Digitizing the act of papyrological interpretation: negotiating spurious exactitude and genuine uncertainty

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Abstract

Digital papyrology encompasses artefact digitization and digital support for its interpretation. Digitization is never neutral, and this article presents how, within the e-Science and Ancient Documents project (eSAD), we are developing a software tool that strives to support the act of interpretation while both avoiding spurious exactitude and allowing genuine uncertainty. We first assert that digitization is both sampling and interpreting. Our model of papyrological interpretation thus takes on board the types of expertise that papyrologists draw onto while interpreting ancient and scarcely legible documents. Mimesis serving as a guiding principle, we present how we digitize our text-bearing artefacts (in particular incised documents), taking into account the real-world strategies of the experts. We then argue that, throughout the interpretation process, uncertainty plays a key role, which we illustrate with the example of a Roman stylus tablet that was interpreted twice 92 years apart. To allow the expression of uncertainty, we show how mimesis is again our design strategy: our tool aims to enable the experts to trace the text—a strategy we observed them deploying; further it will support reasoning about hypotheses of interpretation by setting an epistemological framework in which pieces of evidence towards hypotheses of interpretation can be evaluated as in crossword puzzle solving—another expert strategy.

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1 Introduction

The act of papyrological interpretation is a continuous thought process that unravels non-linearly (Youtie, 1963; Terras, 2006). Throughout this sense-making process, ancient and scarcely legible documents progress from the status of pure physical objects to that of meaningful historical artefacts. Within the e-Science and Ancient Documents (eSAD) project,[1] we aim to make explicit some of the implicit mechanisms that contribute to the development of hypotheses of interpretation by designing and implementing a web-based software offering adapted visualization of the artefact and digital support for the interpretative process. This tool aims to support digital papyrology. Digital papyrology, here, designates as much the digitization of the text-bearing artefact as the digitally supported act of interpretation of the document. To support digital papyrology, care must be taken to understand how experts work in order to provide them with a tool that allows them to transfer their

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workflow from the real-world to the digital world smoothly and with minimum overhead (Audenaert and Furuta, 2010).

The model of papyrological interpretation that we have adopted builds upon Terras's (2006) model. It consists in a network of percepts, where a percept is defined as a minor interpretation that stems from perception and cognition (Roued Olsen *et al.*, 2009; Tarte, 2011). An understanding of expert knowledge and of how it is mobilized is thus required in order to identify what the crucial steps of papyrology are. The implementation of an Interpretation Support System (ISS) poses the questions of how to digitize appropriately an artefact and how to record a thought process; it is an epitome of the 'continuous-to-discrete' (or 'analogue-to-digital') problem. The following two considerations also play an important part in the design process of our ISS: the level of granