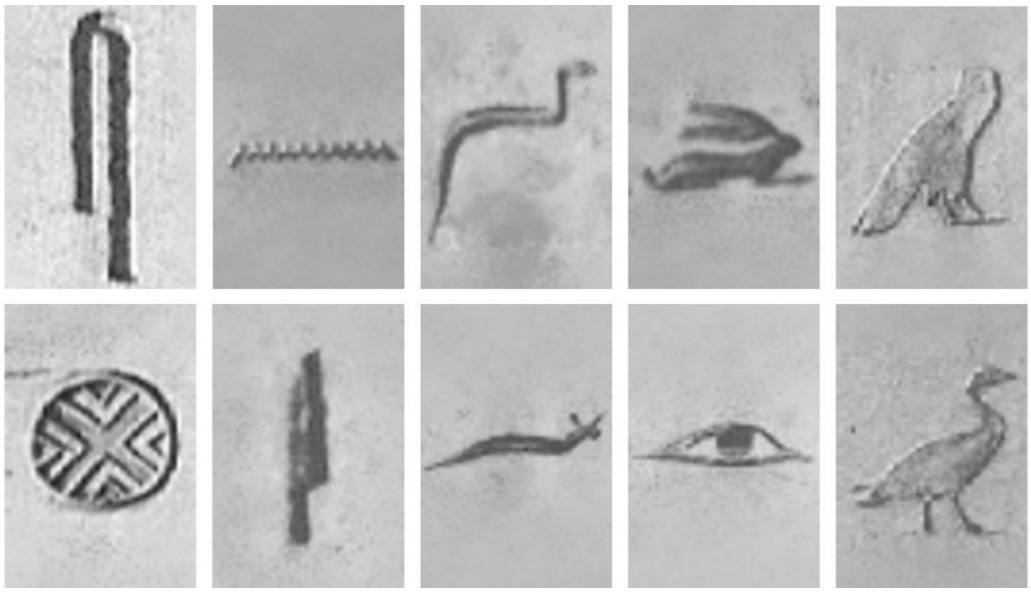


Figure 4.3: Examples of ancient Egyptian hieroglyphs used for Glyphnet training and testing. Images reprinted from the Unas pyramid dataset (available here: https://github.com/morrisfranken/glyphreader).

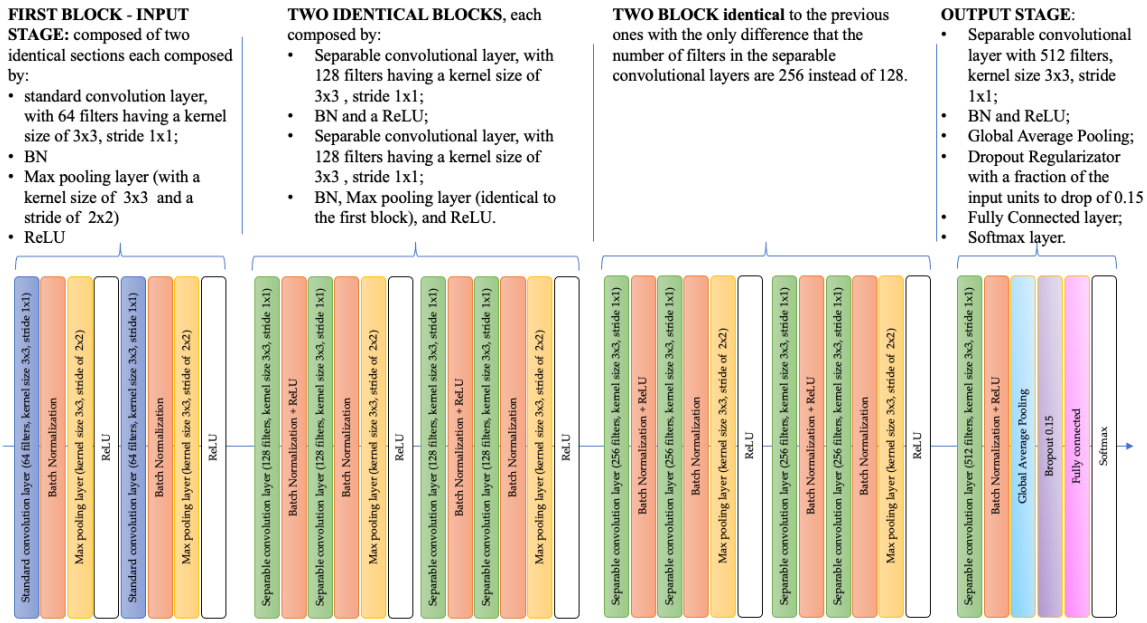


Figure 4.4: Glyphnet structure.

[1] Glyphnet can be downloaded here: https://github.com/GAIA-IFAC-CNR/Glyphnet

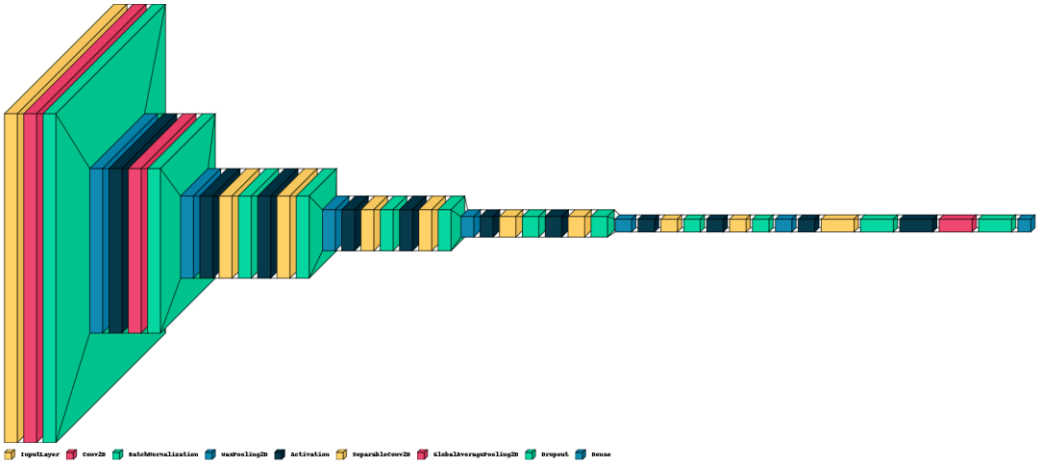


Figure 4.5: Glyphnet structure in 3D using VisualKeras[2].

4.3 – Detectron2

For the challenge of segmenting multiple instances in an image, there are numerous CNNs at our disposal [40]. In this investigation, we employed Detectron2, a framework created by the Facebook AI Research Group (FAIR) that is based on Mask R-CNN [41].

Region based CNN (R-CNN), is a family of Convolutional Neural Networks that tries to extend classical detection and recognition tasks to the case of images with multiple instances of objects of interest [42], [43].

The system is essentially comprised of two parts.

The Region Proposal Network (RPN), the initial module, is in charge of producing category-independent region suggestions, or potential regions of the input image that contain an object of interest. These areas are additionally known as Regions of Interest (RoI). Each ROI has an *objectness score* that estimates the likelihood that an area contains an object from one of the classes of interest compared to background.

The proposed regions are categorized in the second module. The two modules rely on a single deep CNN (the backbone), which is responsible for creating the feature maps, sharing some convolutional layers to streamline calculations. Specifically, we utilized a model that was pre-trained on the COCO dataset [44] and that was fine-tuned over the dataset of segmented hieroglyphs (explained in the following), thereby utilizing the transfer learning paradigm. In this study, we chose the well-known ResNet [45] as the backbone network.

A set of rectangular bounding boxes with a label for the expected class and presumably one for each instance of an object belonging to one of the classes of interest make up the segmentation network's output. In addition to producing a binary mask for each RoI in a parallel branch to the classification task, Mask R-CNN also creates a binary mask that, in a perfect world, should be perfectly superimposed onto the object included in the bounding box. It is important to note that this binary mask—which represents the segmentation task's real output—is produced independently from both bounding-box regression and classification mask.

[2] https://github.com/paulgavrikov/visualkeras

Figure 4.6: VV Image annotator example of hieroglyphs segmentation.

4.3.1 – The training dataset for Detectron2

The availability of a sufficient dataset, having a variety of various Egyptian hieroglyphs as large as feasible with a segmentation mask attached to each of them, is necessary for training the mask R-CNN. There are many photographs available online, for instance in the collections of museums like the "Egyptian Museum in Turin[3]" (Italy) or "The Met[4]" in New York (US), but sadly, virtually all these images are not segmented.

Additionally, because most photographs have varied dimensions, resolutions, points of view, etc., they cannot be used for training. The creation of a dataset for training purposes thus requires precise selection and preparation of the images, just like in many machine learning problems.

In this study, we created our dataset using a variety of resources. A portion of the photos originate from the dataset used by the creators of "GlyphReader[5]", a hieroglyph classifier that analyzes images with just one glyph.

Each image in this collection represents one of the stelae found inside the Egyptian Pyramid of Unas and is covered in numerous hieroglyphs. The number of images is small (ten), and more importantly for their use in a training process, they are quite similar to one another, meaning that they share the same stelae and support. As a result, they lack the "heterogeneity" required to make the network learn the generic features crucial for segmentation.

Because of the above-mentioned web resources, additional photos of various writing styles and supports were included to the dataset.

The segmentation masks for all the hieroglyphs found in the photos were then created by manually segmenting and labeling each instance in the training and validation sets using the "VGG Image Annotator" tool [46].

With VGG, images can have bounding-boxes, circles, or, in this instance, polygonal masks added to them.

The Detectron2 framework can access the annotations created by VGG in the *.json* file format.

A full description of the dataset creation process can be found in [6].

It's important to remember that there are more than 700 different ideograms used to represent hieroglyphs. Using a training dataset that is densely populated with the majority of hieroglyph classes helps the segmentation process.

[3] https://www.museoegizio.it
[4] https://www.metmuseum.org
[5] https://github.com/morrisfranken/glyphreader

In our case, it is worth noting that the glyph classes are not fully represented and that there are occasionally only a few instances of each class.

This phenomenon may be a clear restriction on our model's ability to generalize. Despite this, we shall demonstrate in the experimental results section that the network is also capable of segmenting glyphs that weren't included in the training dataset.

4.4 – Some results using the Detectron2

Here some examples of segmentation using Detectron2 are shown, varying the following training hyperparameters:

- the number of iterations
- threshold: value used to filter out low-scored bounding boxes predicted by the Fast R-CNN component of the model during inference/test time; basically, any prediction with a confidence score above the threshold value is kept, and the remaining are discarded

This analysis was performed by Tommaso Guidi as part of his thesis work.

The tests were carried out using a number of iterations equal to 300, 500, 1000, 3000, with different threshold values such as 0.5 and 0.7. Below is a comparison of the results obtained. All these tests were performed leveraging on Transfer Learning.

The images show how the number of segmented instances increases as the threshold value set decreases and as the number of iterations performed increases. It should be noted that, already at 300 iterations, lowering the threshold to 50% allows a greater number of instances to be highlighted while maintaining a high quality in the generation of the mask.

We observe how the performance improvement gained by increasing the number of iterations is staggering.

At the end of these results based on Transfer Learning, we show the trial of training the network from scratch, therefore without using the model weights obtained on the COCO Dataset and without transfer learning.

Figure 4.7: Original image.

Figure 4.8: Results with 300 iterations and a threshold of 0.7.

Figure 4.9: A zoom on a detail of Figure 4.8.

Figure 4.10: Results with 300 iterations and a threshold of 0.5.

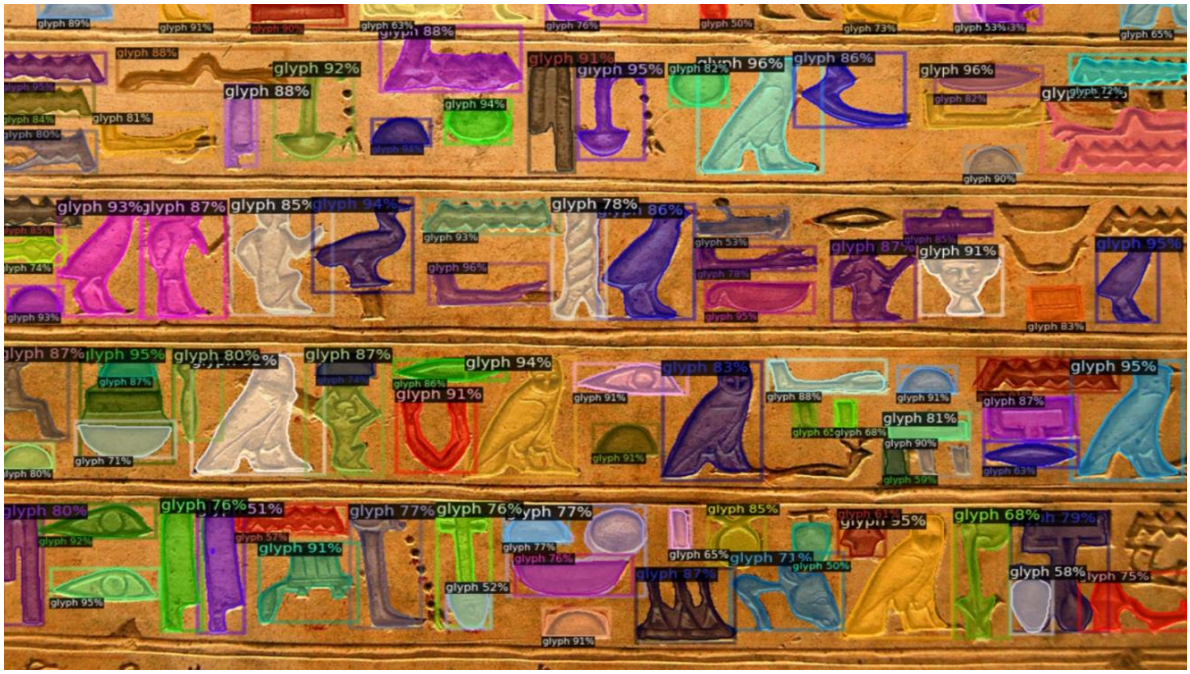


Figure 4.11: Results with 500 iterations and a threshold of 0.5.

Figure 4.12: Zoom of details of Figure 4.11.

Figure 4.13: Results with 1000 iterations and a threshold of 0.7.

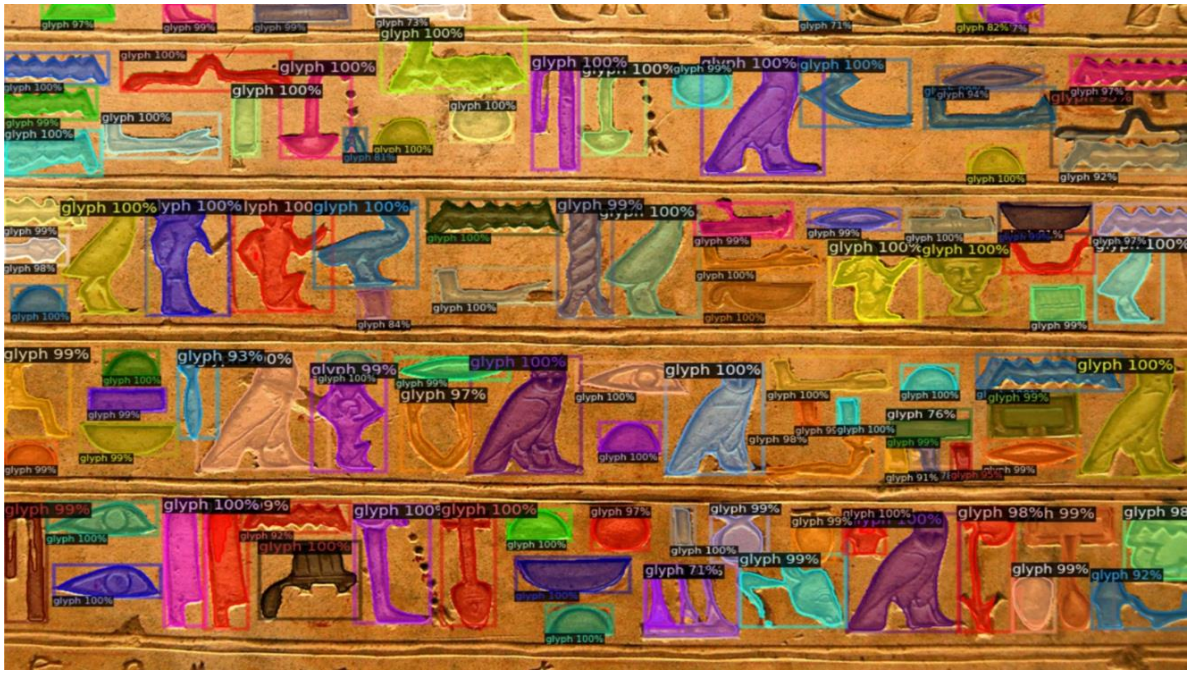


Figure 4.14: Results with 3000 iterations and a threshold of 0.7.

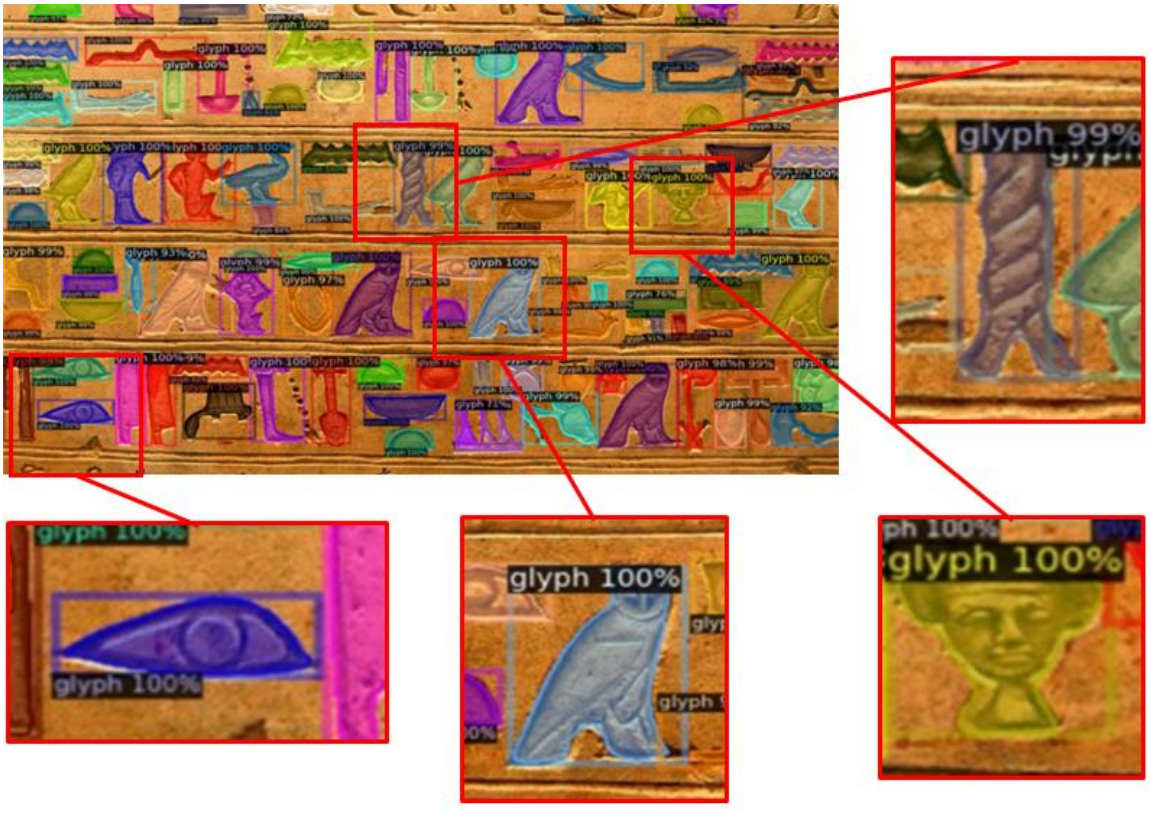


Figure 4.15: Zoom of details of Figure 4.14.

Figure 4.16: Results with 3000 iterations and a threshold of 0.1.

Figure 4.17: Results without Transfer Learning. The CNN was trained from scratch with 3000 iterations and a threshold of 0.7.

Figure 4.18: Results with 500 iterations and a threshold of 0.1.

Figure 4.19: Results for a particular hieroglyph varying the number of iterations (300, 500, 1000, 3000).

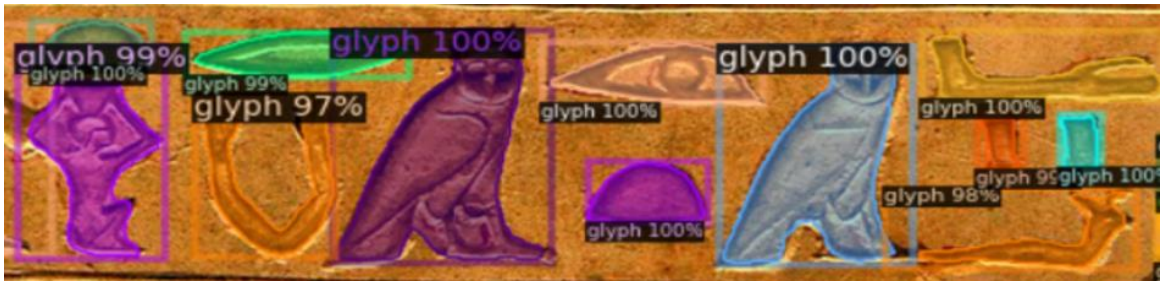


Figure 4.20: A zoom in a particular part of the results for 3000 iterations and a threshold of 0.7.

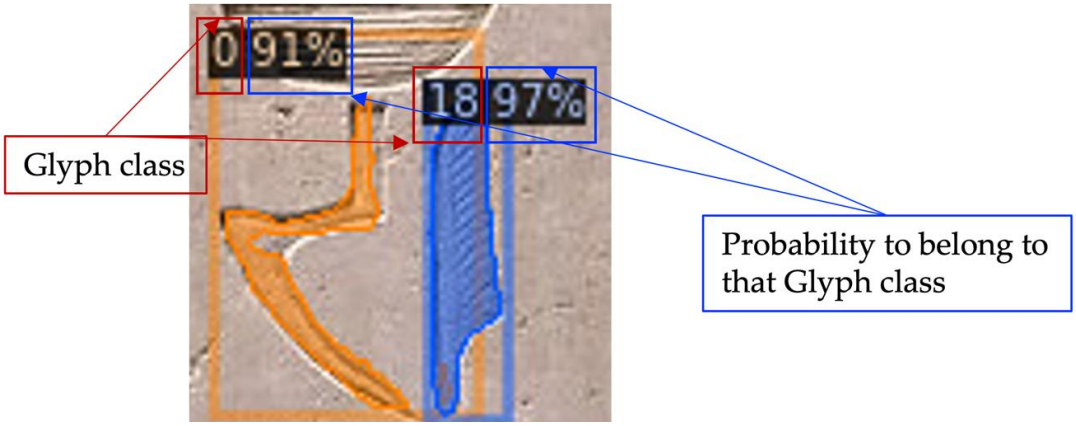


Figure 4.21: Zoom on two glyphs to illustrate the meaning of the numbers around the symbol.

4.5 – A general discussion on the results using the Detectron2

As the previous and the following results show, thanks to Detectron2 it is possible to obtain some very good segmentation. However, our test showed that it is also possible to obtain bad results, with very poor segmentation.
Test performance apparently depends on different image factors such as:

- Colors
- Contrast
- Dimensions of hieroglyphs
- Resolution of the image
- Support

This behavior must be explored in detail and we are working on this issue.

Probably one of the most important limitations of our study was the dimension of the dataset, which was quite small.

With a bigger and more comprehensive dataset we are sure that the generalization performance of Detectron2 can greatly improve.

A bigger dataset means giving to the CNN a broader view of all the variations in data that can be found, such as the kind of supports (papyrus, wood, stone, etc.).

In the following chapters some results obtained on real artifacts belonging to the collections of different museums will be shown. The aim is to show all the results obtained, very good and very bad, highlighting the strength and the limitations of our study.

A general comment is related to the dimension of the hieroglyphs and other figures in the picture; as a matter of fact, pictures where there are hieroglyphs of different dimensions along with figures, seems to create some problems to the segmentation model. We discovered that working with

patches containing hieroglyphs with comparable dimensions may results in better outcomes. Furthermore, when working with artifacts dating back thousands of years, the state of conservation may become critical, with many hieroglyphs potentially damaged and, subsequently, impacting the performances of the segmentation model. We are working on this problem integrating different imaging techniques and these results will be the object of next publication.

Chapter 5

RESULTS ON ARTIFACTS FROM THE EGYPTIAN MUSEUM OF TURIN

5.1 – The source of data

In this chapter we report the results regarding the segmentation task using Detectron2.
Data come from the online collection of the Egyptian Museum of Turin, which thanks to an open and broad view of science has an online database of pictures of many of its artifacts.
Citing from the web page of the Museum:

«*Research and creating an international network are the areas in which the Museo Egizio continues to invest, in order to grow and to become an established and world-renowned institution: this approach is not only addressed to the scientific community, but also to all those who recognize in the dynamism of the institution a way to open up to a broad and heterogeneous audience*».

All these images can be accessed in Creative Commons and with a resolution more than satisfactory for our applications.

Please note that hereafter for some images we reported the original description of the artifacts in "*italics*", reprinted from the website of the museums.

5.2 – Segmentation results

In this section the original pictures along with some cropping and the corresponding segmentation results are reported for different artifacts. For every artifact the description from the web page of the Museum is reported (in *italics*) along with some other information.

5.2.1 - The papyrus from the "Book of the Dead of Nebhepet, scribe of the necropolis" [1]

Figure 5.1: Picture of the papyrus from the "Book of the Dead of Nebhepet, scribe of the necropolis", cat. 1768:

This Book of the Dead belongs to Nebhepet, a son of Butehamon. Although shortened in its text, it is richly decorated with many scenes, and constitutes a typical Book of the Dead of the 21th Dynasty. Especially remarkable are the three scenes of rural life, in which the deceased is represented plowing or harvesting wheat and linen, depending on the season. In a sort of allegorical picture, Nebhepet is juxtaposed to Osiris in his various manifestations. The first is the vegetating Osiris, who is linked to the maturation of the grain under sunlight. The second, the lunar form, is associated with the growth of linen under the rays of the moon.

[1] Inv. no. : Cat. 1768
Material: Cyperus papyrus, ink
Dimensions: 22 x 282 cm
Date: 1076–944 BCE
Period: Third Intermediate Period
Dynasty: Twenty-first Dynasty
Provenance: Thebes

Figure 5.2: Cat. 1768. Examples of cropped areas and segmentation results.

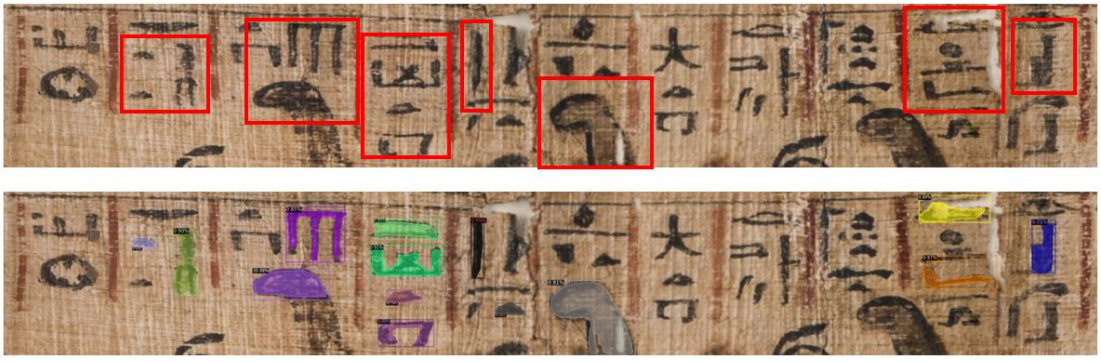


Figure 5.3: Cat. 1768. Examples of cropped areas and segmentation results.

Figure 5.4: Cat. 1768. Example of cropped area and segmentation results.

Figure 5.5: Cat. 1768. Example of cropped area and segmentation results.

Figure 5.6: Cat. 1768. Examples of cropped areas and segmentation results.

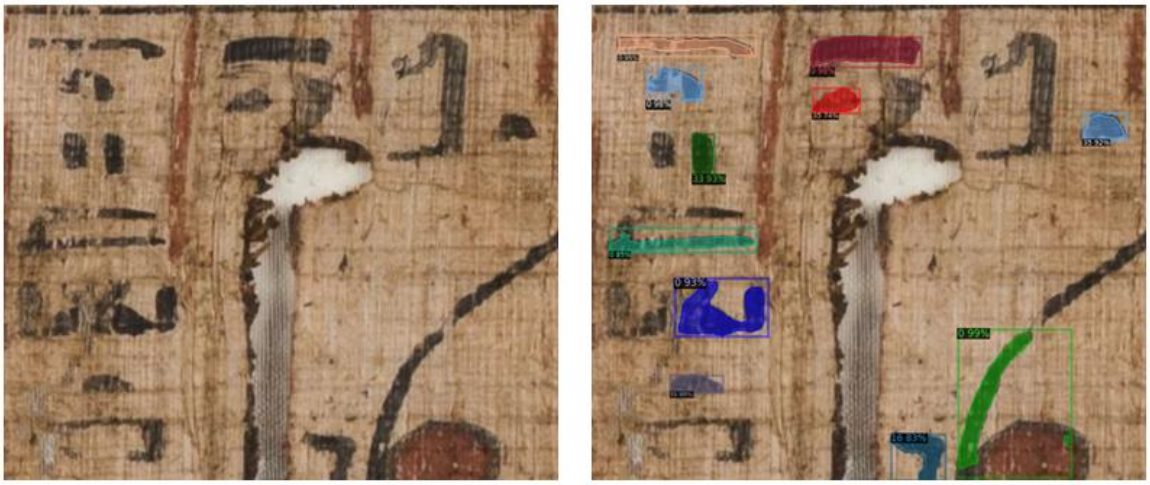


Figure 5.71: Cat. 1768. Examples of cropped areas and segmentation results.

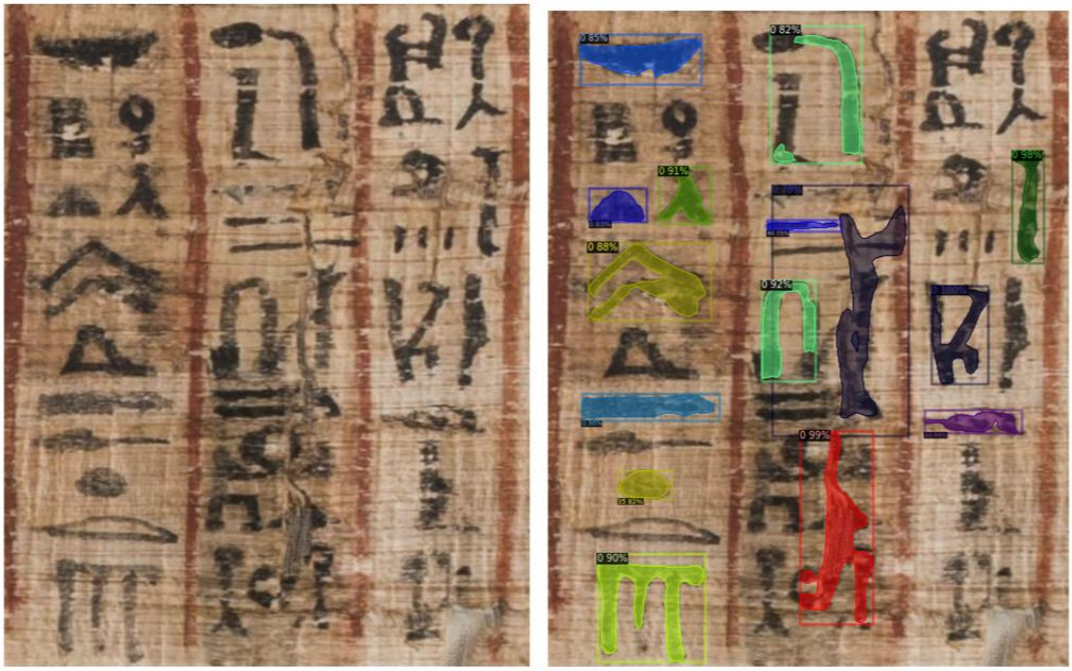


Figure 5.82: Cat. 1768. Examples of cropped areas and segmentation results.

Figure 5.93: Cat. 1768. Examples of cropped areas and segmentation results.

Figure 5.104: Cat. 1768. Examples of cropped areas and segmentation results.

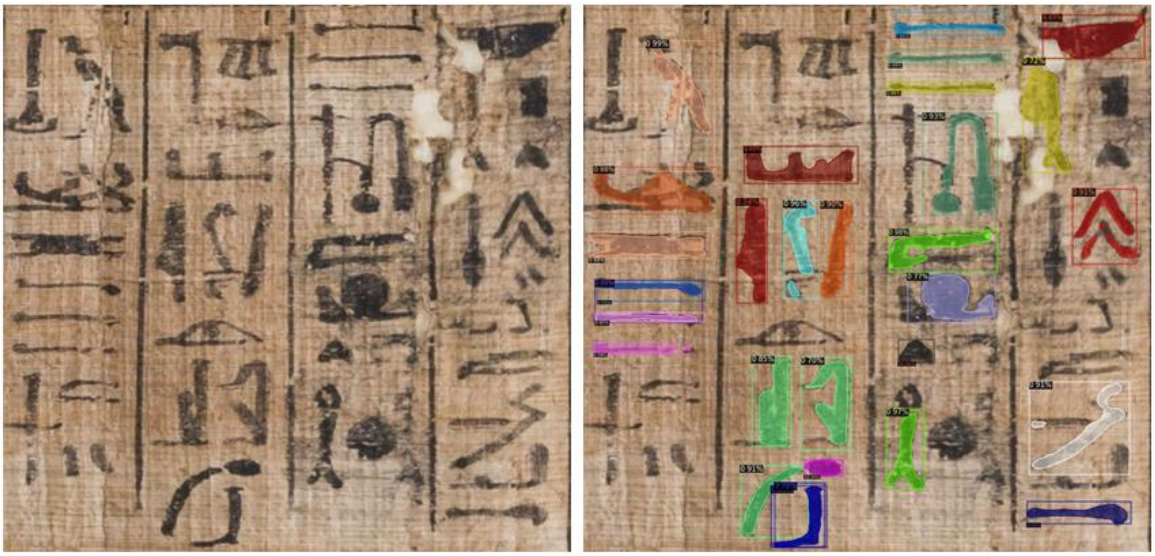


Figure 5.115: Cat. 1768. Examples of cropped areas and segmentation results.

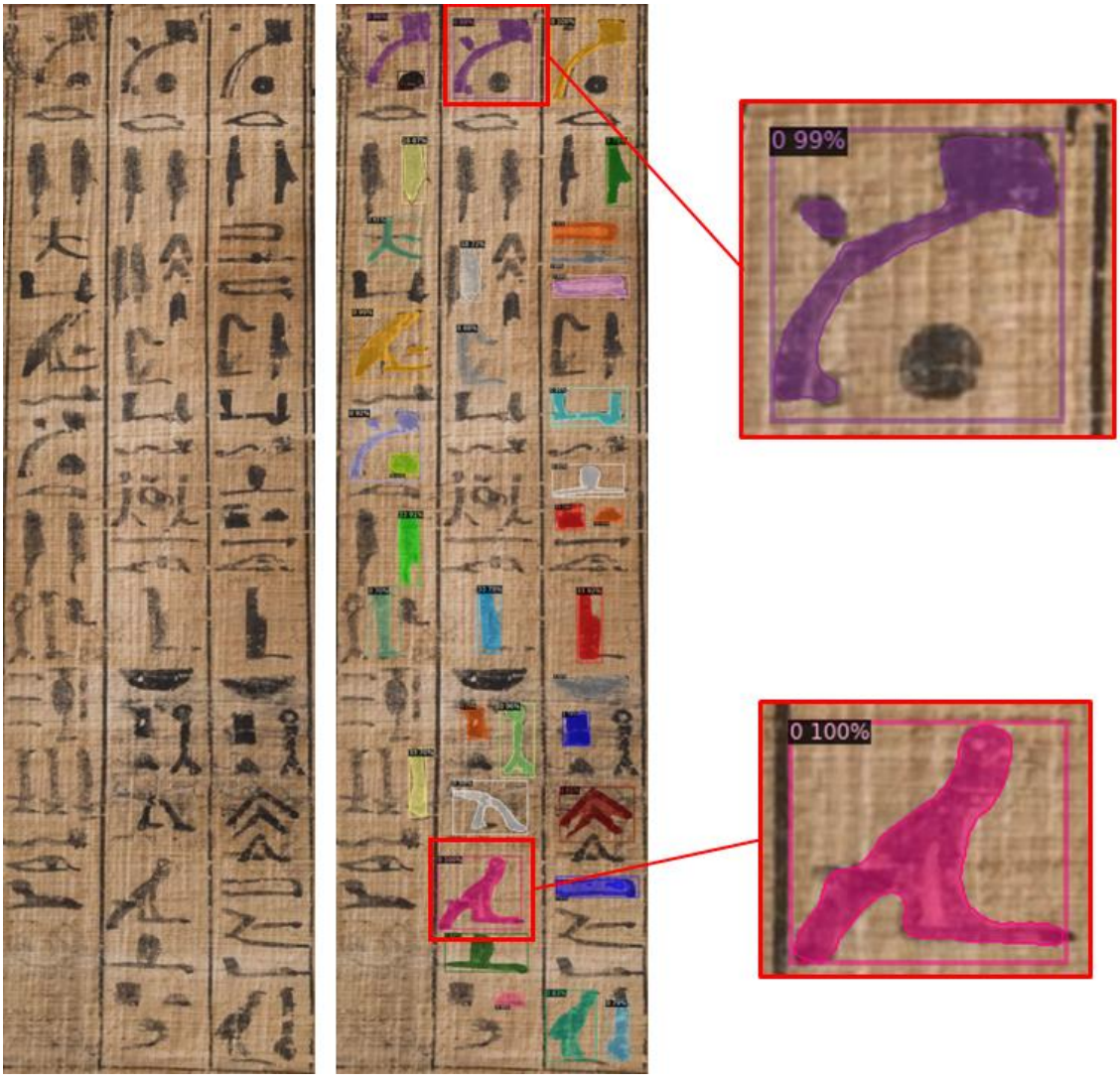


Figure 5.126: Cat. 1768. Examples of cropped areas and segmentation results.

Figure 5.137: Cat. 1768. Examples of cropped areas and segmentation results.

Figure 5.148: Cat. 1768. Examples of cropped areas and segmentation results.

Figure 5.159: Cat. 1768. Examples of cropped areas and segmentation results.

Figure 5.1610: Cat. 1768. Examples of cropped areas and segmentation results.

Figure 5.1711: Cat. 1768. Examples of cropped areas and segmentation results.

Figure 5.1812: Cat. 1768. Examples of cropped areas and segmentation results.

Figure 5.1913: Cat. 1768. Examples of cropped areas and segmentation results.

Figure 5.2014: Cat. 1768. Examples of cropped areas and segmentation results.

5.2.2 - Funerary papyrus of Djehutymes

Figure 5.2115: Funerary papyrus of Djehutymes, cat. 1781[2]:

To the right is depicted the solar boat pulled by four dogs or jackals. This differs from most of the canonical representations, in which they are human beings. In the lower register, two falcon-headed capture whoever would threaten the sunrise. To the left, two pairs of cobras are workshipping the hieroglyph of the horizon, symbol of the sun as it rises. In the upper register, the seven seated characters with cobra heads represent darkness.

Figure 5.22: Cat. 1781. Examples of cropped areas and segmentation results.

[2] Inv. no. : Cat. 1781
Material: Cyperus papyrus, ink
Dimensions: 23 x 104 cm
Date: 1076–944 BCE
Period: Third Intermediate Period
Dynasty: Twenty-first Dynasty
Provenance: Thebes West

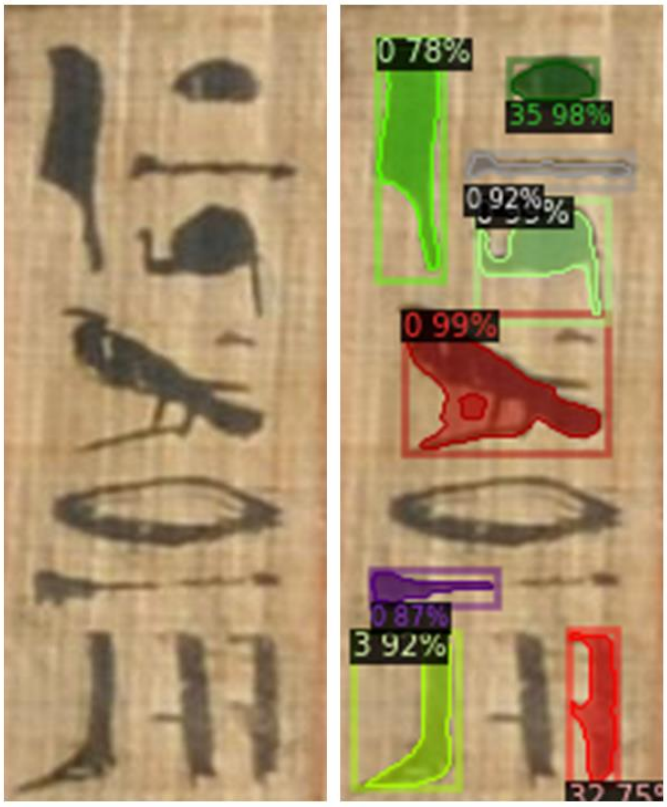


Figure 5.23: Cat. 1781. Examples of cropped areas and segmentation results.

5.2.3 - Mythological papyrus of Nesamun

Figure 5.23: Mythological papyrus of Nesamun. Cat. 1780[3]:

In this fragment of the Book of the Imy-Duat the eleventh hour is shown. It is entirely devoted to the preparations of the sun at its rising. The snake called "the winder of the world", which precede the boat, will permit the rejuvenation of the sun. in the lower register, the snake emanates a scorching fire that burns the enemies, which fall with their ba souls and shadows into pits full of fire. The snake and the goddesses armed with knives keep away whoever would threat the sunrise.

[3] Inv. no.: Cat. 1780
Material: Cyperus papyrus, ink
Dimensions:24 x 106 cm
Date:1076–944 BCE
Period: Third Intermediate Period
Dynasty: Twenty-first Dynasty
Provenance: Thebes

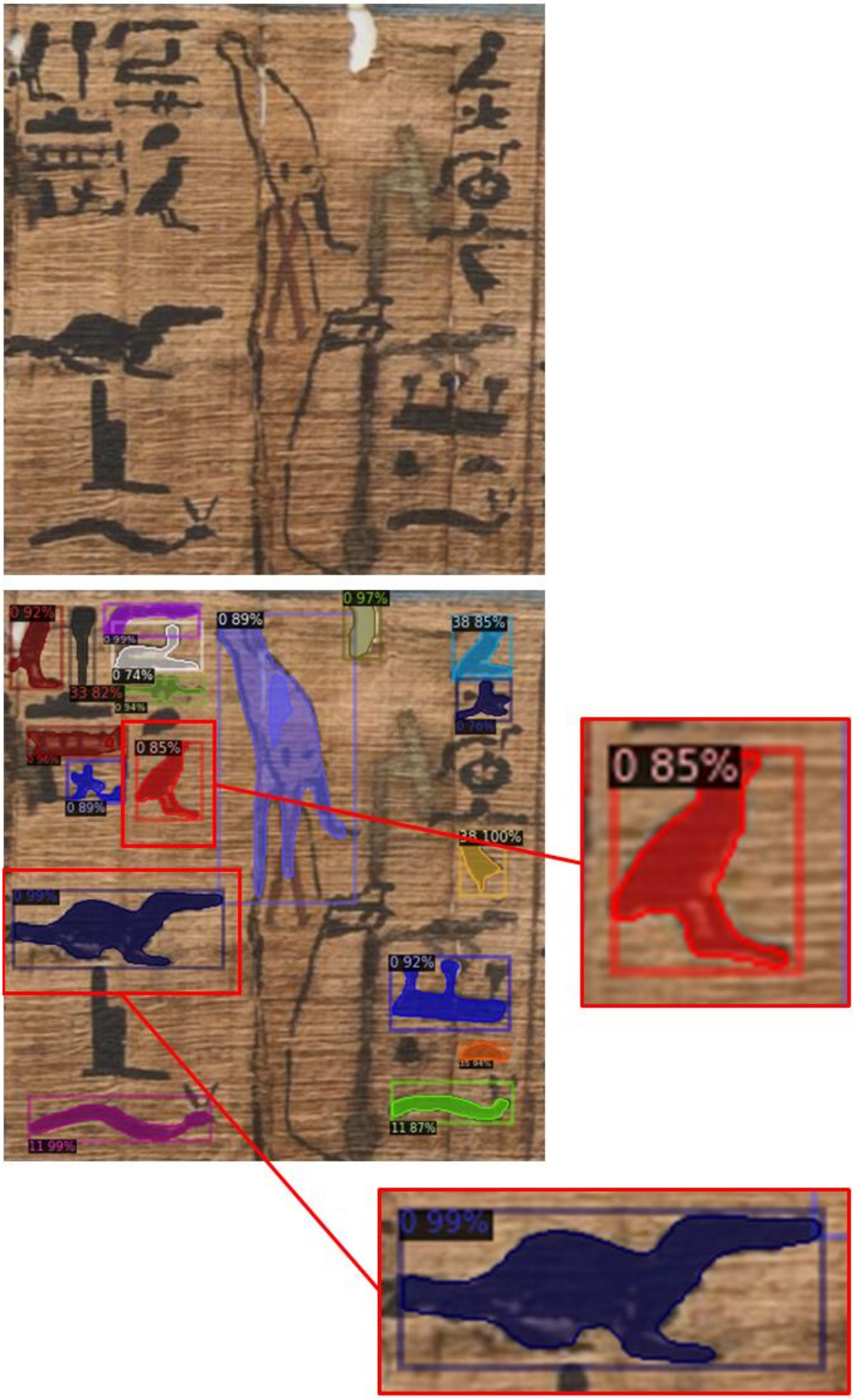


Figure 5.24: Cat. 1780. Examples of cropped areas and segmentation results.

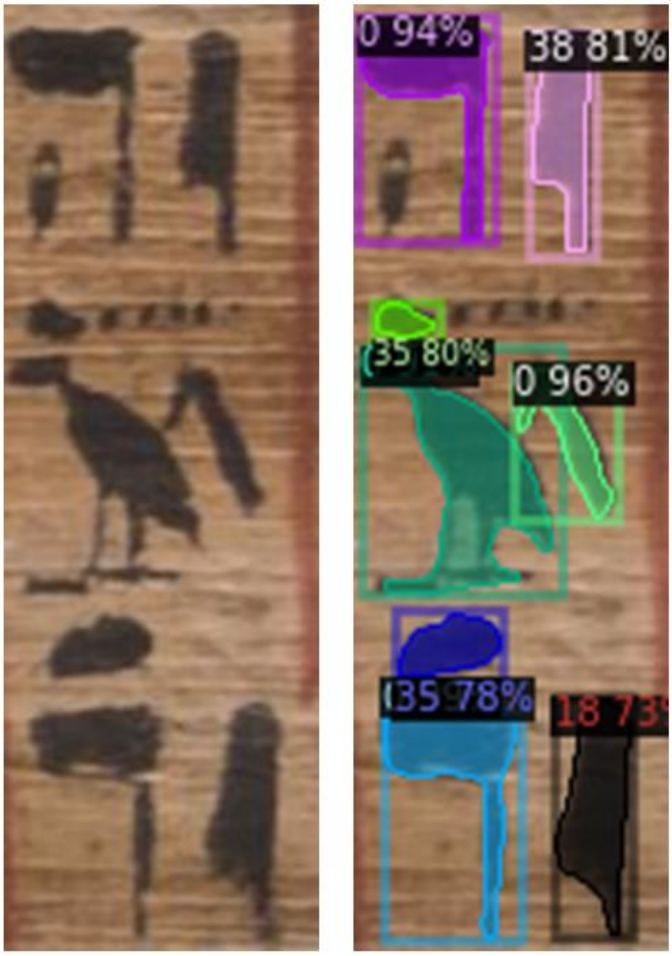


Figure 5.25: Cat. 1780. Examples of cropped areas and segmentation results.

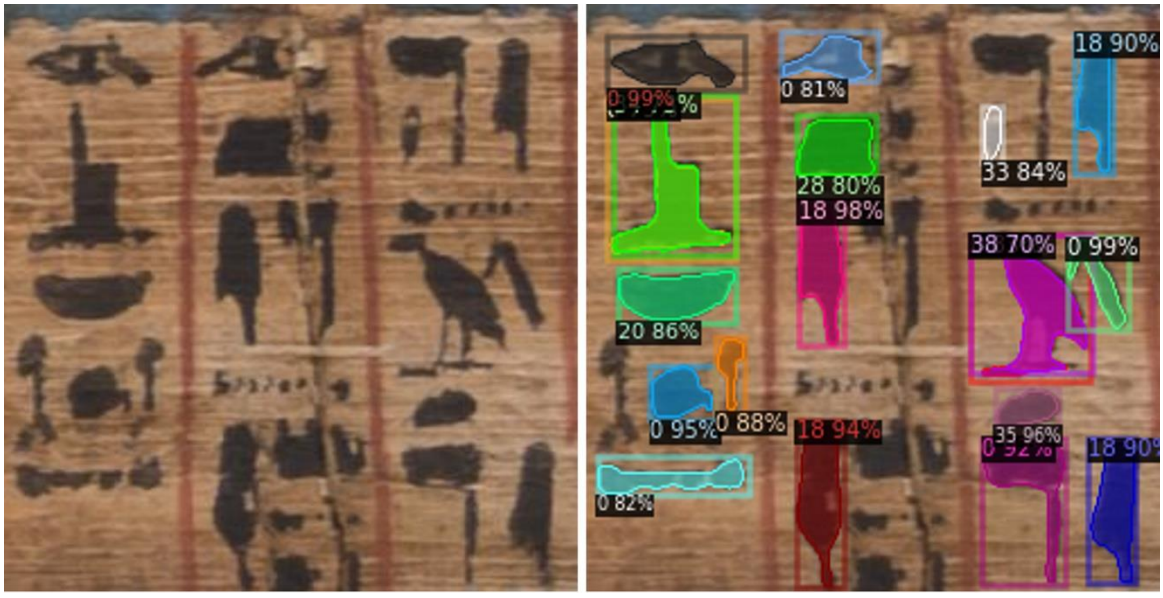


Figure 5.26: Cat. 1780. Examples of cropped areas and segmentation results.

5.2.4 - Stela of Kelutj nicknamed Neskhonsu, sistrum player of Amun-Re

Figure 5.27: Stela of Kelutj nicknamed Neskhonsu, sistrum player of Amun-Re. Cat. 1597[4].

[4] Inv. no. : Cat. 1597
Material: Wood, plaster, paint
Dimensions: 58.5 x 33.5 x 3 cm
Date: 332–30 BCE
Period: Hellenistic Period
Provenance: Unknown

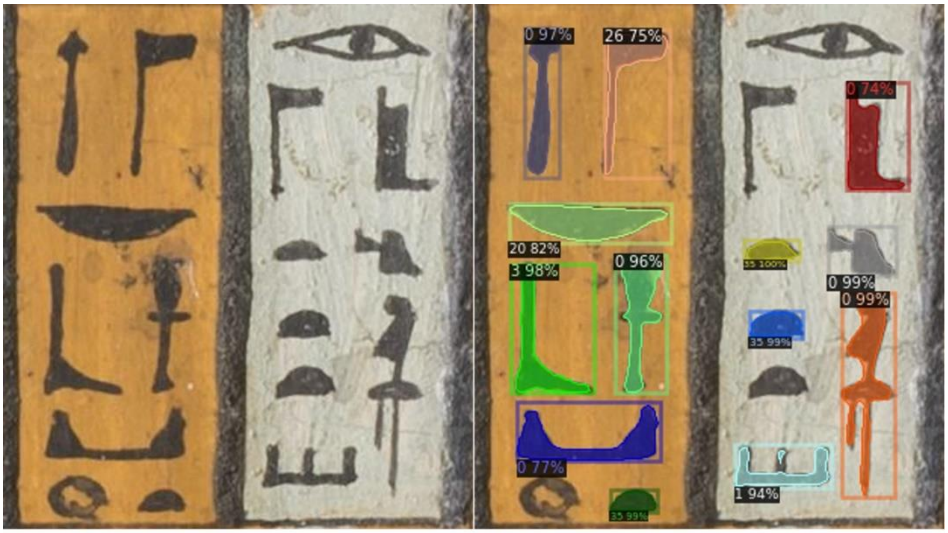


Figure 5.28: Cat. 1597. Example of cropped area and segmentation results.

Figure 5.29: Cat. 1597. Example of cropped area and segmentation results.

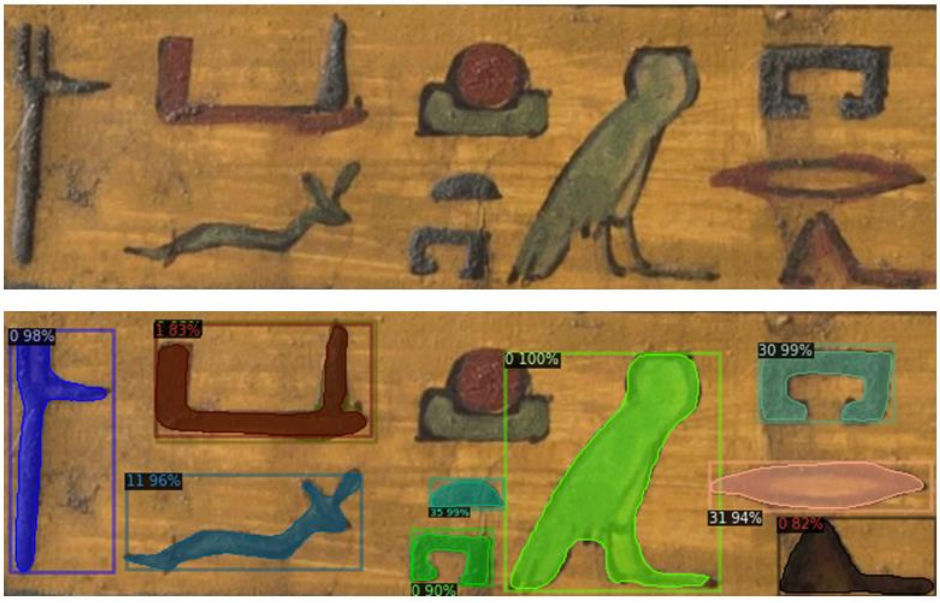


Figure 5.30: Cat. 1597. Example of cropped area and segmentation results.

Figure 5.31: Cat. 1597. Example of cropped area and segmentation results.

Figure 5.32: Cat. 1597. Example of cropped area and segmentation results.

5.2.5 - Stela of Sennefer, dedicated to Amenhotep I and Ahmose Nefertari, Tuthmosis I, Tuthmosis II and Amenhotep II

Figure 5.33: Stela of Sennefer. Cat. 1455[5].

[5] Inv. no. : Cat. 1455
Material: Stone / limestone
Dimensions: 55.5 x 37.5 x 3 cm
Date: 1292–1190 BCE
Period: New Kingdom
Dynasty: Nineteenth Dynasty
Provenance: Deir el-Medina (?)

Figure 5.34: Cat. 1455. Example of cropped area and segmentation results.

Figure 5.35: Cat. 1455. Example of cropped area and segmentation results.

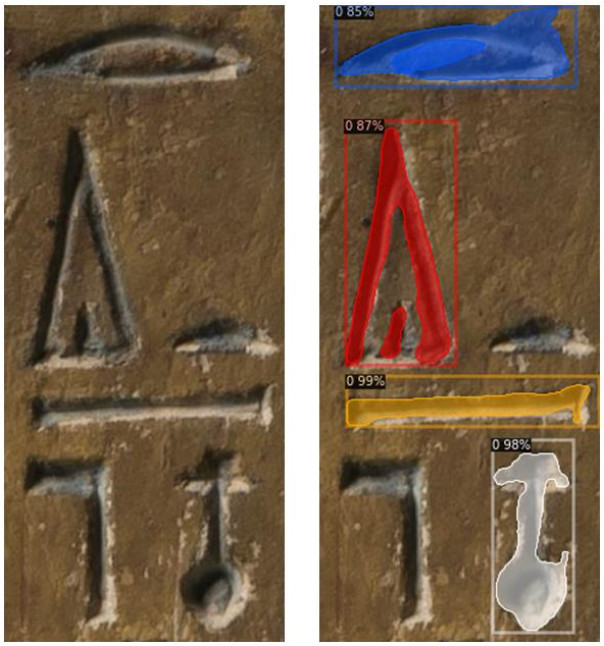


Figure 5.36: Cat. 1455. Example of cropped area and segmentation results.

Figure 5.37: Cat. 1455. Example of cropped area and segmentation results.

Chapter 6

ANALYSIS ON THE ARTIFACTS FROM THE METROPOLITAN MUSEUM OF NEW YORK

6.1 - Open Access at MET

The Metropolitan Museum of Art in New York gives the opportunity to explore their collection in Open Access, including about 500000 images of public-domain artworks, available for free and unrestricted use. More information can be found on the Museum web site: https://www.metmuseum.org/about-the-met/policies-and-documents/open-access.

The short description (in *italics*) before the results come from the original description of the artifact in the web page of the museum.

6.2 - The results on Egyptian artifacts

6.2.1 - Meketre papyrus

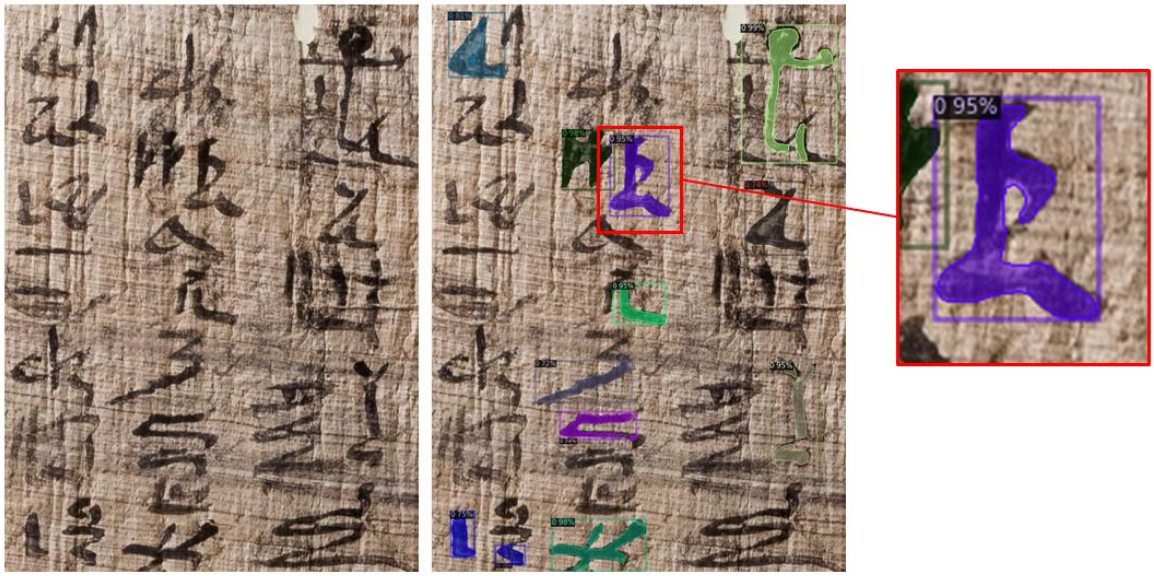


Figure 6.1: Meketre papyrus[1] segmentation results on a cropped area:

This letter was written by Netjeriuhem to an unnamed recipient concerning the sending of the writer's subordinate with various types of birds. It has been suggested that the letter was in fact written as an exercise, meant to familiarize the apprentice copying the text with common terms and formulae.

[1] Period: Middle Kingdom
Dynasty: Dynasty 12
Reign: reign of Senwosret I
Date: ca. 1981–1975 B.C.
Geography: From Egypt, Upper Egypt, Thebes, Southern Asasif, Tomb of Meketre (TT 280, MMA 1101), MMA excavations, 1919–20
Medium: Papyrus, ink
Dimensions: H. 26 cm (10 1/4 in.), W. 16 cm (6 5/16 in.)
Credit Line: Rogers Fund and Edward S. Harkness Gift, 1922
Accession Number: 22.3.524

6.2.2 - False door from the tomb of Metjetji

Figure 6.2: False door from the tomb of Metjetji[2].

Metjetji had himself depicted no fewer than eight times on his false door. In the offering scene just above the door recess, he sits in front of an offering table with a large stock of unguent jars arranged for his use in sunken panels on either side.

[2] Period: Old Kingdom
Dynasty: Dynasty 5–6
Reign: reign of Unis or slightly later
Date: ca. 2353–2323 B.C.
Geography: From Egypt, Memphite Region, Saqqara, Tomb of Metjetji
Medium: Limestone, paint traces
Dimensions: H. 109 cm (42 15/16 in.); W. 66.5 cm (26 3/16 in.)
Credit Line: Gift of Mr. and Mrs. J. J. Klejman, 1964
Accession Number: 64.100

The results showed here refer to three different cropping of areas belonging to the FALSE DOOR FROM THE TOMB OF METJETJI.

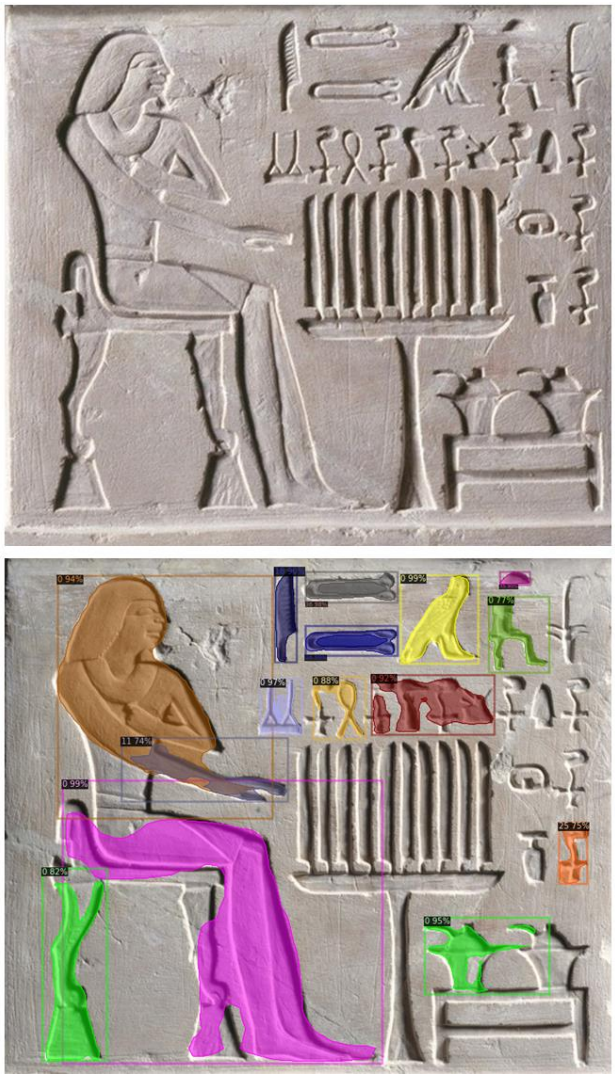


Figure 6.3: False door from the tomb of Metjetji segmentation results on a cropped area. Top: original image; Bottom: segmentation results.

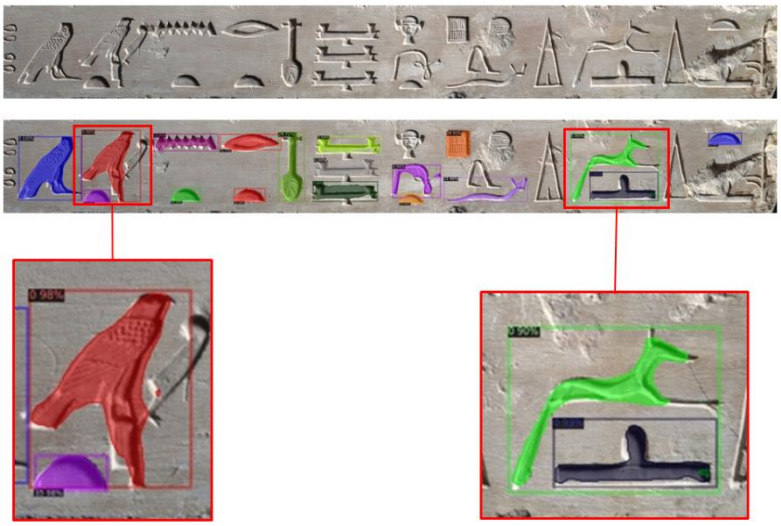


Figure 1.4: Second cropped area from the FALSE DOOR FROM THE TOMB OF METJETJI. Top: original image; Bottom: segmentation results.

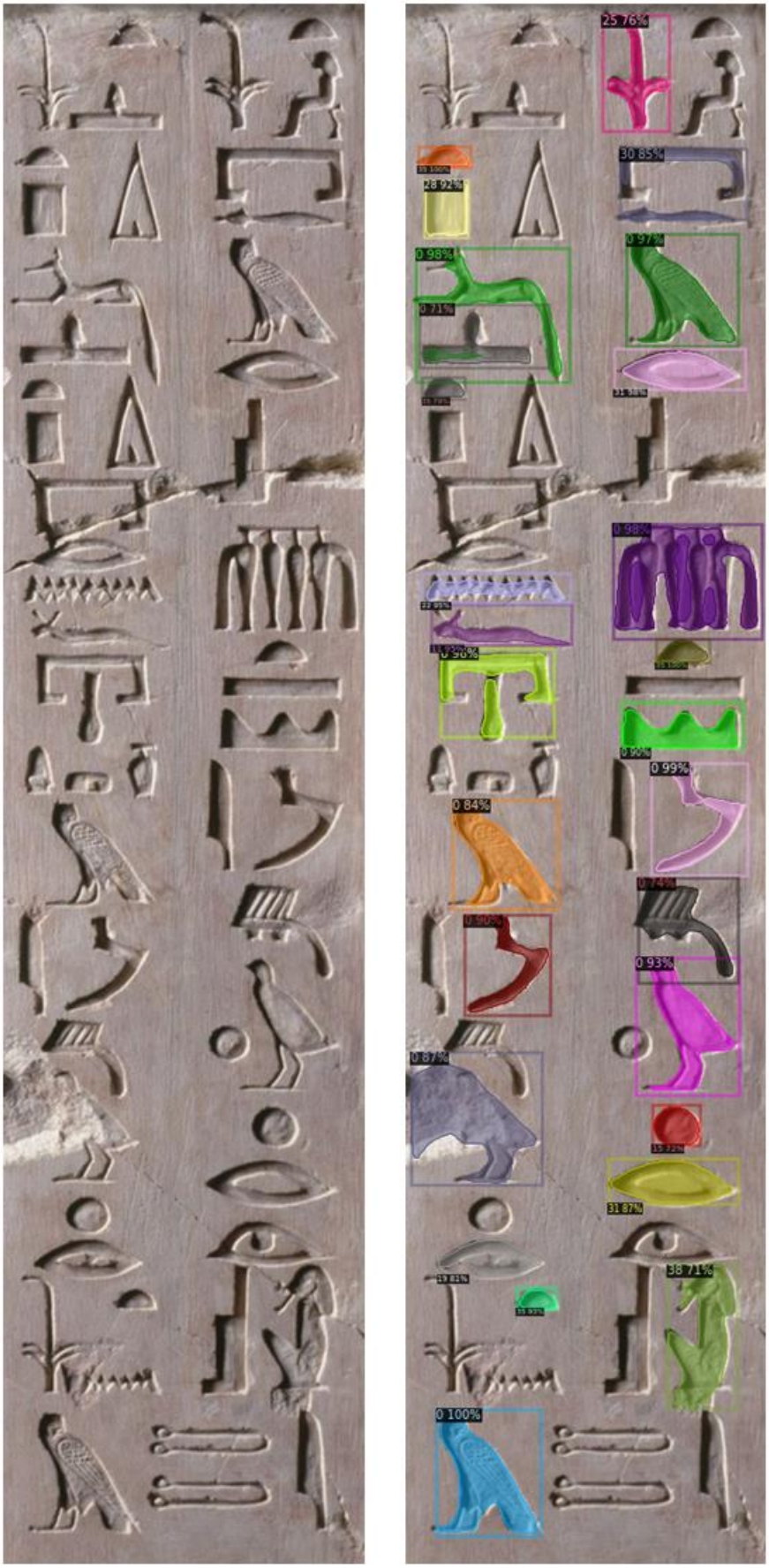


Figura 6.2: Third cropped area from the FALSE DOOR FROM THE TOMB OF METJETJI. Top: original image; Bottom: segmentation results.

6.2.3 - Painted wooden panel of Tabakenkhonsu

Figure 6.8: Painted wooden panel of Tabakenkhonsu[3]:

As part of the burial equipment, funerary stelae made a prayer for offerings for the maintenance of the deceased. In addition to forms of Osiris, Re-Harakhty and Atum—as the rising and setting sun and thus connected with continued life—are particularly favored focal gods. In contrast to stelae of the Third Intermediate Period, usually a more subdued coloring and a more standardized style are adopted in this period.

This stela depicts the woman Tabakenkhonsu led by the god Thoth being presented to Isis and Osiris beneath the body of the goddess Nut arching over the top of the stela. An offering of Geb is recorded. Tabakenkhonsu's father's name is damaged, but her mother was Tami.

[3] Period: Third Intermediate Period
Dynasty: Dynasty 25 (Kushite)
Date: ca. 680–670 B.C.
Geography: From Egypt, Upper Egypt, Thebes, Deir el-Bahri, Temple of Hatshepsut, Hathor Shrine, pit in hypostyle hall, Egypt Exploration Fund excavations, 1894–95
Medium: Wood, gesso, paint
Dimensions: H. 31.1 cm (12 1/4 in); W. 26.7 cm (10 1/2 in)
Credit Line: Gift of Egypt Exploration Fund, 1896
Accession Number: 96.4.4

Figure 6.9: First cropped area from the PAINTED WOODEN PANEL OF TABAKENKHONSU. Top: original image; Bottom: segmentation results.

Figure 6.10: Second cropped area from the PAINTED WOODEN PANEL OF TABAKENKHONSU. Top: original image; Bottom: segmentation results.

6.2.4 - Stela of the Gatekeeper Maati

Figure 6.11: Stela of the Gatekeeper Maati[4]:

Maati is shown seated in front of an offering table with a jar for a sacred oil in his left hand. The text on this masterpiece of early Middle Kingdom relief art contains references to other prominent figures of the time, including Maati's overseer, the treasurer Bebi, who later became a vizier, and an ancestor of the ruling family called Intef "the Great." The inscriptions demonstrate the close ties that bound together rulers and followers in Theban of the time.

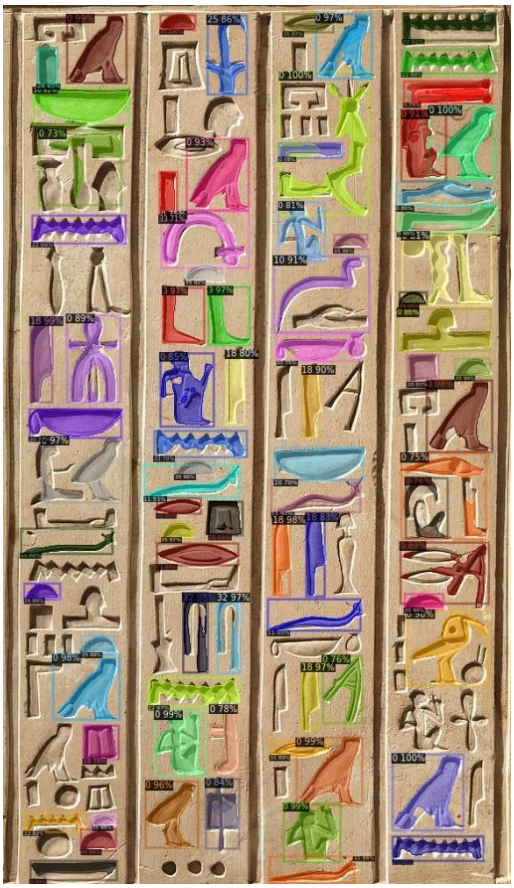


Figure 6.12: Segmentation results on the STELA OF THE GATEKEEPER MAATI. The results are obtained by analyzing the right part of the artifact.

[4] Period: First Intermediate Period
Dynasty: Dynasty 11
Reign: reign of Mentuhotep II, early
Date: ca. 2051–2030 B.C.
Geography: From Egypt, Upper Egypt, Thebes; Probably from Tarif
Medium: Limestone
Dimensions: L: 59 cm (23 1/4 in.), H: 36.3 cm (14 5/16 in.), D: 8 cm (3 1/8 in.)
Credit Line: Rogers Fund, 1914
Accession Number: 14.2.7

6.2.5 - Stela of King Intef II Wahankh

Figure 6.13: STELA OF KING INTEF II WAHANKH[5]:

Horus Wahankh Intef II was the third king of Dynasty 11, a period when Egypt was not unified under one ruler. Intef II engaged in numerous battles with the rival rulers of Heracleopolis (the capital of the northern part of the country) and eventually secured control over southern Egypt, from Abydos to Aswan. This laid the foundation for the reunification of the country under King Mentuhotep II (07.230.2; 26.3.29)

This stele was probably one of a number of small stela set up in the courtyard of his tomb at Thebes. The king presents a bowl of beer and a jug of milk to the god Re and the goddess Hathor. He is wearing a minutely pleated kilt, heavy broad collar and elaborately curled wig. The figure is well carved in very high raised relief. The text of the stele includes a request to Re for protection during the night and a hymn of praise to Hathor as well as a prayer for mortuary offerings.

[5] Period: First Intermediate Period
Dynasty: Dynasty 11
Reign: reign of Intef II
Date: ca. 2108–2059 B.C.
Geography: From Egypt, Upper Egypt, Thebes, El Tarif possibly; (none assigned
Medium: Limestone
Dimensions: H. 44.5 × W. 46 × Th. 11.5 cm, 29.8 kg (17 1/2 × 18 1/8 × 4 1/2 in., 65.8 lb.)
Credit Line: Rogers Fund, 1913
Accession Number: 13.182.3

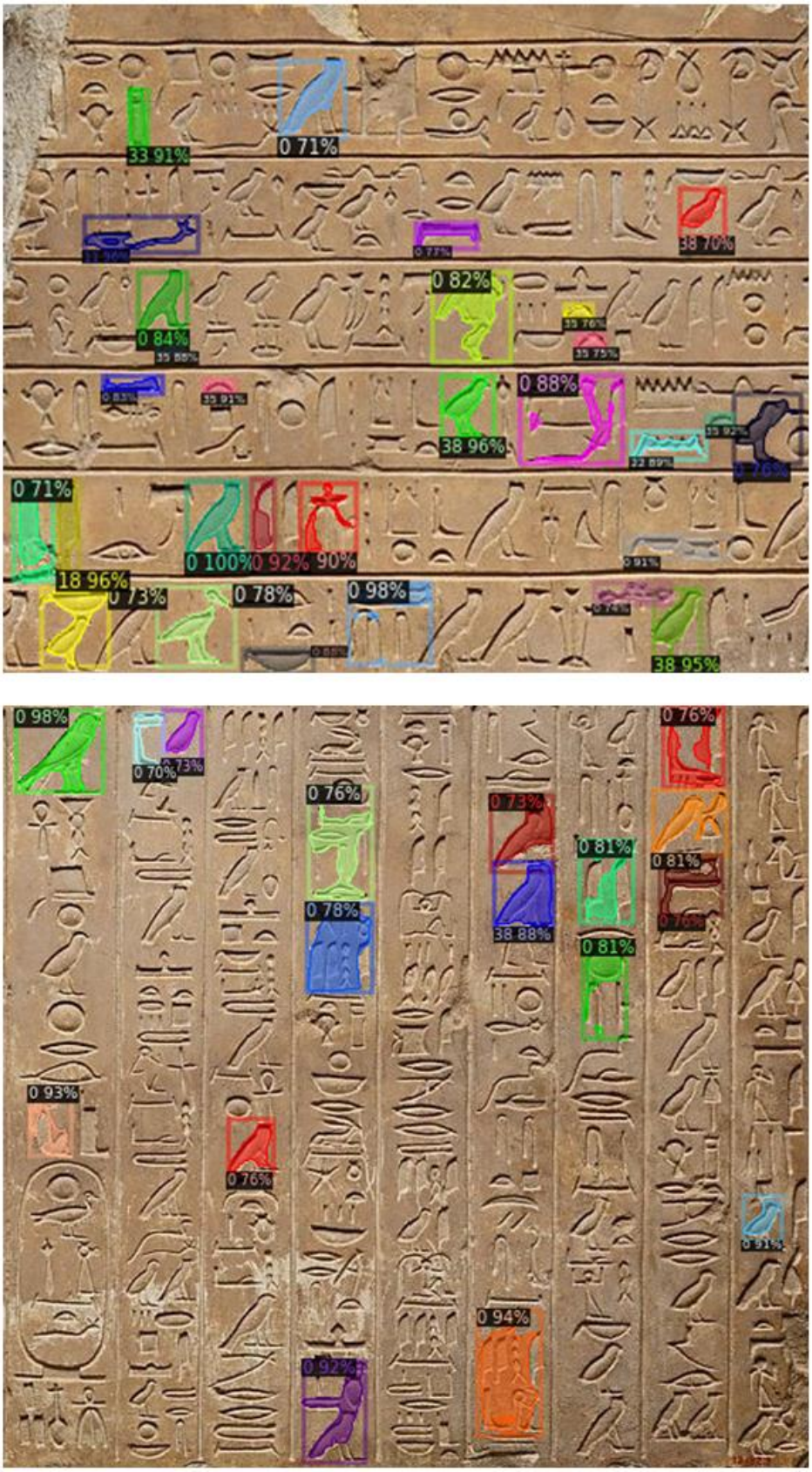


Figure 6.14: Segmentation results from the STELA OF KING INTEF II WAHANKH. Top: results from the upper part of the artifact. Bottom: results from the lower part of the artifact.

6.2.6 - Tomb Chapel of Raemkai: False Door on West Wall

Figure 6.153: TOMB CHAPEL OF RAEMKAI: FALSE DOOR ON WEST WALL[6]:

A False Door is a stylized representation of an actual door. The rectangular slot-like niche at the center (here filled with the name and titles of Raemkai) stands for the opening through a real doorway. This niche-like feature is flanked by inner doorjambs on which figures of the deceased appear in relief and is topped by a lower lintel. Below that lintel is a flattened version of the drum representing the rolled-up matting with which a real doorway would have been closed. Above that lintel is a rectangular slab with an empty recess at each side, a configuration that conveys the impression of a partially shuttered transom window. On the slab the tomb owner is depicted seated before an offering table. An upper inscribed lintel and two outer doorjambs--here with four relief images of the tomb owner--surround the whole. In front of the False Door, relatives and friends of the tomb owner deposited offerings, in the belief that this was a place where the dead would come forward to meet the living.

Text Changes on the False Door

[6] Period: Old Kingdom
Dynasty: Dynasty 5
Date: ca. 2446–2389 B.C.
Geography: From Egypt, Memphite Region, Saqqara, North of the Djoser pyramid complex, Mariette D3, Egyptian Antiquities Service/Quibell excavations, 1907–08
Medium: Limestone, paint
Credit Line: Rogers Fund, 1908
Accession Number: 08.201.1e

This tomb chapel was originally dedicated to the official Neferiretenes, and only later adapted for Raemkai. Changes are most extensive on the False Door. Traces of erased original text are still discernible on the lower lintel, enabling Egyptologists to decipher the titles "senior overseer of documents, royal property master, Neferiretenes." Fragments of additional titles are preserved above the inner lower left figure: "priest of King ...'s pyramid..., priest of King ...'s pyramid ...," and "under-superintendent of priests of Re in every place of his." A longer list above the outer lower figures reads: "senior district administrator of preeminent rank, personal document scribe of the king, senior overseer of documents, senior document inspector, Neferiretenes." Raemkai's name and titles have been inserted at the left end of the upper lintel, above the two upper figures and above the right lower inner figure. The inscription in sunken relief at the center is the most prominent: "member of the elite, king's bodily son, chief lector priest, temple scribe, unique associate, representative of El-Kab, possessor of honor by the great god, Raemkai."

Image Changes on the False Door

When the tomb of Nefertiretenes was adapted for Raemkai's use, only a few changes were made to the reliefs. The most important concerned the upper standing figures of the tomb owner on the False Door. Originally, both of these were noticeably obese, and their kilts were of calf-length. During the Old Kingdom it was the custom to include among the mostly idealizing images of a tomb owner at least one representation showing him as a mature heavy-set man. Such images emphasized the deceased's success in life and his high social standing. For Raemkai, the full breasts and abdomens were removed, and the kilts were shortened. The prince was evidently of such a young age when he died that the mature representations common for elite men were deemed inappropriate.

Figure 6.16: Segmentation results on a cropped area from the Tomb Chapel of Raemkai.

6.2.7 - Lintel block from the false door of Mery's chapel

Figure 6.17: Lintel Block from the false door of Mery's Chapel[7]:

This portion of a lintel block above gives some of Mery's priestly and administrative titles. His wife and child are depicted in another relief (X.179).

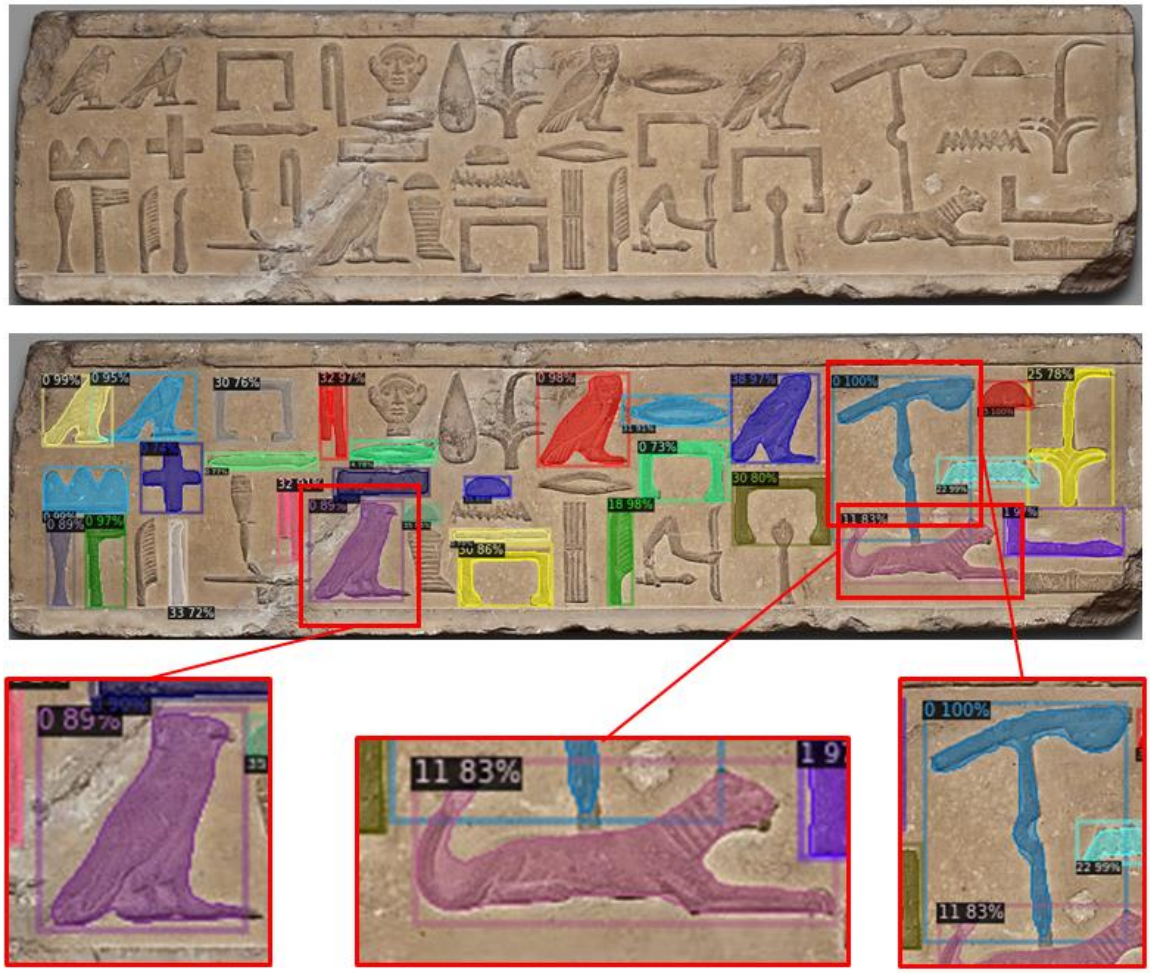


Figure 6.184: LINTEL BLOCK FROM THE FALSE DOOR OF MERY'S CHAPEL segmentation results. Top: original image; Bottom: analysis results.

[7] Period: Old Kingdom
Dynasty: Dynasty 4
Date: ca. 2575–2520 B.C.
Geography: From Egypt, Memphite Region, Saqqara, Djoser precinct, north of the Step Pyramid
Medium: Limestone
Dimensions: L. 90.2 cm (35 1/2 in.)
Credit Line: Gift of Mrs. Edmund Lassalle, 1967
Accession Number: 67.50

6.2.8 - Stela of Djemi

Figure 6.19: Original image of stela of Djemi[8]:

Djemi was an officer of the Nubian mercenaries and claims to have enslaved northern Nubia.

Figure 6.201: Original image and some results on the Stela of Djemi.

[8] Period: First Intermediate Period
Dynasty: Dynasty 11, early
Date: ca. 2120–2030 BC
Geography: From Egypt; Probably from Southern Upper Egypt, Gebelein (Krokodilopolis)
Medium: Limestone
Dimensions: H. 49.5 × W. 66 cm (19 1/2 × 26 in.)
Credit Line: Rogers Fund, 1965
Accession Number: 65.107

6.2.9 - Stela of Inamennayefnebu

Figure 6.21: Original image of the Stela of Inamennayefnebu[9]:

This is one of four stelae found near the doorway of the brick chapel of the family of Saiah, a wab, or purification priest of Amun who lived during the latter half of the 22nd Dynasty. The original tomb in whose courtyard this chapel was built dates to the 11th Dynasty, over a millennium earlier. All of the stelae are made of wood, painted in green, red, yellow and black on a white gesso ground.

Inamennayefnebu, a son of Saiah and a low-ranking official in the service of Amun, stands before a statue of Re-Harakhty-Atum and raises his arms in an attitude of worship. Between the two figures is an offering stand; flanking the scene are the emblems of the east (viewer right) and west (viewer left) supporting a curved sky line. The back of the stela is undecorated.

The style of Inamennayefnebu's stela is less elegant than that of his father, Saiah, with the colors painted in solid blocks within thick black outlines. The owner's figure, garbed in a pleated, transparent festival robe, is comparatively broad and heavy, common traits of this period.

[9] Period: Third Intermediate Period
Dynasty: late Dynasty 22
Date: ca. 825–712 B.C.
Geography: From Egypt, Upper Egypt, Thebes, Deir el-Bahri, west of Priests' Cemetery, Tomb MMA 801, MMA excavations, 1921–22
Medium: Wood, paste, paint
Dimensions: H. 27.8 × W. 24.2 × D. 1.7 cm (10 15/16 × 9 1/2 × 11/16 in.)
Credit Line: Rogers Fund and Edward S. Harkness Gift, 1922
Accession Number: 22.3.32

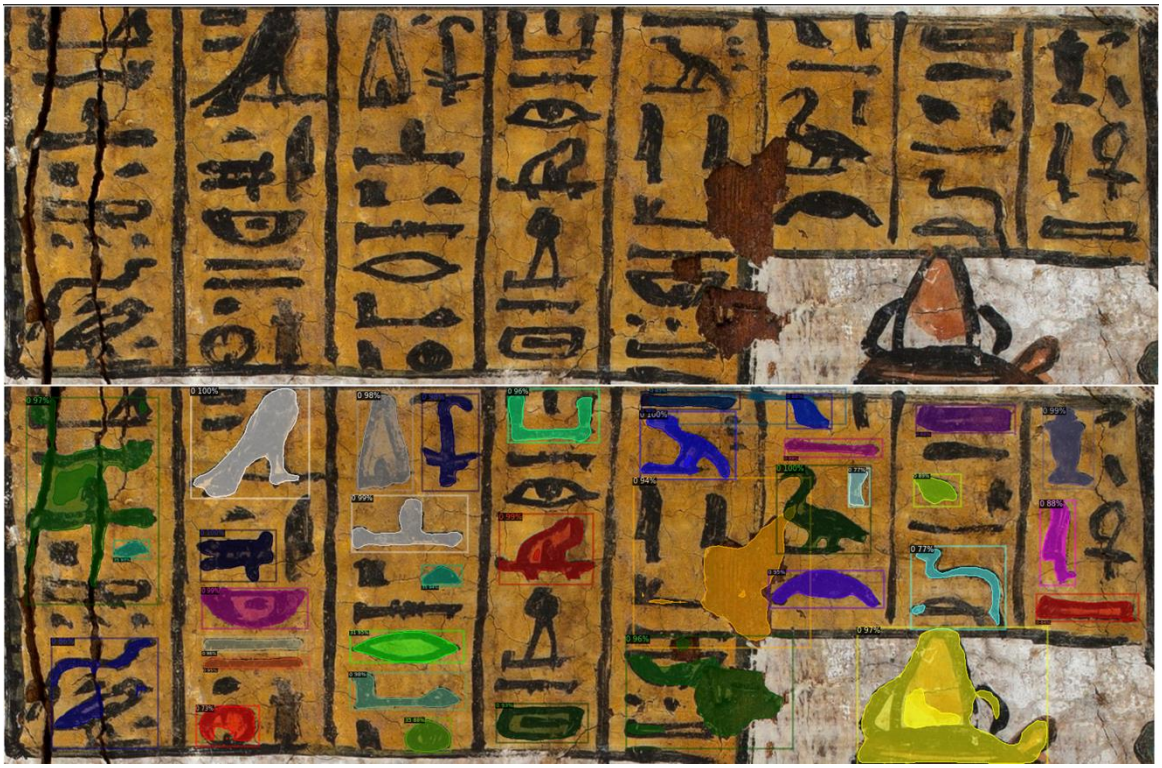


Figure 6.22: Segmentation results on the Stela of Inamennayefnebu.

6.2.10 - Stela of Tetu and Nefertjentet

Figure 6.23: Original image on the STELA OF TETU AND NEFERTJENTET[10]:

[10] Period: First Intermediate Period–Middle Kingdom

The uneven proportions of the figures and irregular relationship between figures and objects, the lack of a base line for the upper register of women, and the existence of a wider margin on the left than on the right, place this image somewhat outside the canon of Egyptian art. However, the lively color scheme and the spontaneity in the individual treatment of figures and objects lends it a charm quite of its own. As noted by Henry G. Fischer (MMJ 9, 1974, p. 29 n. 104), certain features such as the single shoulder strap in the women's garments link the iconography with the early New Kingdom.

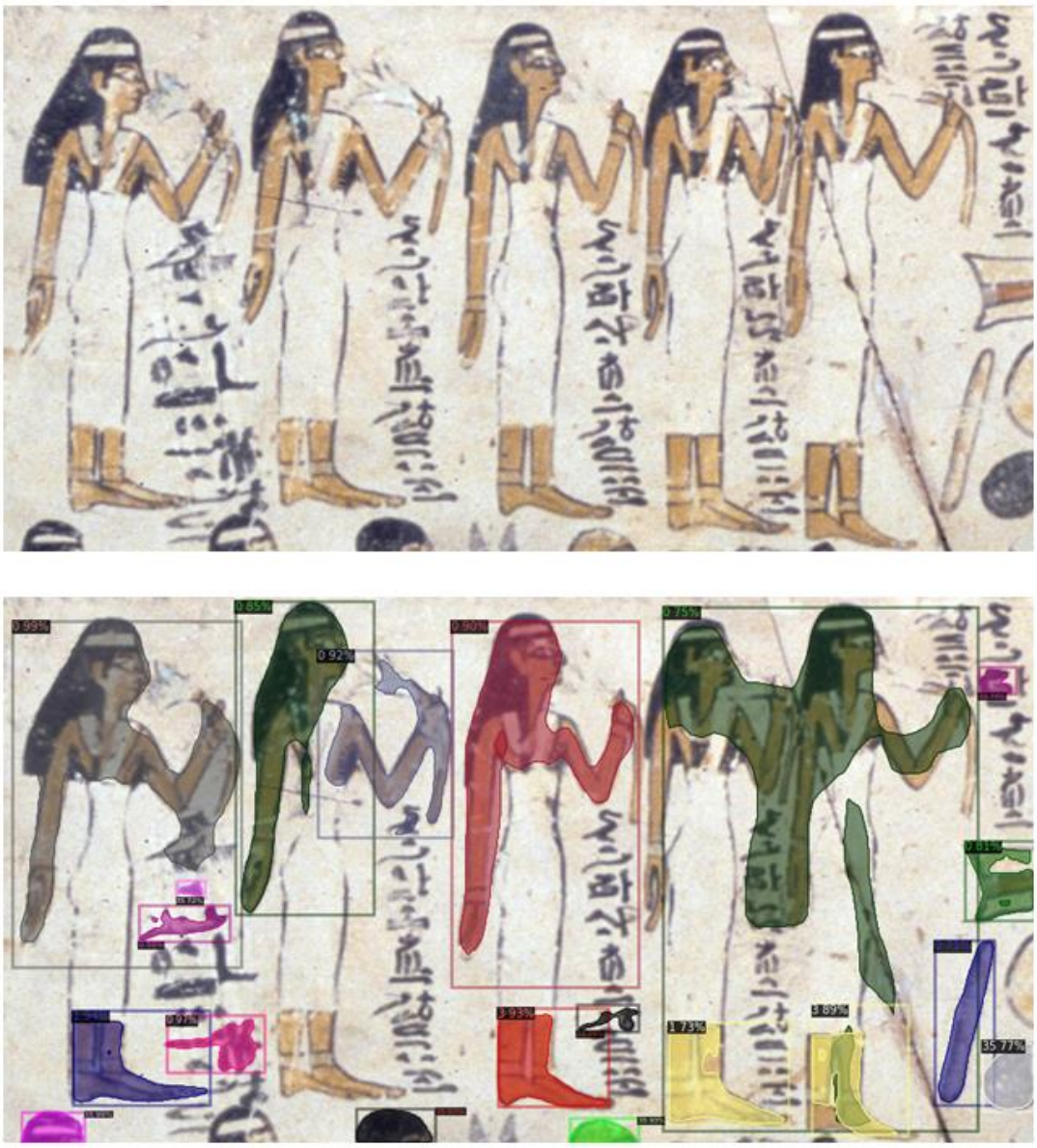


Figure 6.24: Results on STELA OF TETU AND NEFERTJENTET.

Dynasty: Dynasty 11
Date: ca. 2124–1981 BC
Geography: From Egypt, Upper Egypt, Thebes, Asasif, east of the tomb of Pabasa (TT 279), "redim" (debris), MMA excavations, 1918–19
Medium: Limestone, red, yellow and black paint
Dimensions: H. 22.7 × W. 41 × Th. 7 cm (8 15/16 × 16 1/8 × 2 3/4 in.)
Credit Line: Rogers Fund, 1919
Accession Number: 19.3.33

6.2.11 - Stela of Saiah

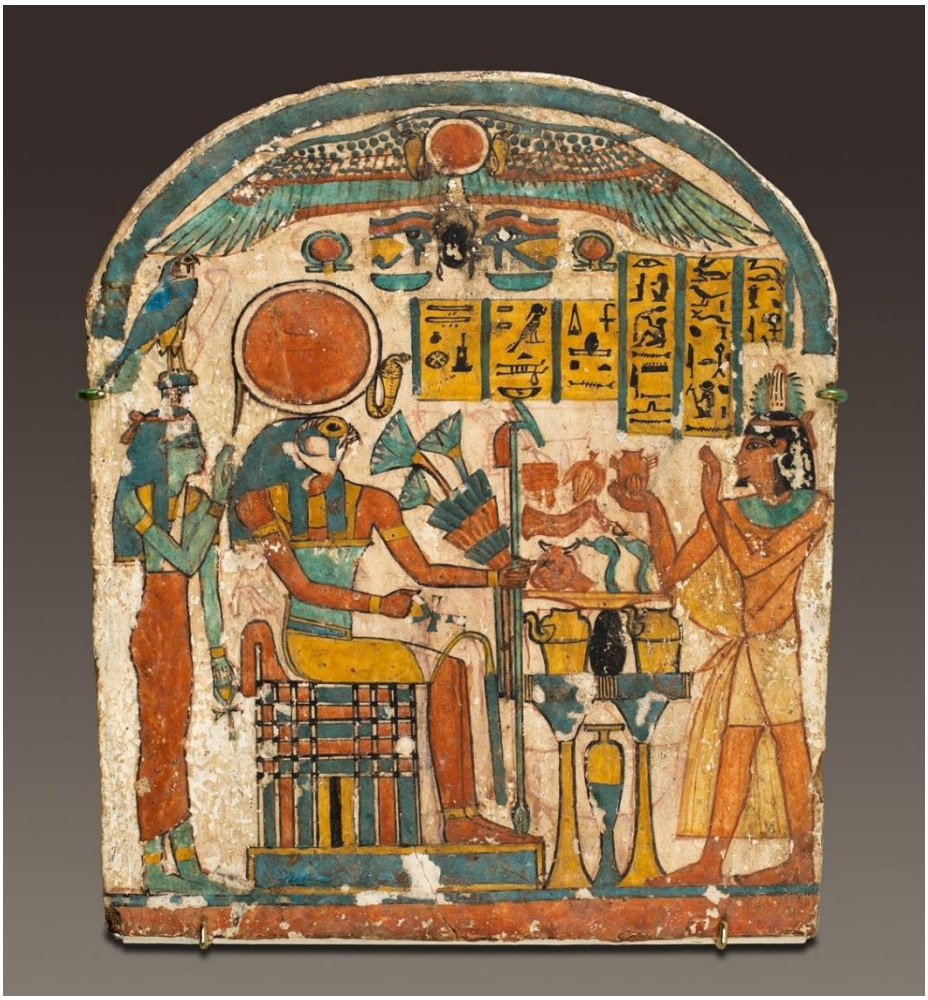


Figure 6.25: Original image of the Stela of Saiah[11]:

This is one of four stelae found near the doorway of the brick chapel of the family of Saiah, a wab, or purification priest of Amun who lived during the latter half of the 22nd Dynasty. The original tomb in whose courtyard this chapel was built dates to the 11th Dynasty, over a millennium earlier. All of the stelae are made of wood, painted in green, red, yellow and black on a white gesso ground.

Inscribed for Saiah himself, this stela is painted on both sides. On the front, the deceased, to viewer right, presents a heart-shaped object to a figure of the falcon-headed god Re-Harakhty-Atum, who sits on a cubic throne atop a reed mat. Before the god is a table piled high with offerings, and standing behind him is the goddess of the West, Imentet. In the lunette of the stela is a winged sun disk, two wedjat eyes (eyes of Horus), and two shen rings, symbols of eternity. The inscription above the offering table asks that Re-Harakhty-Atum, lord of the Two Lands and of Iunu (Heliopolis) give offerings. Above Saiah's head is written, "the Osiris, the purification priest of Amun who has no fault, Siah, son of Djed-Bastetankh."

On the back are two registers. In the bottom register, the goddess of the sycomore stands and pours water into the out-stretched hand of a male figure seated to viewer right, most likely Saiah himself; a second identical male figure sits to the left, but there is a loss in the area between the goddess and the human, with only a bit of a libation vessel preserved. Above is the sun bark, held up by a kneeling god flanked by two kneeling goddess, presumably Isis and her sister Nephthys. Standing figures of Saiah with his arms raised in prayer frame the upper register; before the figure to the left is inscribed, "Worship by the purification priest of Amun, Saiah."

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[11] Period: Third Intermediate Period
Dynasty: late Dynasty 22
Date: ca. 825–712 B.C.
Geography: From Egypt, Upper Egypt, Thebes, Deir el-Bahri, west of Priests' Cemetery, Tomb MMA 801, MMA excavations, 1921–22
Medium: Wood, paste, paint
Dimensions: H. 23.8 cm (9 3/8 in.)
Credit Line: Rogers Fund and Edward S. Harkness Gift, 1922
Accession Number: 22.3.31

Figure 6.262: Results on the Stela of Saiah.

Chapter 7

ANALYSIS ON THE MAYA AND BYZANTINE ARTIFACTS FROM THE METROPOLITAN MUSEUM OF NEW YORK

7.1 – The results on Byzantine and Maya artifacts

The aim here was to test our CNN, trained on ancient Egyptian hieroglyphs, on different writing systems. The test was performed on two artifacts coming from the MET.

7.2 – The results on Funerary stelae from the Byzantine period in Egypt

Figure 7.1: Funerary Stele with Architectural Frame from the Byzantine period in Egypt:[1]

Funerary stelae from the Byzantine period in Egypt, carved in stone and usually painted, were permanent monuments to the deceased. While normally embedded in walls or floors near the tomb, some were part of larger structures. Their decorations include scenes of paradise and symbols of the Christian Church. This example, said to be from the Upper Nile Delta town of Armant, bears the name of a prominent citizen who was buried near the marker.

[1] Date: 6th–7th century
Geography: Made in Egypt
Medium: Limestone; carved in relief and painted
Dimensions: H. 20 11/16 in. (52.5 cm) W. 14 9/16 in. (37 cm)
Classification: Sculpture
Credit Line: Rogers Fund, 1936
Accession Number: 36.2.6

The composition of this Christian funerary stela has two parts. Below is an architectural frame defined by two columns, the bases of which stand on representations of fish. Above, resting on the capitals, is a highly decorated apse described by an arching vine scroll and interlace patterns following the semicircular shape of the stela. At the center of the concentric arches is a rosette. The polychromy adds details not found in the carving; there are, for example, red and green sections in the straited columns and, between the columns, small black circles ornament the frame that surrounds an inscription in Coptic: "To the memory of the deceased, Taeiam, who departed from this life on the 18th of Choiak (December) of the 7th indiction. She sleeps in Christ."

That the deceased was not dead but simply asleep was widely believed by early Christians and is referred to in many funerary inscriptions. "Taeiam sleeps in Christ" is an avowal that her soul has ascended to the kingdom of heaven. As if in confirmation, the composition represents a vision of the kingdom of heaven in the form of a tabernacle, where the pious Taeiam will sojourn until the second coming of Christ. Her hopes are also expressed in the Coptic lithurgy for the dead:

"And these, O Lord, and all these names we have recited...who have fallen asleep and have gone to their rest in the faith of Christ, vouchsafe to grant rest to all their souls in the bosom of the holy fathers...nourish them in a place of pasturage beside the waters of comfort in the paradise of joy, whence sorrow and sighting and weeping have fled away in the light of thy saints..."[2]

Figure 7.21: Segmentation results on the Funerary Stele from the Byzantine period in Egypt.

Results shows a kind of network ability to deal with symbols different from ancient Egyptian hieroglyphs. This result could have been expected due to the deeper layers of the CNN to work with any kind of objects. This again is a demonstration of the power of CNN, in particular of the power of hierarchical learning.

7.3 – The results on Maya artifact

The aim here was to test our CNN, trained on ancient Egyptian hieroglyphs, on different writing systems. The test here was performed on a Stela Fragment with Glyphs coming from Maya.

[2] *Thelma K. Thomas in [Friedman 1989].F. Brightman ed. Lithurgies, Eastern and Western. Reprint 1965. Oxford, 1898, pp. 170–1.*

Figure 7.3: Maya artifact:

This is a fragment of the bas relief known as Tortuguero Monument 6, which contains one of the most infamous and contentious hieroglyphic texts in the Classic Maya (ca. a.d. 250–900) corpus. For many years epigraphers and lay enthusiasts honed in on the final passage of the text as a "prophecy," a tale of what would have happened on the date 13.0.0.0.0 4 Ahaw 3 K'ank'in in the Maya calendar. This corresponded to a day in December 2012, leading to spurious and sensational claims about an end of days predicted by the ancient Maya. The Met's fragment contains a pivotal portion of the text.

The main event of the Tortuguero Monument 6 text is the ritual dedication of a building, quite possibly a mortuary structure, on the date January 11, a.d. 669 (9.11.16.8.18 9 Etz'nab 6 K'ayab). A local lord of Tortuguero, calling himself "Lord Jaguar," burned fire for the first time in the structure on that date, activating it as a ritual space. Throughout the text, the sculptor makes reference to future and past calendric period endings, similar to saying something like "just before the New Year," or "after last Fourth of July." Scribes did this to anchor these mortal events in the giant cosmic cycles recorded in both the Long Count (a linear calendar counting up from a fixed point in 3114 b.c.) and the Calendar Round (an interlocking set of coefficients, months, and days that cycled completely every fifty-two years).

The local history of Tortuguero is intimately linked with that of the great Classic Maya kingdom of Palenque, in modern-day Chiapas, Mexico. In fact, rulers at Tortuguero, in the nearby state of modern-day Tabasco, used the same emblem glyph as Palenque, part of a sort of dynastic heraldic symbol or toponym. Scholars know little about the origins of the dynasty at Tortuguero: Was the lineage using the same emblem glyph because they were subordinate to the dynasts at Palenque, or were the rulers at Tortuguero members of a rival faction that splintered from the Palenque patrilineal sequence? The modest site's unfortunate destruction in the mid-twentieth century make future archaeological and epigraphic work challenging.

Returning to the entire text of Monument 6, it is read in two columns from left to right and then up to down. The Met's fragment begins with a distance number that projects the narrative forward in time: "One hundred sixteen days later he was seated, then he descended (or arose); it was his first, his flint and shield (and) lances were joined at Ayiin, then Xam, he of Uux Te'K'uh suffered a "star war"; it was on the day 13 Kimi 14 Sek (9.10.11.9.6) [a.d. 644]. Ninety-two days later, on 10 Ok 18 K'ayab (9.10.12.3.10) [a.d. 645], then it was chopped ..." This passage is a common construction in late Classic Maya texts in which kings list off conquests in the commemoration of an anniversary or dedication of a shrine, such as this case.

The middle two columns of the Met's fragment begin with another distance number and the recording of an accession of someone into rulership in December a.d. 647, or the day 11 Chuwen 4 Muwaan (9.10.15.1.11), using the metaphors "seating into rulership" and "tying/binding the word." The following distance number projects back in time to remind the reader that thirty-one days prior to the seating of the ruler was an important calendric checkpoint, 9.10.15.0.0., occurring on the day 6 Ajaw, 13 Mak (November a.d. 647).

The third pair of columns preserved on the Met's fragment record something that happened on the date 9.11.15.0.0 (a.d. 667), twenty years after the anniversary mentioned on the preceding columns. The brief text commemorates the dedication of a building called the "Six-Stone House of Six Cached Hammer Celts." The agent of this dedication, Bahlam Ajaw, the Holy Lord of Tortuguero, is mentioned on the following part of the text from another fragment. The building is likely the one that held this monument recording its dedication.

The monument's text conveys several metaphors for violence found in Classic Maya inscriptions. The "star war" verb has received a lot of scholarly attention for its purported relationship to cycles of the appearance of Venus in the sky—in other words, that these "war" events were scheduled around astronomical phenomenon. However, the precise meaning of the hieroglyph of the star-spilling liquid over an emblem glyph remains elusive. Regardless, these "star war" events usually end up in a starkly negative political situation, as evidenced by a hiatus in building programs or monument dedications, for the named royal court on the receiving end.

Equally gruesome are two phrases on the largest fragment of Tortuguero Monument 6 describing the pooling of blood and piling up of skulls. Through the metaphor employed in this poetic couplet, the sculptor allows the reader to visualize the violence and carnage that resulted in lakes of blood and mountains of bones. However, it is quite possible that Lord Jaguar had his sculptor's amp up the rhetoric on his past conquests in order to enhance his own prestige in the shadow of the more powerful lords of Palenque.

Figure 7.4: Results on Stela Fragment with Glyphs coming from Maya. Left: cropped area; Right: segmentation results.

As shown in figure above, the CNN is not able to detect any kind of glyph inside the image. This can be related to different phenomena, the first is that the network was not trained on this kind of glyphs. However, as seen above for the Egyptian and Bizantine cases, the network shows some abilities to detect objects not in the training dataset. This is related to the features learned in the deeper layers of the network, which are able to detect objects starting from hierarchical features, which can be general for many objects in the world. For example, some features can be able to detect boundaries.

Chapter 8

RESULTS ON THE ARTIFACTS FROM THE ARCHEOLOGICAL MUSEUM OF FLORENCE

8.1 - Artifacts of the Museo Archeologico di Firenze – "Museo Egizio"

8.1.1 - Stela of Haimentaraeni

Figure 8.1: Stela of Haimentaraeni[1], inv. N. 42484 (ME2484). From the collection of the Museo Archeologico Nazionale di Firenze – "Museo Egizio" (Direzione regionale Musei della Toscana). Reprinted with permission:

Round-topped stela, dated to the Late Period and purchased by the Franco-Tuscan Expedition (1828-1829), with three sections. Above a winged solar disc with the label "That of Behedet, the gread god". In the section above, the priest Haimentaraeni is represented on the right in front of a table of offerings. The goddess Maat behind him presents him to the gods standing before the table: Osiris, Isis and Nephthys, Thoth and the four sons of Isis. In the last section, an inscription with the formula of the offer to Osiris for the deceased (S. Bosticco, Museo Archeologico di Firenze, Vol. III: Le stele egiziane di epoca tarda, Roma 1972, p, pp. 33-34, n. 22).

[1] "Museo Archeologico Nazionale di Firenze (Direzione regionale Musei della Toscana)", Inv. n. 42484 (ME 2484).

Figure 8.2: Example of segmentation analysis on the "Stela of Haimentaraeni", inv. N.42484 (ME 2484). From the collection of the Museo Archeologico Nazionale di Firenze – "Museo Egizio" (Direzione regionale Musei della Toscana). Reprinted with permission.

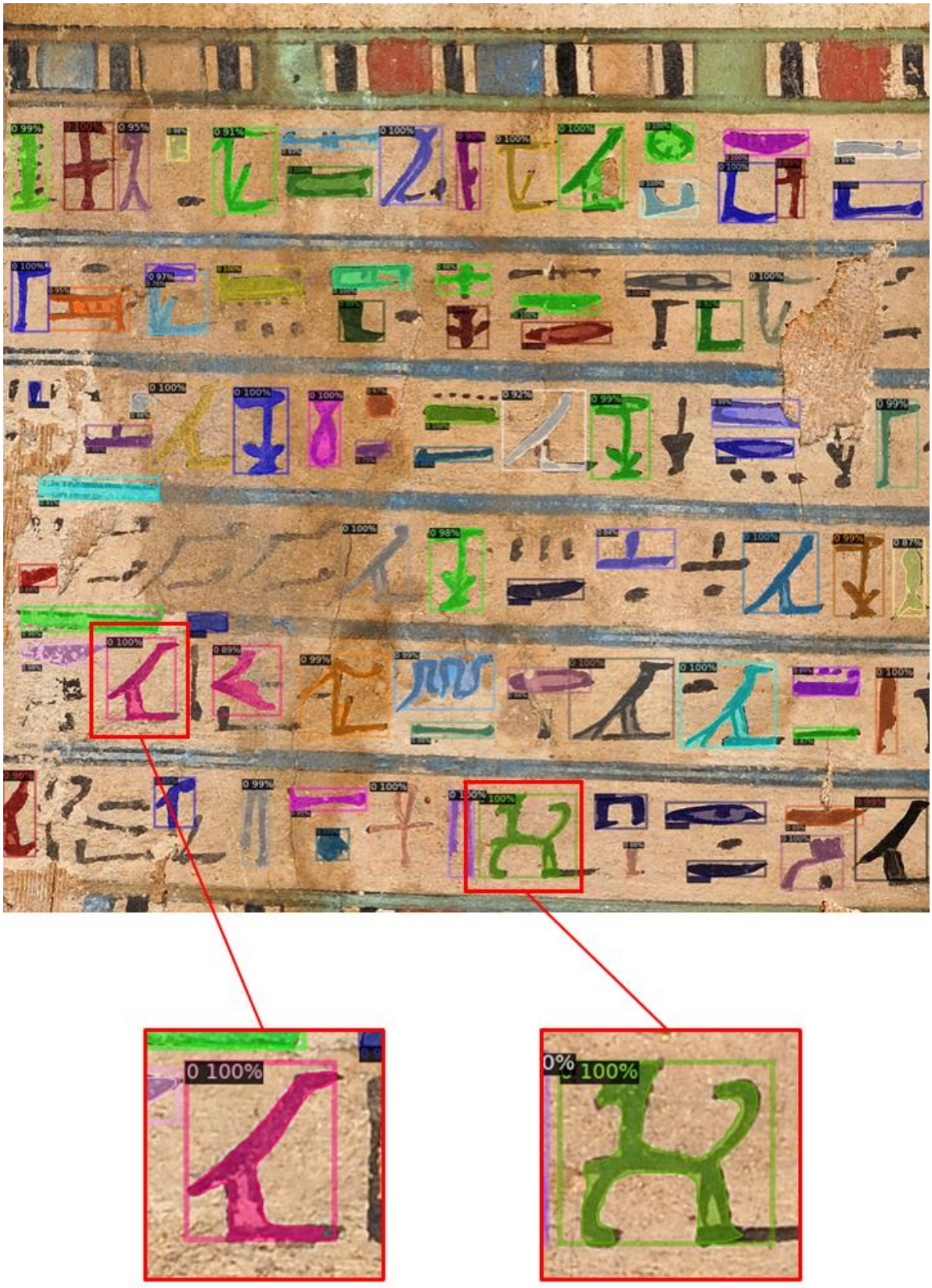

Figure 8.3: Example of segmentation analysis from a patch coming from the "Stela of Haimentaraeni", inv. N. 42484 (ME2484). From the collection of the Museo Archeologico Nazionale di Firenze – "Museo Egizio" (Direzione regionale Musei della Toscana). Reprinted with permission.

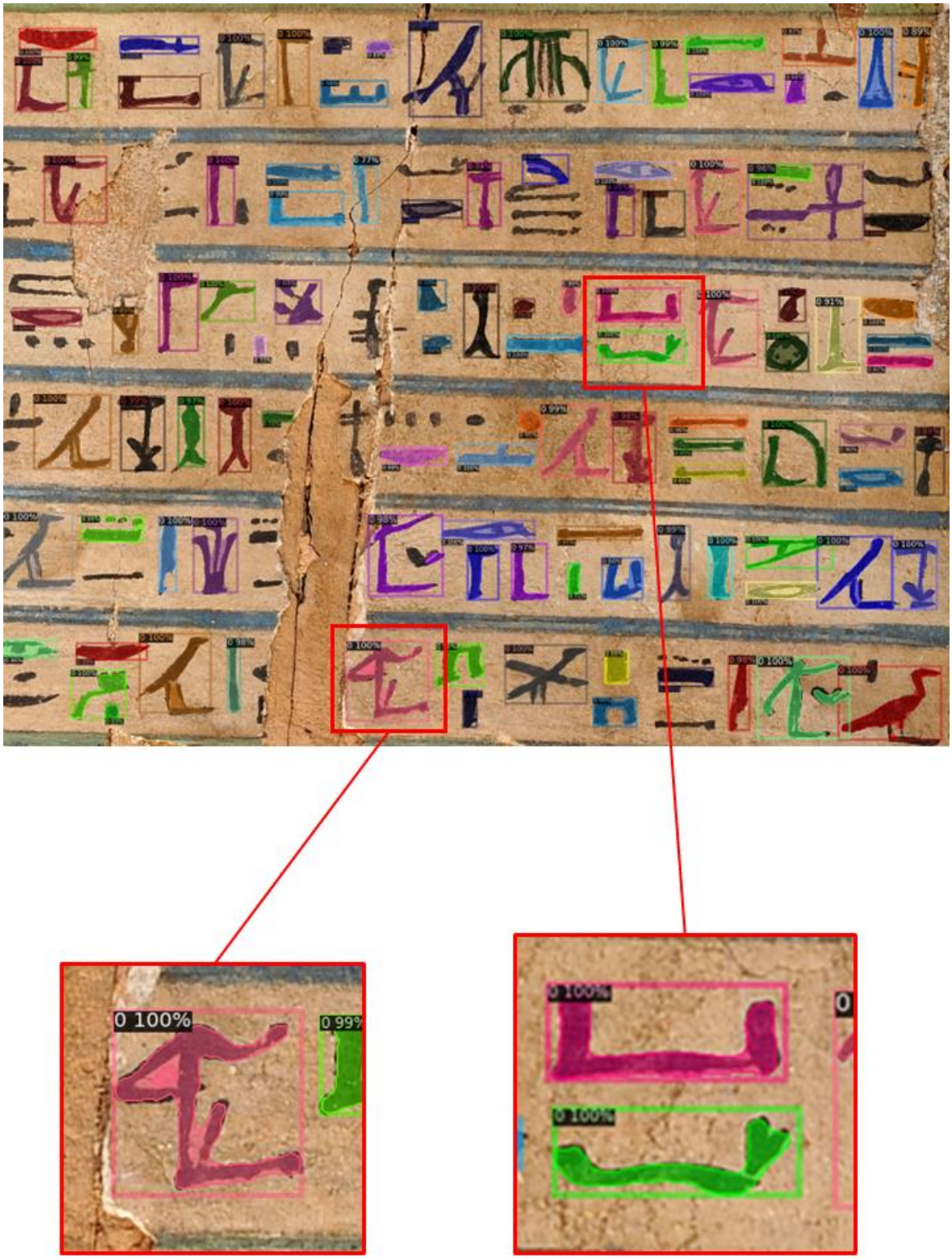

Figure 8.4: Example of segmentation analysis from a patch coming from the "Stela of Haimentaraeni", inv. N. 42484 (ME2484). From the collection of the Museo Archeologico Nazionale di Firenze – "Museo Egizio" (Direzione regionale Musei della Toscana). Reprinted with permission.

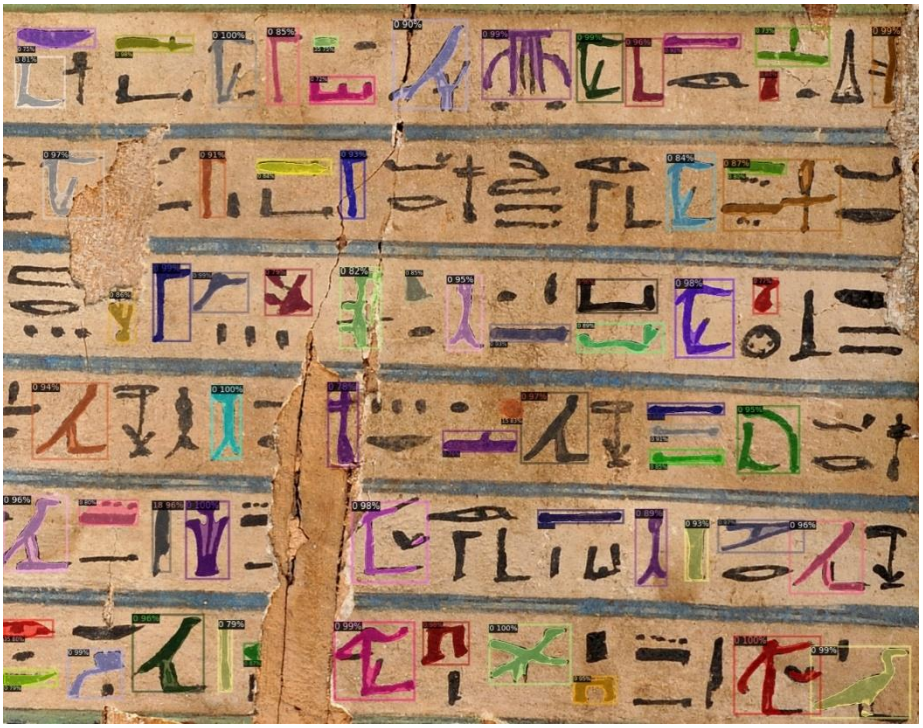

Figure 8.51: Example of segmentation analysis from a patch coming from the "Stela of Haimentaraeni", inv. N. 42484 (ME2484). From the collection of the Museo Archeologico Nazionale di Firenze – "Museo Egizio" (Direzione regionale Musei della Toscana). Reprinted with permission.

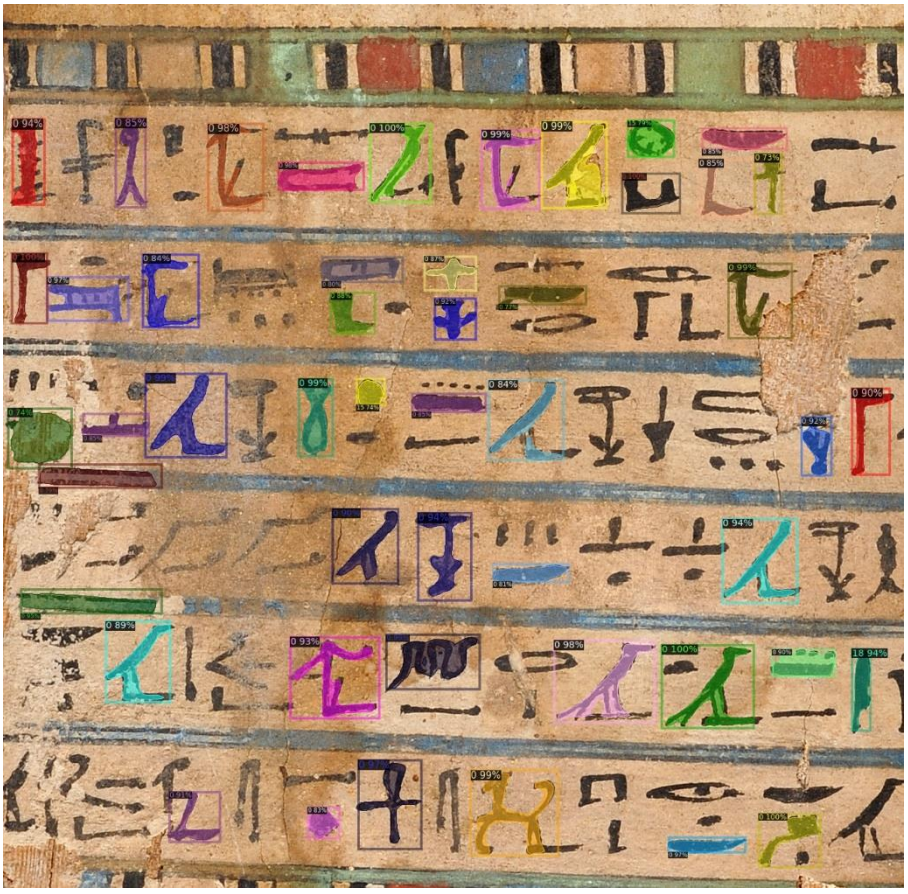

Figure 8.6: Example of segmentation analysis from a patch coming from the "Stela of Haimentaraeni", inv. N. 42484 (ME2484). From the collection of the Museo Archeologico Nazionale di Firenze – "Museo Egizio" (Direzione regionale Musei della Toscana). Reprinted with permission.

8.1.2 - Stela of Djedkhonsuefankh

Figure 8.7: Stela of Djedkhonsuefankh[2], inv. N. 42490 (ME2490). From the collection of the Museo Archeologico Nazionale di Firenze – "Museo Egizio" (Direzione regionale Musei della Toscana). Reprinted with permission.

The stele probably comes from the tomb of Tjesraperet, the nurse of a daughter of Pharaoh Taharqa (25th dynasty), discovered by Ippolito Rosellini during the Franco-Tuscan Expedition to Egypt (1828-1829). Under the rib, inside which is represented a winged solar disc, the deceased is portrayed twice in the act of adoration of Atum on the right and Ra-Horakhty on the left, which have their backs to the center of the stele. Below, two hieroglyphic inscriptions separated by a central line report prayers of the deceased to the two deities (S. Bosticco, Museo Archeologico di Firenze, Vol. III: Le stele egiziane di epoca tarda, Roma 1972, p, pp. 15-16, n. 4).

[2] "Museo Archeologico Nazionale di Firenze (Direzione regionale Musei della Toscana)", Inv. n. 42490 (ME 2490)

Figure 8.82: Example of segmentation analysis on the "Stela of Djedkhonsuefankh", inv. N. 42490 (ME 2490). From the collection of the Museo Archeologico Nazionale di Firenze – "Museo Egizio" (Direzione regionale Musei della Toscana). Reprinted with permission.

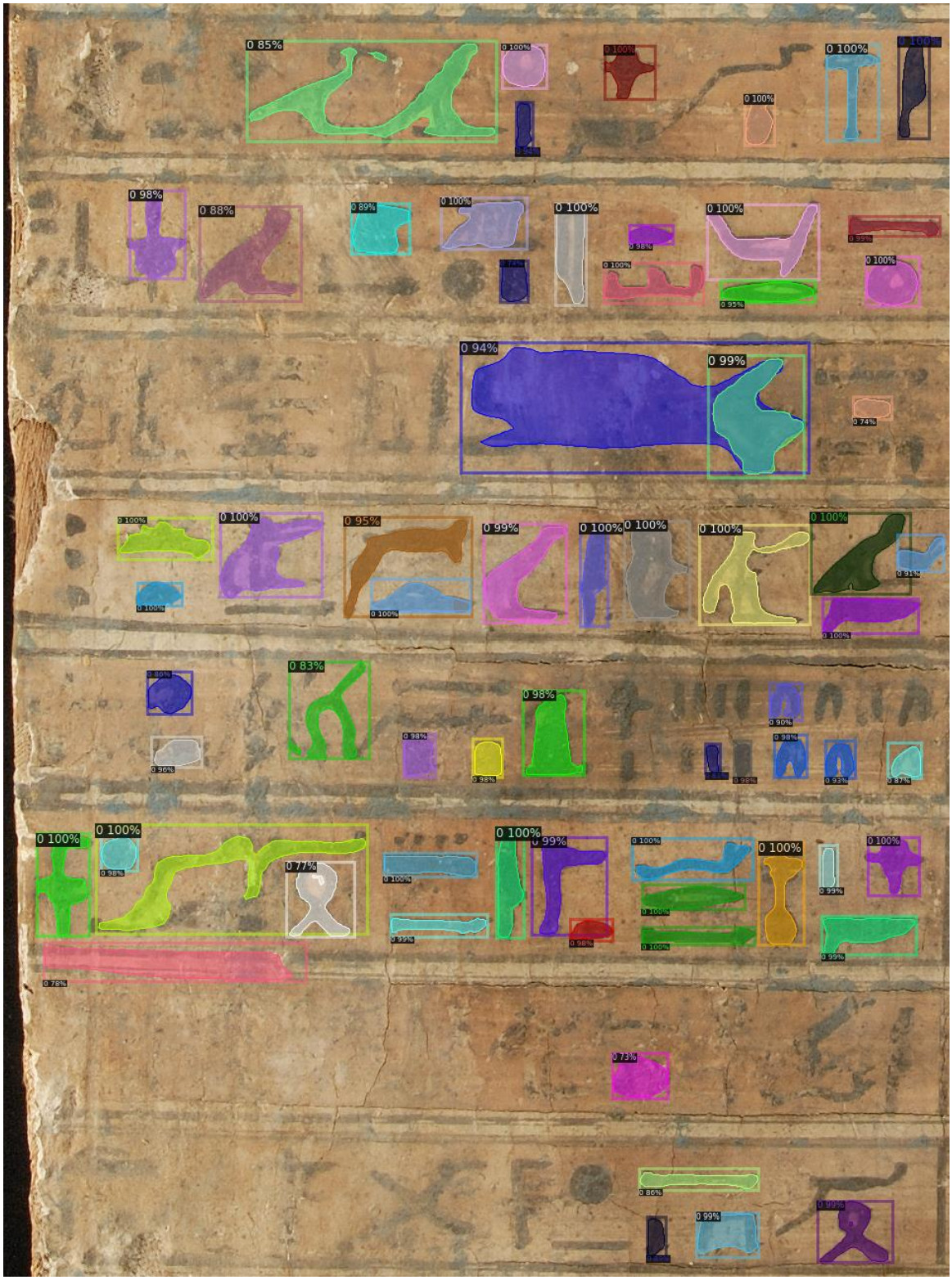

Figure 8.93: Example on a patch from the "Stela of Djedkhonsuefankh", inv. N. 42490 (ME 2490). From the collection of the Museo Archeologico Nazionale di Firenze – "Museo Egizio" (Direzione regionale Musei della Toscana). Reprinted with permission.

Figure 8.104: Example on a patch from the "Stela of Djedkhonsuefankh", inv. N. 42490 (ME 2490). From the collection of the Museo Archeologico Nazionale di Firenze – "Museo Egizio" (Direzione regionale Musei della Toscana). Reprinted with permission.

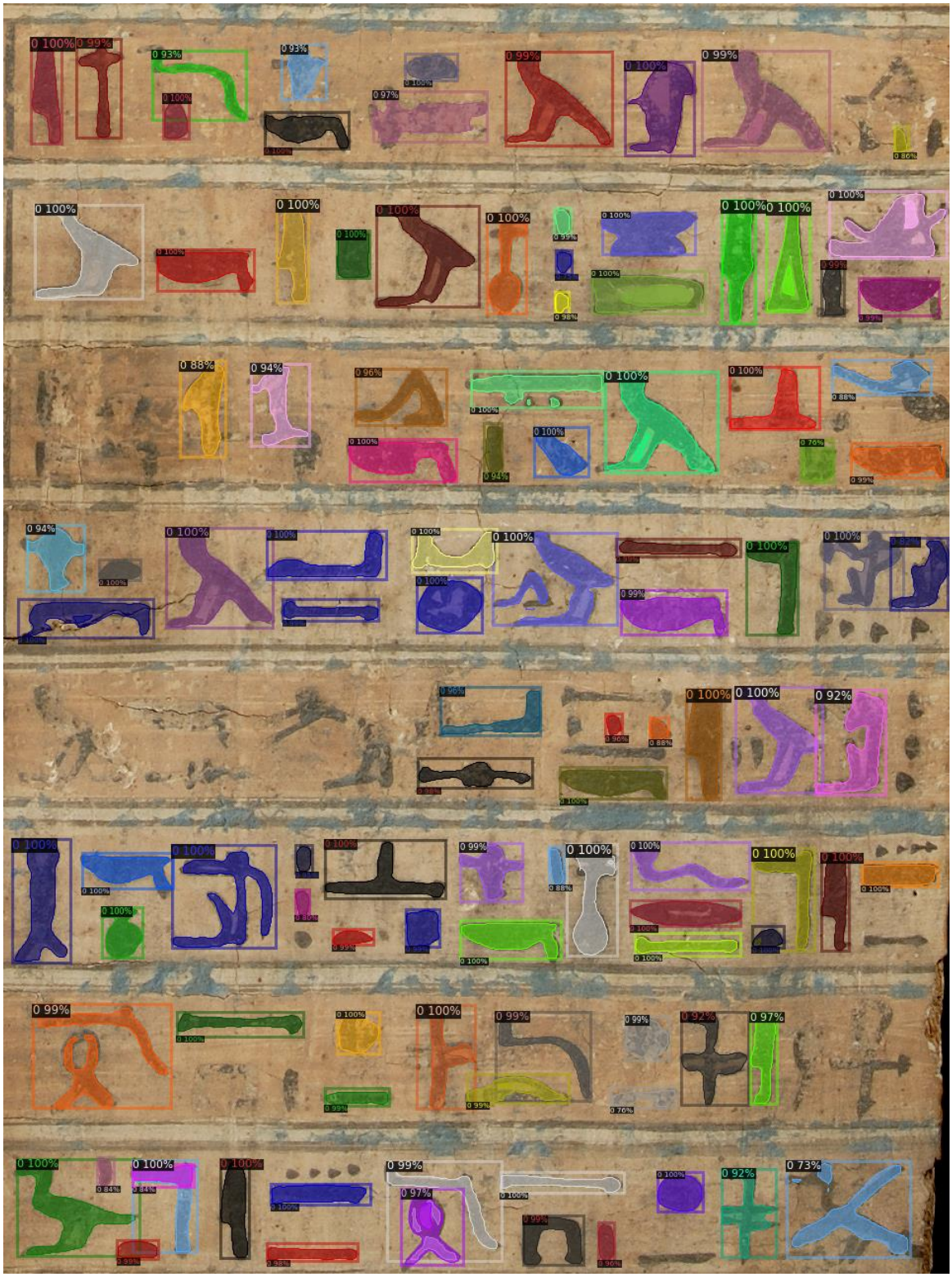

Figure 8.11: Example on a patch from the "Stela of Djedkhonsuefankh", inv N. 42490 (ME 2490). From the collection of the Museo Archeologico Nazionale di Firenze –"Museo Egizio" (Direzione regionale Musei della Toscana). Reprinted with permission.

Figure 8.12: Example on a patch from the "Stela of Djedkhonsuefankh", inv. N. 42490 (ME 2490). From the collection of the Museo Archeologico Nazionale di Firenze – "Museo Egizio" (Direzione regionale Musei della Toscana). Reprinted with permission.

8.1.3 - Stela of Samentuoser

Figure 8.13: Stela of Samentuoser[3], inv. N. 46365 (ME6365). From the collection of the Museo Archeologico Nazionale di Firenze – "Museo Egizio" (Direzione regionale Musei della Toscana). Reprinted with per-mission:

Round topped stela with the representation of the deceased, sitting on a seat, with a long stick ending with a head of bat in his left hand. Below the seat there is a squatting bitch. In front of Samentuoser stands a heap of offerings, among which are identified vases, breads, a leg of ox, a bird and vegetables. Above the scene there is an inscription of seven horizontal lines. (S. Bosticco, Museo Archeologico di Firenze, Vol. I: Le stele egiziane dall'Antico al Nuovo Regno, Roma 1959, p, p, 25, n. 18).

[3] "Museo Archeologico Nazionale di Firenze (Direzione regionale Musei della Toscana)", Inv. n. 46365 (ME 6365)

Figure 8.14: Example of segmentation analysis on the "Stela of Samentuoser", inv. N. 46365 (ME 6365). From the collection of the Museo Archeologico Nazionale di Firenze – "Museo Egizio" (Direzione regionale Musei della Toscana). Reprinted with permission.

Figure 8.15: Example of segmentation analysis on the "Stela of Samentuoser", inv. N. 46365 (ME 6365). From the collection of the Museo Archeologico Nazionale di Firenze – "Museo Egizio" (Direzione regionale Musei della Toscana). Reprinted with permission.

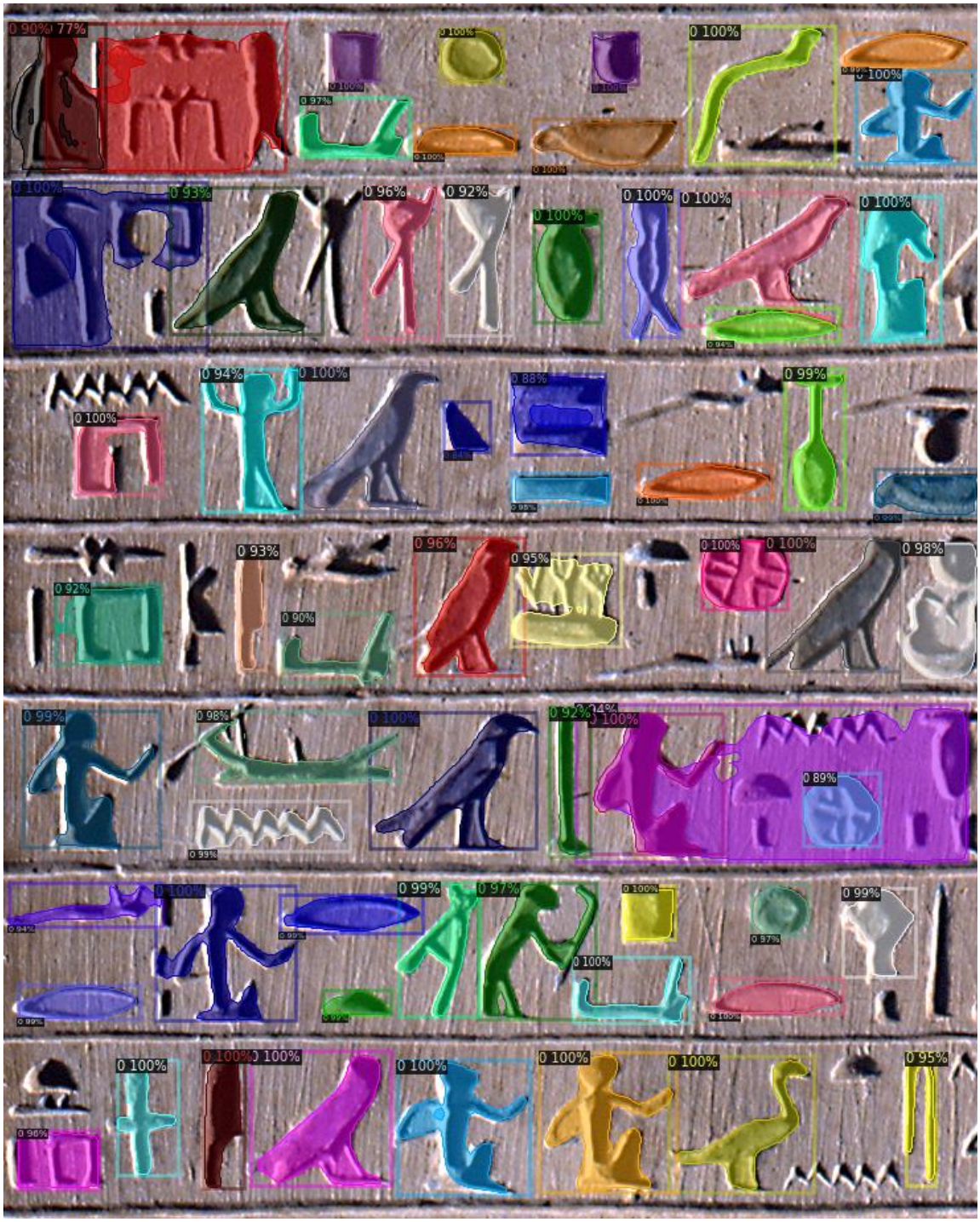

Figure 8.16: Example of segmentation analysis from a patch coming from the "Stela of Samentuoser", inv. N. 46365 (ME 6365). From the collection of the Museo Archeologico Nazionale di Firenze – "Museo Egizio" (Direzione regionale Musei della Toscana). Reprinted with permission.

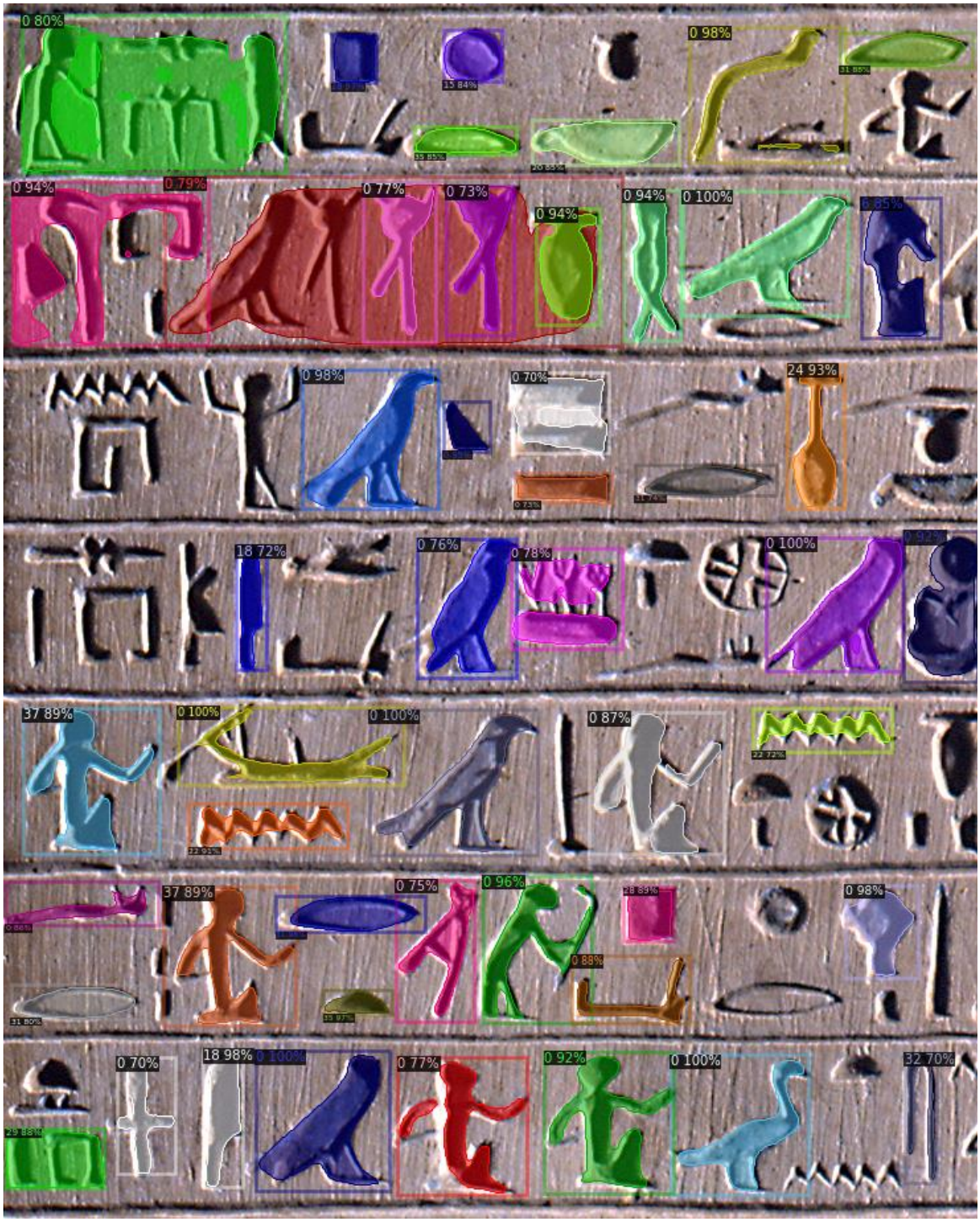

Figure 8.17: Example of segmentation analysis from a patch coming from the "Stela of Samentuoser", inv. N. 46365 (ME 6365). From the collection of the Museo Archeologico Nazionale di Firenze –"Museo Egizio" (Direzione regionale Musei della Toscana). Reprinted with permission.

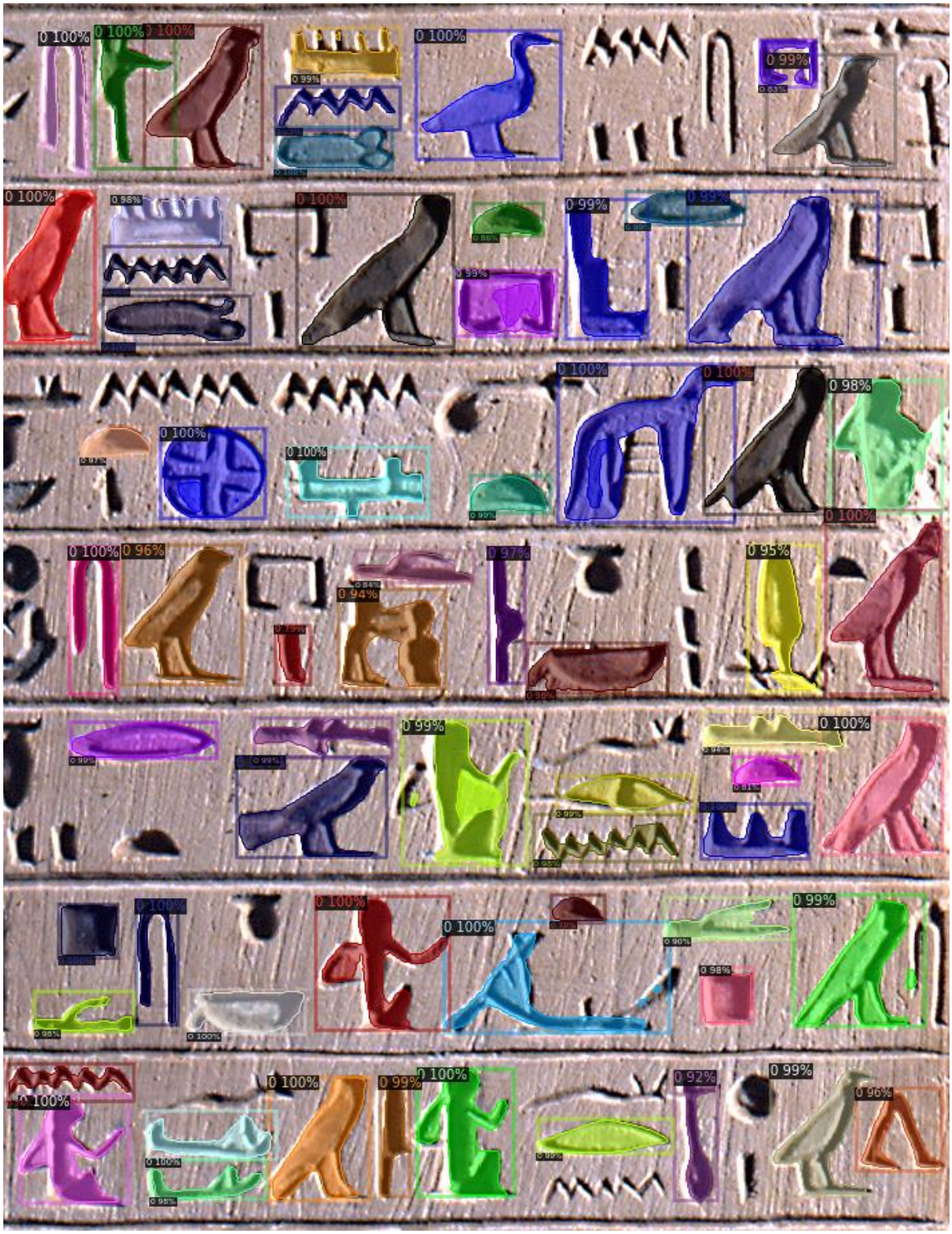

Figure 8.185: Example of segmentation analysis from a patch coming from the "Stela of Samentuoser", inv. N. 46365 (ME 6365). From the collection of the Museo Archeologico Nazionale di Firenze – "Museo Egizio" (Direzione regionale Musei della Toscana). Reprinted with permission.

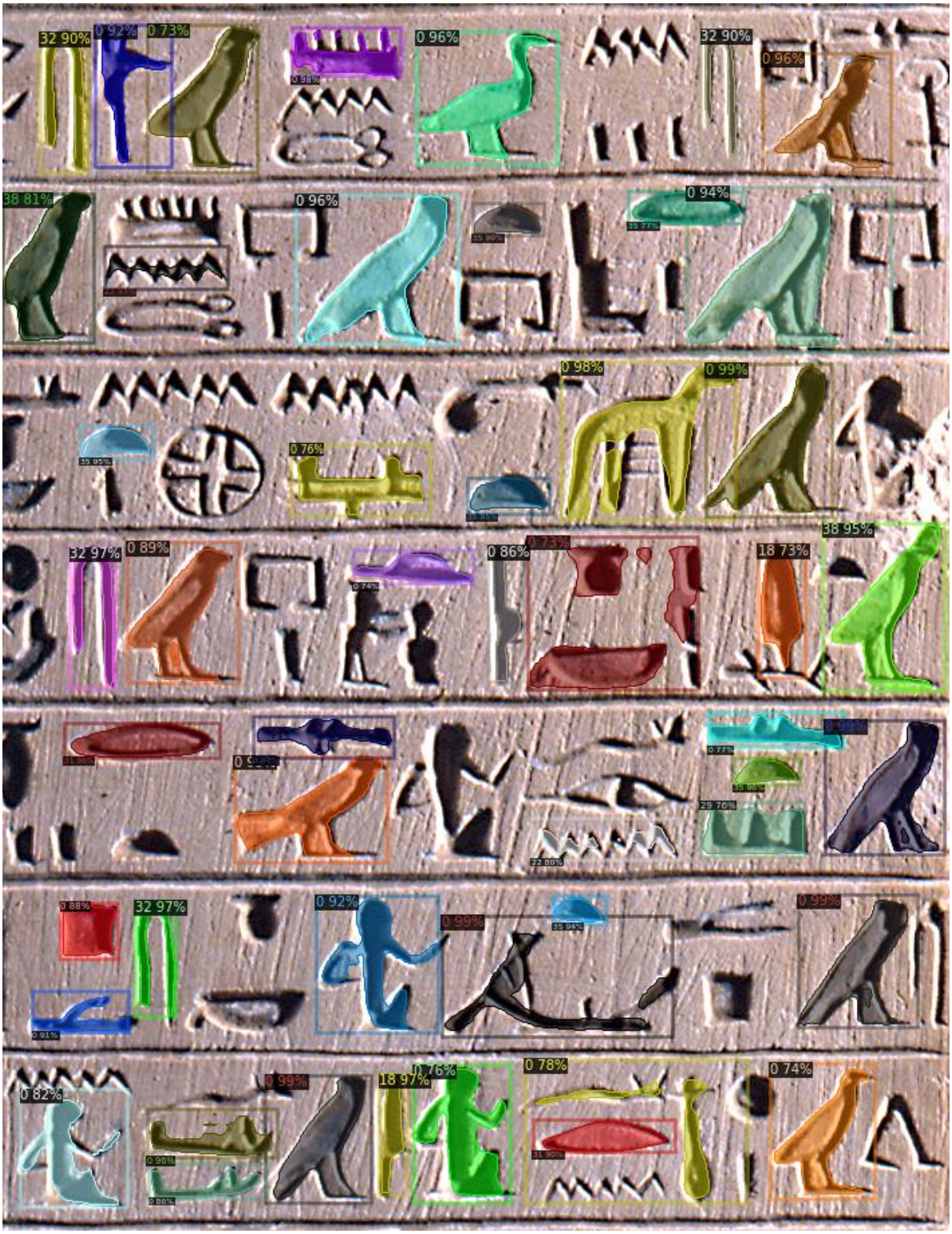

Figure 8.196: Example of segmentation analysis from a patch coming from the "Stela of Samentuoser", inv. N. 46365 (ME 6365). From the collection of the Museo Archeologico Nazionale di Firenze – "Museo Egizio" (Direzione regionale Musei della Toscana). Reprinted with permission.

8.1.4 - Stela of Senbi

Figure 8.20: Stela of Senbi[4], inv. N. 42506 (ME 2506). From the collection of the Museo Archeologico Nazionale di Firenze – "Museo Egizio" (Direzione regionale Musei della Toscana). Reprinted with permission:

Curtained funerary stela, engraved on a rectangular plate, with a narrow band that defines the shape. In the rib appears, within cartouche, the first name of Pharaoh Amenemhat III (12th Dynasty): on the right, there is the image of Osiris mummiform; on the left, there is the god Upuaut in the form of jackal. Under the rib three lines of inscription. At the center of the stela is depicted the funeral meal of the deceased Senbi, sitting on an elegant seat, in the act of smelling a lotus flower. To the right of the heap of offerings Senbi's parents sit. At the bottom of the stele four pairs of kneeling characters are depicted, in the act of take possession of heaps of funeral offerings. (S. Bosticco, Museo Archeologico di Firenze, Vol. I: Le stele egiziane dall'Antico al Nuovo Regno, Roma 1959, pp. 36-37, n. 32).

[4] "Museo Archeologico Nazionale di Firenze (Direzione regionale Musei della Toscana)", Inv. n. 42506 (ME 2506)

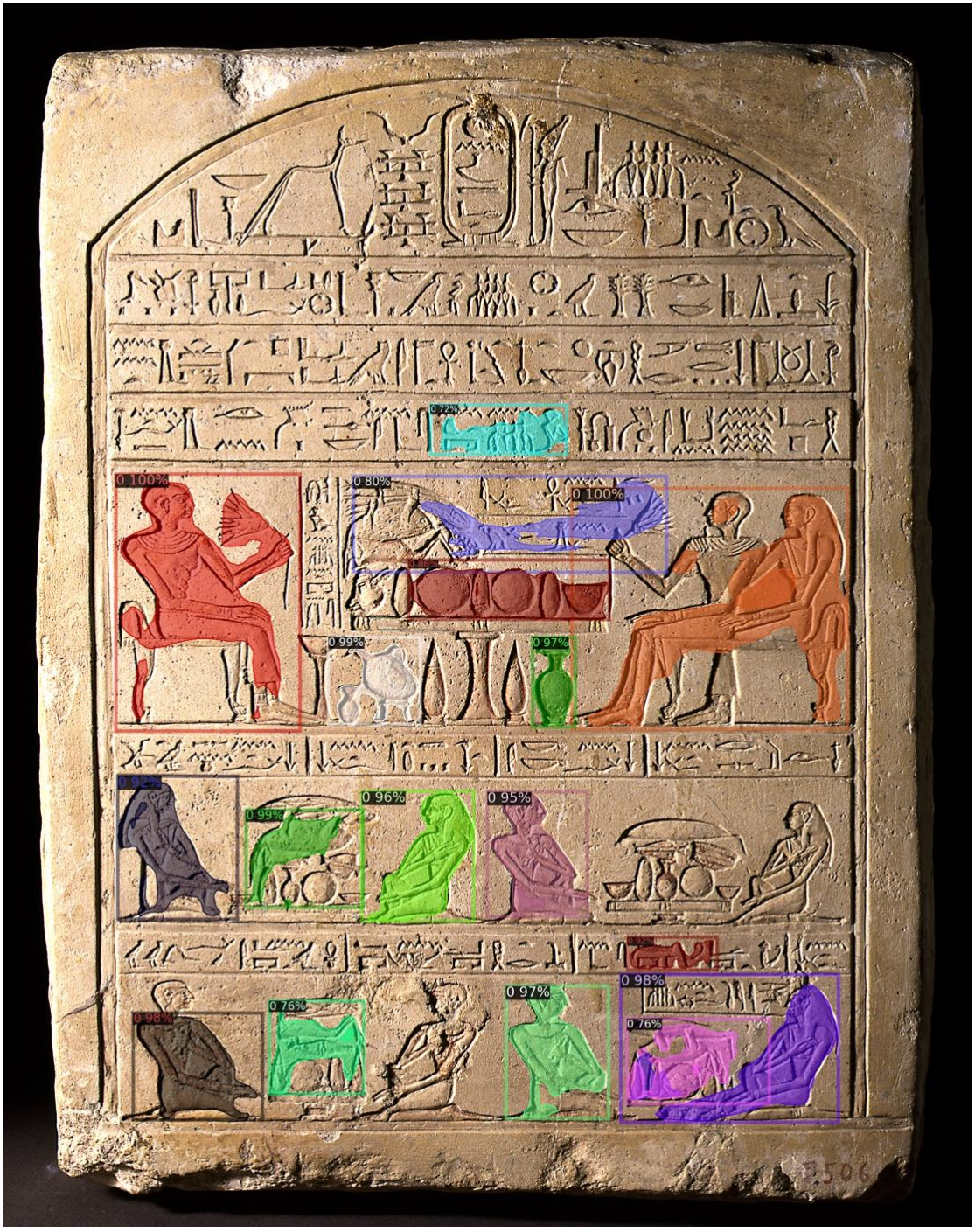

Figure 8.21: Example of segmentation analysis on the "Stela of Senbi", inv. N. 42506 (ME 2506). From the collection of the Museo Archeologico Nazionale di Firenze – "Museo Egizio" (Direzione regionale Musei della Toscana). Reprinted with permission.

Figure 8.22: Example of segmentation analysis on the "Stela of Senbi", inv. N. 42506 (ME 2506). From the collection of the Museo Archeologico Nazionale di Firenze – "Museo Egizio" (Direzione regionale Musei della Toscana). Reprinted with permission.

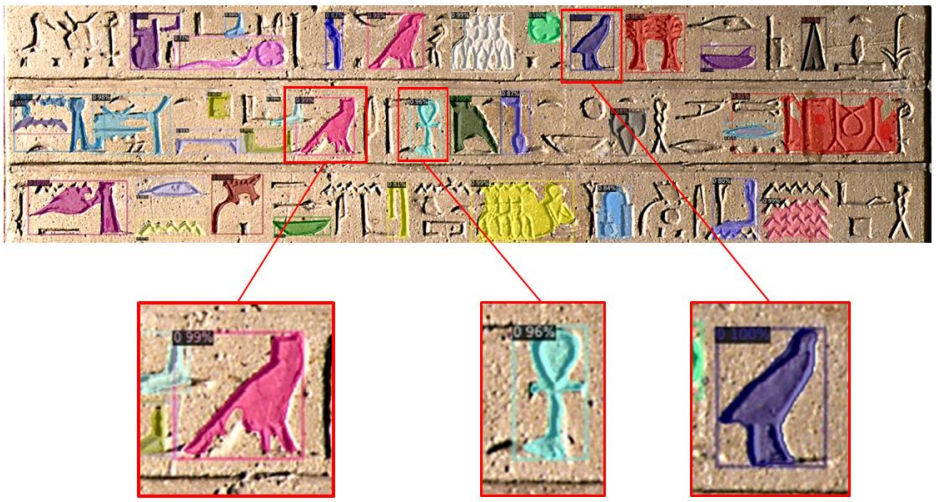

Figure 8.23: Example of segmentation analysis on a patch coming from the "Stela of Senbi", inv. N. 42506 (ME 2506). From the collection of the Museo Archeologico Nazionale di Firenze – "Museo Egizio" (Direzione regionale Musei della Toscana). Reprinted with permission.

Figure 8.24: Example of segmentation analysis on a patch coming from the "Stela of Senbi", inv. N. 42506 (ME 2506). From the collection of the Museo Archeologico Nazionale di Firenze – "Museo Egizio" (Direzione regionale Musei della Toscana). Reprinted with permission.

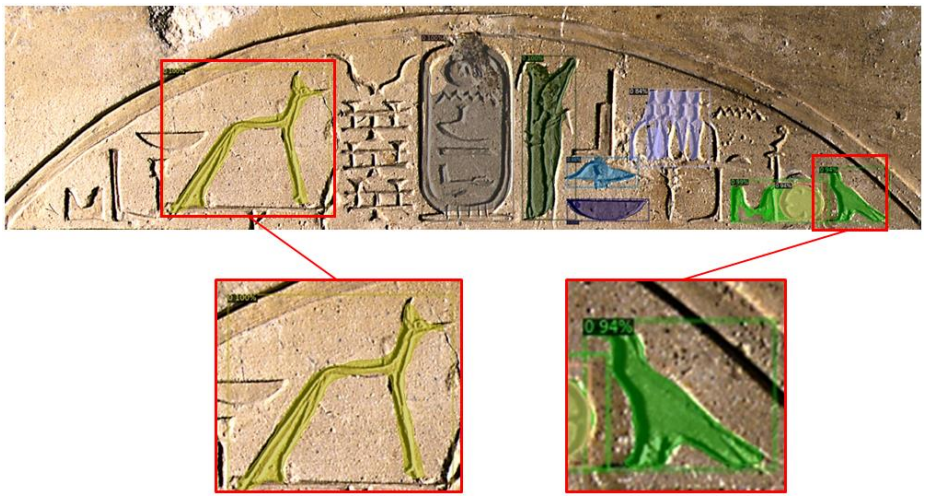

Figure 8.25: Example of segmentation analysis on a patch coming from the "Stela of Senbi", inv. N. 42506 (ME 2506). From the collection of the Museo Archeologico Nazionale di Firenze – "Museo Egizio" (Direzione regionale Musei della Toscana). Reprinted with permission.

Figure 8.26: Example of segmentation analysis on a patch coming from the "Stela of Senbi", inv. N. 42506 (ME 2506). From the collection of the Museo Archeologico Nazionale di Firenze – "Museo Egizio" (Direzione regionale Musei della Toscana). Reprinted with permission.

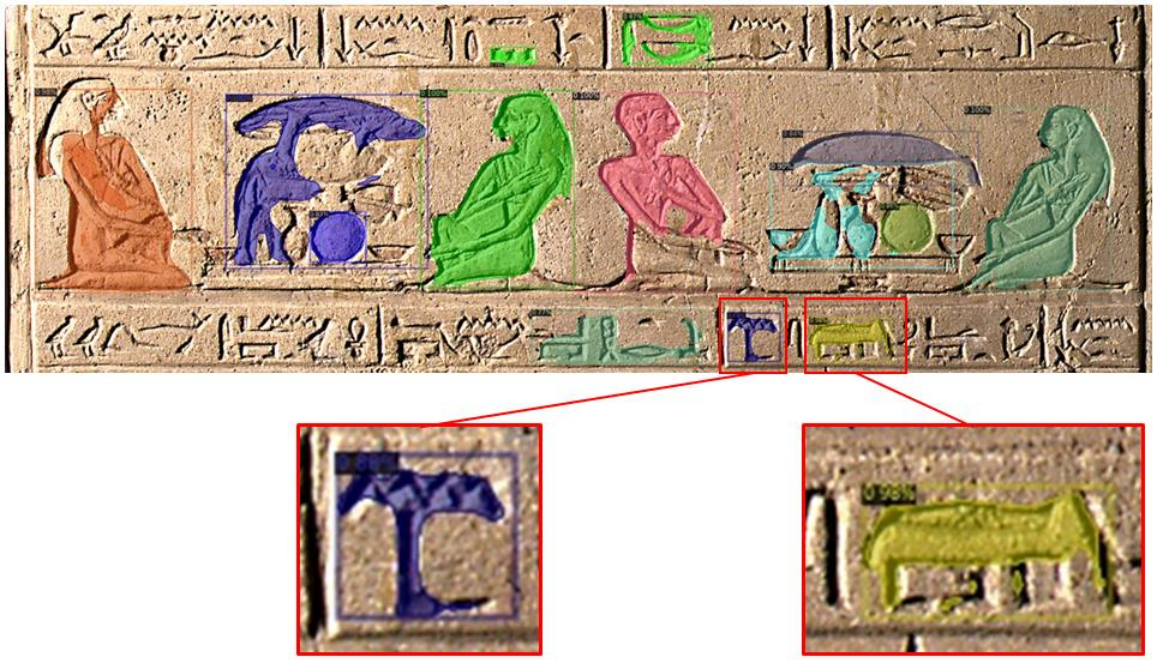

Figure 8.277: Example of segmentation analysis on a patch coming from the "Stela of Senbi", inv. N. 42506 (ME 2506). From the collection of the Museo Archeologico Nazionale di Firenze – "Museo Egizio" (Direzione regionale Musei della Toscana). Reprinted with permission.

Figure 8.28: Example of segmentation analysis on a patch coming from the "Stela of Senbi", inv. N. 2506 (ME 2506). From the collection of the Museo Archeologico Nazionale di Firenze – "Museo Egizio" (Direzione regionale Musei della Toscana). Reprinted with permission.

8.1.5 - Canopic box of Takharu

Figure 8.29: Original picture of the "Canopic box of Takharu" [5], inv. N. 42184 (ME 2184). From the collection of the Museo Archeologico Nazionale di Firenze –"Museo Egizio" (Direzione regionale Musei della Toscana). Reprinted with permission:

Canopic box of approximately cubic shape, closed by a slightly rounded lid; two knobs on the lid and on the side of the cassette allowed to close it using a string that tied them both. The upper part of the walls ends in the shape of an Egyptian gorge. Inside there are two rectangular doors painted black that open on four compartments, made through four partition walls. The lid and exterior walls are fully decorated. On the lid is depicted the goddess Nut, with outstretched wings, kneeling over two images of Anubis in the form of jackal. On the sides are painted, two by two, the images of the four sons of Horus alternating with those of the four goddesses in charge of the protection of the deceased. The figures are accompanied by the usual formulas that appear on the canopic jars. (M.C. Guidotti, "A proposito di Deir el-Medina prima della scoperta: un pezzo della collezione Ricci nel Museo Egizio di Firenze", in C. Morigi Govi, S. Curto, S. Pernigotti, L'Egitto fuori dall'Egitto. Dalla riscoperta all'Egittologia. Atti del Convegno Internazionale, Bologna 1991, pp. 209-219).

[5] "Museo Archeologico Nazionale di Firenze (Direzione regionale Musei della Toscana)", Inv. n. 42184 (ME 2184)

Figure 8.30: Example of segmentation analysis on the "Canopic box of Takharu", inv. N- 42184 (ME 2184). From the collection of the Museo Archeologico Nazionale di Firenze – "Museo Egizio" (Direzione regionale Musei della Toscana). Reprinted with permission.

Figure 8.31: Example of segmentation analysis on the "Canopic box of Takharu", inv. N. 42184 (ME 2184). From the collection of the Museo Archeologico Nazionale di Firenze – "Museo Egizio" (Direzione regionale Musei della Toscana). Reprinted with permission.

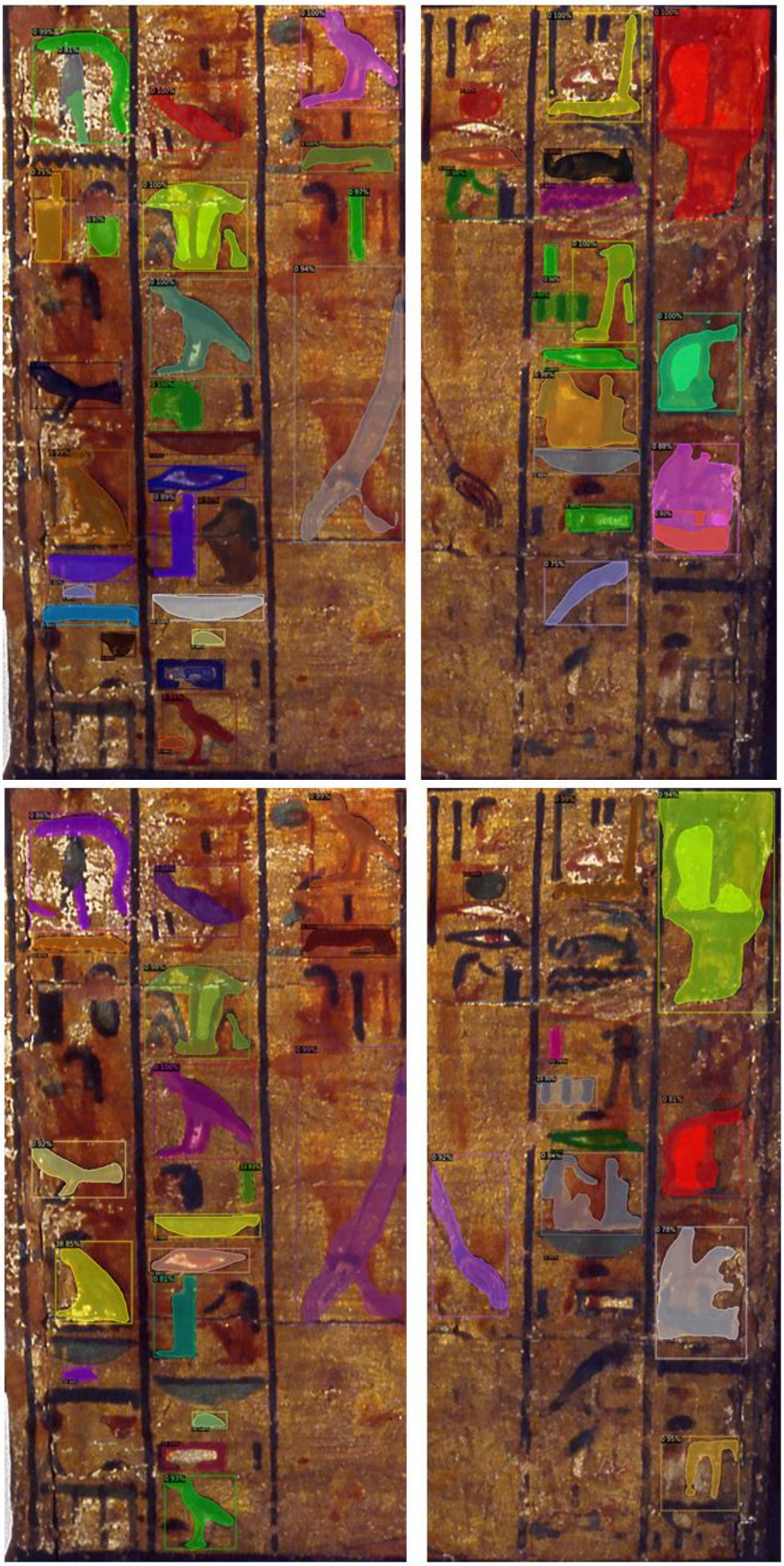

Figure 8.32: Example of segmentation analysis on 4 different patches coming from the "Canopic box of Takharu", inv. N. 42184 (ME 2184). From the collection of the Museo Archeologico Nazionale di Firenze – "Museo Egizio" (Direzione regionale Musei della Toscana). Reprinted with permission.

8.1.6 - Stela of Akhet-tjy

Figure 8.33: Original picture of the "Stela of Akhet-tjy"[6], inv. N. 42497 (ME 2497). From the collection of the Museo Archeologico Nazionale di Firenze – "Museo Egizio" (Direzione regionale Musei della Toscana). Reprinted with permission:

Round-topped stela, dated to the Late Period, with two baboons adoring barque with sun god in lunette and above the winged solar disc. Inside the boat sits the god Ra, holding the feather of Maat, symbol of truth and justice. Below, the sky ideogram is the upper frame of a scene in which a series of deities, including Ra, Nephthys and Isis, are portrayed standing in front of a table of offerings, to which the god Thot leads the deceased. The inscription shows the formula of offer to Ra-Horakhty for Akhet-tjy. (S. Bosticco, Museo Archeologico di Firenze, Vol. III: Le stele egiziane di epoca tarda, Roma 1972, p, pp. 51-53, n. 40).

[6] "Museo Archeologico Nazionale di Firenze (Direzione regionale Musei della Toscana)", Inv. n. 42497 (ME 2497)

Figure 8.34: Example of segmentation analysis of the "Stela of Akhet-tjy", inv. N. 42497 (ME 2497). From the collection of the Museo Archeologico Nazionale di Firenze – "Museo Egizio" (Direzione regionale Musei della Toscana). Reprinted with permission.

Figure 8.35: Example of segmentation analysis of the "Stela of Akhet-tjy", inv. N. 42497 (ME 2497). From the collection of the Museo Archeologico Nazionale di Firenze – "Museo Egizio" (Direzione regionale Musei della Toscana). Reprinted with permission.

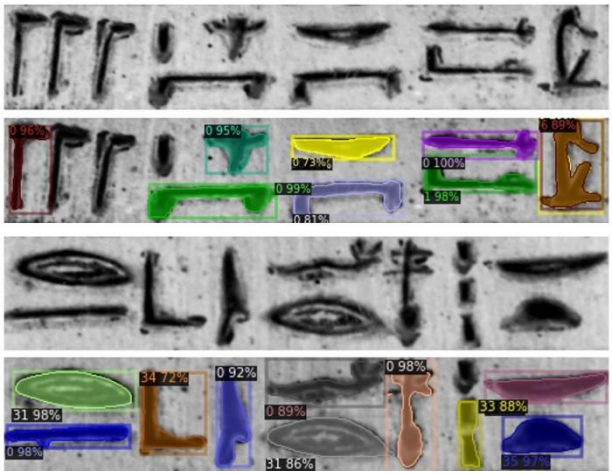

Figure 8.368: Example of segmentation analysis of some patches coming from the "Stela of Akhet-tjy", inv. N. 42497 (ME 2497). From the collection of the Museo Archeologico Nazionale di Firenze – "Museo Egizio" (Direzione regionale Musei della Toscana). Reprinted with permission.

8.1.7 - Jambs of a gateway from the tomb of Djehutihotep at Deir el-Bersha

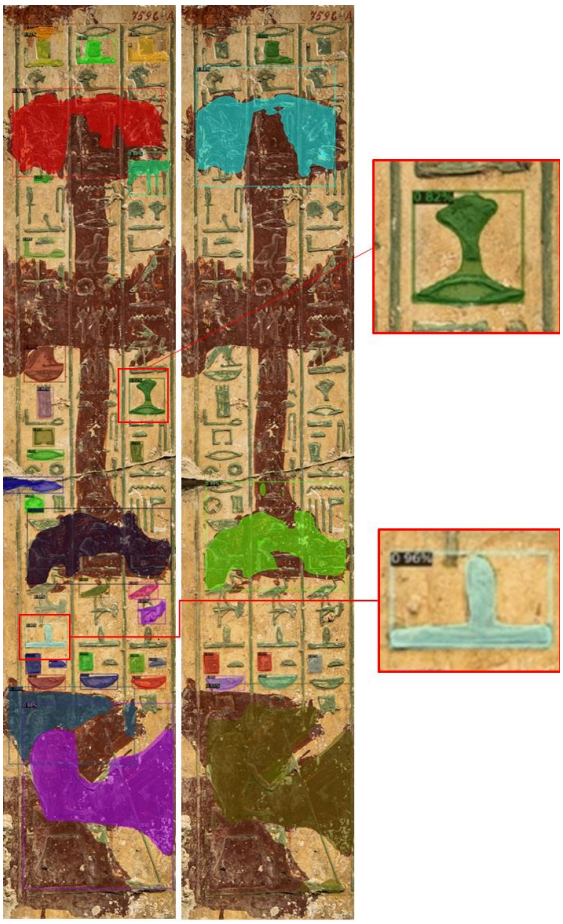

Figure 8.379: Example of segmentation analysis of the "Jambs of a gateway from the tomb of Djehutihotep"[7], inv. N. 47596 (ME 7596). From the collection of the Museo Archeologico Nazionale di Firenze – "Museo Egizio" (Direzione regionale Musei della Toscana). Reprinted with permission:

The tomb of Djehutyhotep, Great Chief of the Hare Nome, is the most important of the tombs of the site of el-Bersheh. These two fragments come from the decoration of the left wall of the inner hall, cut away about in I888 and acquired by E. Schiaparelli during his second expedition to Egypt (1891-1892).

[7] "Museo Archeologico Nazionale di Firenze (Direzione regionale Musei della Toscana)", Inv. n. 47596 (ME 7596)

8.1.8 - Relief: King receives menat from Hathor

Figure 8.38: King receives menat from Hathor[8]. Inv. N. 2468 (ME 2468). From the collection of the Museo Archeologico Nazionale di Firenze – "Museo Egizio" (Direzione regionale Musei della Toscana). Reprinted with permission:

In this relief the King receveis menat from Goddess Hathor. It is the left jamb of the door leading to Corridor G of the tomb of Sethy I (19th Dynasty) in the Valley of the King at Thebes, visited during the Franco-Tuscan Expedition to Egypt (1828-1829). The right jamb is now at Louvre.

[8] "Museo Archeologico Nazionale di Firenze (Direzione regionale Musei della Toscana)", Inv. n. 2468 (ME 2468)

Figure 8.3910: Example of segmentation analysis of some patches coming from the "Relief: King receives menat from Hathor", inv. N. 2468 (ME 2468). From the collection of the Museo Archeologico Nazionale di Firenze – "Museo Egizio" (Direzione regionale Musei della Toscana). Reprinted with permission.

Figure 8.4011: Example of segmentation analysis of some patches coming from the "Relief: King receives menat from Hathor", inv. N. 2468 (ME 2468). From the collection of the Museo Archeologico Nazionale di Firenze – "Museo Egizio" (Direzione regionale Musei della Toscana). Reprinted with permission.

Figure 8.4112: Example of segmentation analysis of some patches coming from the "Relief: King receives menat from Hathor", inv. N. 2468 (ME 2468).. From the collection of the Museo Archeologico Nazionale di Firenze – "Museo Egizio" (Direzione regionale Musei della Toscana). Reprinted with permission.

8.1.9 - Relief of Goddess Maat

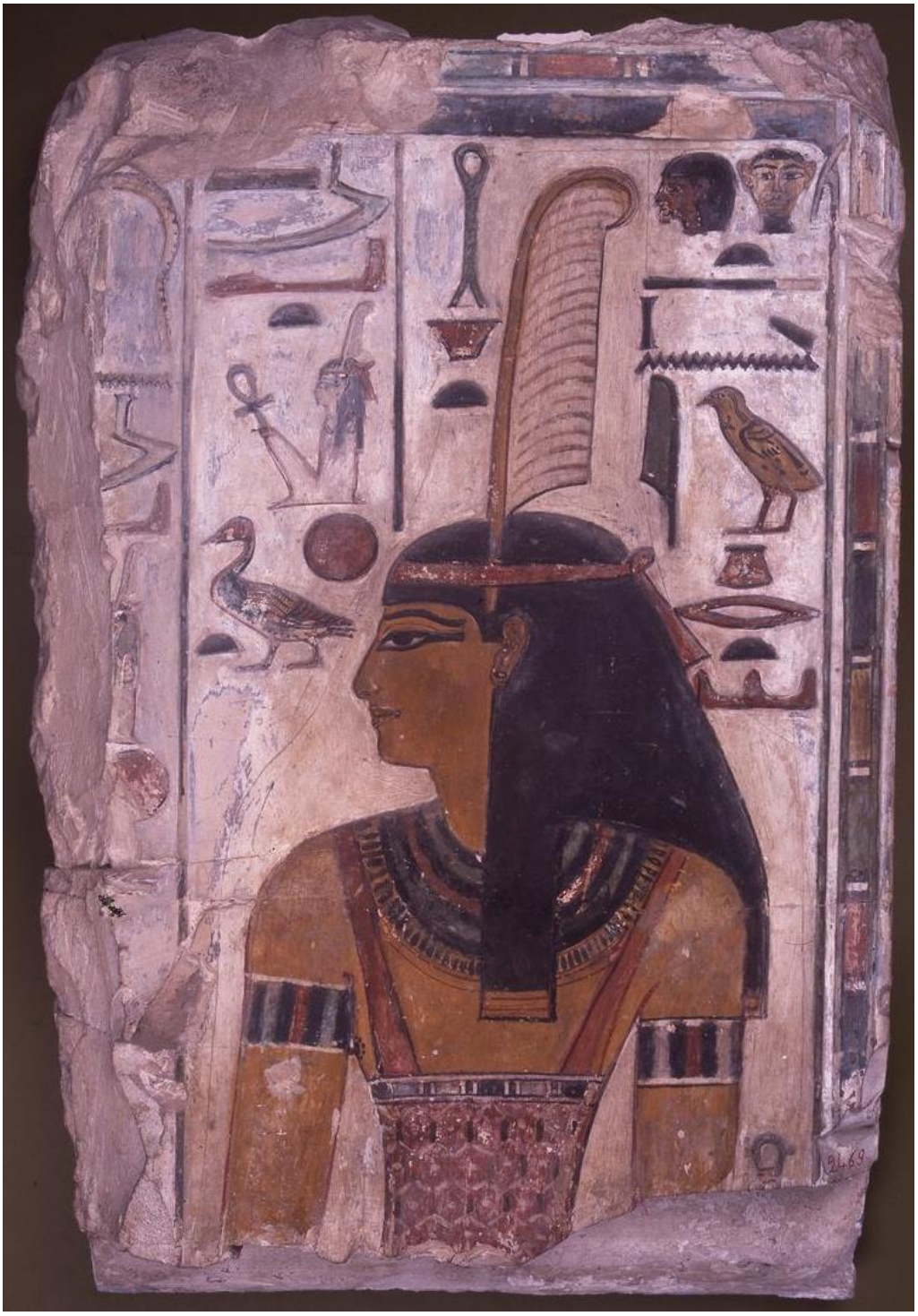

Figure 8.42: Original image on the left and examples of segmentation analysis (on the right) of some patches coming from the "Relief of Goddess Maat" [9], inv. N. 2469 (ME 2469). From the collection of the Museo Archeologico Nazionale di Firenze – "Museo Egizio" (Direzione regionale Musei della Toscana). Reprinted with permission:

In this relief the goddess Maat is represented, surrounded by an inscription that qualifies her as the daughter of Ra and lady of the land of silence, ie the necropolis. The fragment comes from the tomb of Sethy I in the Valley of the Kings, visited during the Franco-Tuscan Expedition in Egypt (1828-1829).

[9] "Museo Archeologico Nazionale di Firenze (Direzione regionale Musei della Toscana)", Inv. n. 2469 (ME 2469).

Figure 8.43: Original image on the left and examples of segmentation analysis (on the right) of some patches coming from the "Relief of Goddess Mat", inv. N. 2469 (ME 2469). From the collection of the Museo Archeologico Nazionale di Firenze – "Museo Egizio" (Direzione regionale Musei della Toscana). Reprinted with permission.

8.1.10 - Stela of Djedmutiusankh

Figure 8.44: Original image of the "Stela of Djedmutiusankh"[10], inv. N. 42485 (ME 2485). From the collection of the Museo Archeologico Nazionale di Firenze – "Museo Egizio" (Direzione regionale Musei della Toscana). Reprinted with permission:

On this round-topped stela, discovered during the Franco-Tuscan expedion (1828-1829) in a 25th Dynasty tomb in Thebes, the dead, a woman called Djedmutiusankh, followed by Maat, is painted in fornt of an offering table adoring the gods Sokar, Isis and Nephtys. At the bottom an offering formula for the dead (S. Bosticco, Museo Archeologico di Firenze, Vol. III: Le stele egiziane di epoca tarda, Roma 1972, p. 19).

[10] "Museo Archeologico Nazionale di Firenze (Direzione regionale Musei della Toscana)", Inv. n. 42485 (ME 2485)

Figure 8.45: Examples of segmentation analysis of a patch coming from the "Stela of Djedmutiusankh", inv. N. 42485 (ME 2485). From the collection of the Museo Archeologico Nazionale di Firenze – "Museo Egizio" (Direzione regionale Musei della Toscana). Reprinted with permission.

8.1.11 - Stela of Tentpessumedju

Figure 8.4613: Original image on the left and examples of segmentation analysis (on the right) of some patches coming from the "Stela of Tentpessumedju" [11], inv. N. 42489 (2489). From the collection of the Museo Archeologico Nazionale di Firenze – "Museo Egizio" (Direzione regionale Musei della Toscana). Reprinted with permission:

Round-topped stela, dated to the Late Period. Above, the winged solar disc under the sign of the sky, used to divide even the other logs. The first one depicts the solar boat, with on the right the ba, a human-headed bird representing the soul of the deceased, a woman called Tentpessumedju. In the second register the woman is portrayed in the act of adoration in front of a table of offerings to which four deities are turned, Osiris, Isis, Nephthys and Horus. Below is an inscription with the offer formula to Ra-Horakhty for the deceased. (S. Bosticco, Museo Archeologico di Firenze, Vol. III: Le stele egiziane di epoca tarda, Roma 1972, pp. 34-35, n. 23).

[11] "Museo Archeologico Nazionale di Firenze (Direzione regionale Musei della Toscana)", Inv. n. 42489 (ME 2489)

Figure 8.4714: Original image on the left and examples of segmentation analysis (on the right) of some patches coming from the "Stela of Tentpessumediu", inv. N. 42489 (ME_2489). From the collection of the Museo Archeologico Nazionale di Firenze – "Museo Egizio" (Direzione regionale Musei della Toscana). Reprinted with permission.

Figure 8.48: Examples of segmentation analysis of some patches coming from "Stela of Tentpessumediu", inv. N. 42489 (ME_2489). From the collection of the Museo Archeologico Nazionale di Firenze – "Museo Egizio" (Direzione regionale Musei della Toscana). Reprinted with permission.

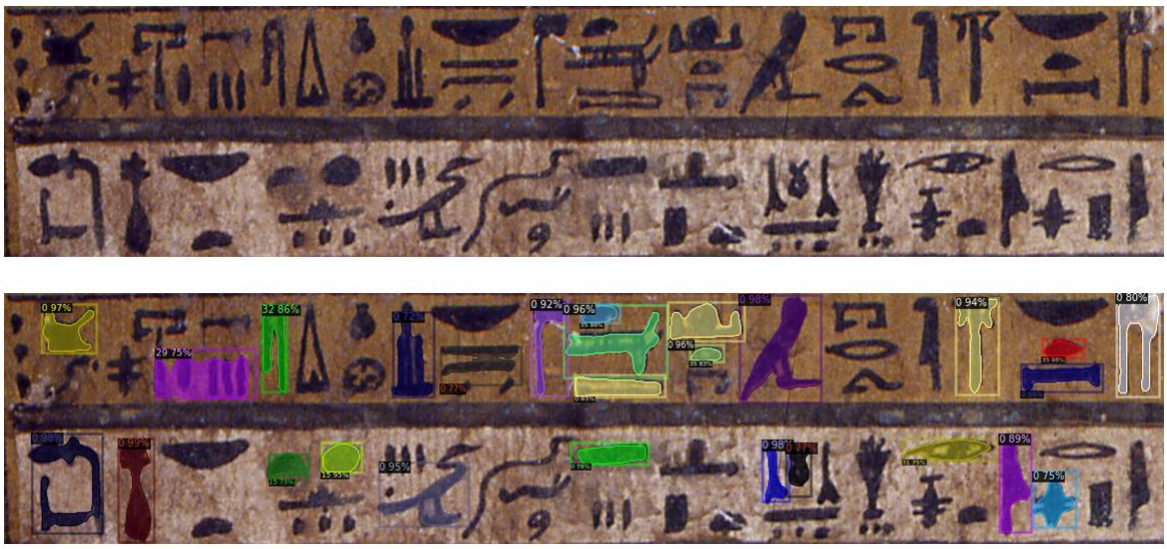

Figure 8.49: Examples of segmentation analysis of some patches coming from the "Stela of Tentpessumediu", inv. N. 42489 (ME_2489). From the collection of the Museo Archeologico Nazionale di Firenze – "Museo Egizio" (Direzione regionale Musei della Toscana). Reprinted with permission.

8.1.12 - Stela of Ankhmutnofret

Figure 8.50: Original image of the Stela of Ankhmutnofret [12], inv. N._42475 (2475). From the collection of the Museo Archeologico Nazionale di Firenze – "Museo Egizio" (Direzione regionale Musei della Toscana). Reprinted with permission:

Round-topped stela, dated to the Late Period. Above a winged solar disc. In the centre Ankhmutnofret, Songstress of the interior of Amun, in adoration before Osiris and Isis. At the botton, two lines of text of an offering formula. (S. Bosticco, Museo Archeologico di Firenze, Vol. III: Le stele egiziane di epoca tarda, Roma 1972, p, 20, n. 9).

[12] "Museo Archeologico Nazionale di Firenze (Direzione regionale Musei della Toscana)", Inv. n. 42475 (ME 2475)

Figure 8.51: Example of segmentation analysis of a patch coming from the "Stela of Ankhmutnofret", inv. N. 42475 (ME 2475). From the collection of the Museo Archeologico Nazionale di Firenze – "Museo Egizio" (Direzione regionale Musei della Toscana). Reprinted with permission.

8.1.13 - Stela of Tjembu

Figure 8.52: Original image of the "Stela of Tjembu" [13], inv. N. 42511 (ME 2511). From the collection of the Museo Archeologico Nazionale di Firenze – "Museo Egizio" (Direzione regionale Musei della Toscana). Reprinted with permission.

Round-topped stela with a girl called Senui (dedicator of stela) libating in front of her parents seated: her mother, Tjembu, and her father, Weri. At the bottom two lines with an offering formula. (S. Bosticco, Museo Archeologico di Firenze, Vol. III: Le stele egiziane del Nuovo Regno, Roma 1965, pp. 19-20, n. 8).

[13] "Museo Archeologico Nazionale di Firenze (Direzione regionale Musei della Toscana)", inv. n. 42511 (ME 2411)

Figure 8.53: Example of segmentation analysis of a patch coming from the "Stela of Tjembu", inv. N. 42511 (ME 2411). From the collection of the Museo Archeologico Nazionale di Firenze – "Museo Egizio" (Direzione regionale Musei della Toscana). Reprinted with permission.

Figure 8.5415: Example of segmentation analysis of a patch coming from the "Stela of Tjembu", inv. N. 42511 (ME 2411). From the collection of the Museo Archeologico Nazionale di Firenze – "Museo Egizio" (Direzione regionale Musei della Toscana). Reprinted with permission.

8.1.14 - Fragment of stela

Figure 8.55: Original image of the "fragment of stela"[14], inv. N 42525 (ME2525. From the collection of the Museo Archeologico Nazionale di Firenze – "Museo Egizio" (Direzione regionale Musei della Toscana). Reprinted with permission:

Fragment of a stela dated to the 18th Dynasty: a man and wife seated, with cat under chair. Two remaining incomplete lines of text mention Hathor chieftainess of Thebes, (S. Bosticco, Museo Archeologico di Firenze, Vol. III: Le stele egiziane del Nuovo Regno, Roma 1965, p. 24, n. 15).

[14] "Museo Archeologico Nazionale di Firenze (Direzione regionale Musei della Toscana)", Inv. n. 42525 (ME2525.

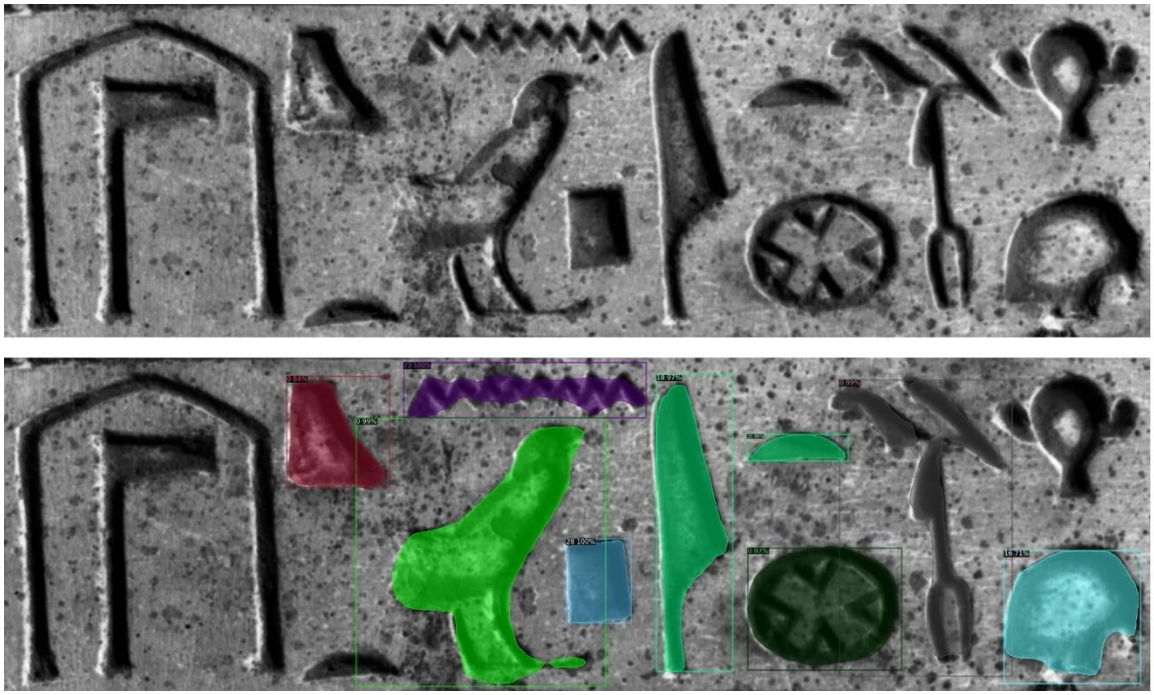

Figure 8.56: Example of segmentation analysis of a patch coming from the "Fragment of stela", inv. N. 42525 (ME2525). From the collection of the Museo Archeologico Nazionale di Firenze – "Museo Egizio" (Direzione regionale Musei della Toscana). Reprinted with permission.

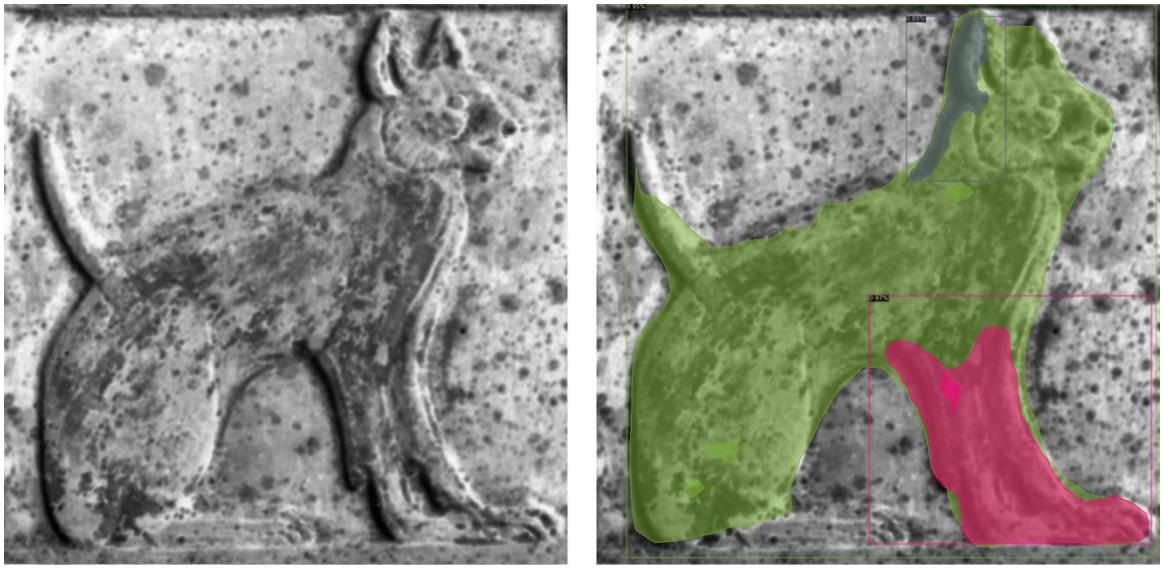

Figure 8.57: Example of segmentation analysis of a patch coming from the "Fragment of stela", inv. N. 42525 (ME2525). From the collection of the Museo Archeologico Nazionale di Firenze – "Museo Egizio" (Direzione regionale Musei della Toscana). Reprinted with permission.

Chapter 9

CONCLUSIONS

The aim of this book is to show how Deep Convolutional Neural Networks can represent valuable tools to be used in support of Egyptologist's work. We have shown how very good results can be obtained if the condition of the hieroglyphs in the picture are suitable for the network to learn the pattern. At the same time, bad results have given us the opportunity to study strategies to mitigate segmentation and recognition problems.

At the moment we are working on that problem, trying to figure out how can we recover lost information from degraded or partially erased hieroglyphs. Many techniques can be used to face this problem, some related to the structure of the convolutional neural network algorithm, some related to the dataset to train the network, some other moving towards images acquisition techniques able to uncover hidden patterns. The first trials have been done, and we hope to share the results with the scientific community in the next months.

It is worth to note that since our first application of this Deep Convolutional Neural Networks on ancient Egyptian Hieroglyphs in 2021, the world is changed. Many other architectures have been proposed with very interesting results, which deserve to be studied. Although there is no universal solution and no one size fits all approach, we are certain that deep learning algorithms will help make significant progress in the pattern recognition of ancient languages over the coming years. In addition, Large Language Models, such as the famous ChatGPT from OpenAI, are opening the era of Artificial General Intelligence, with models apparently for the first time able to show "sparks of Intelligence".

We are just at the beginning, but things are moving quickly, faster than what we expected just six months ago, so who knows which will be the impact of such technology, able to deal with languages, in the field of ancient languages transliteration and translation in the years coming.

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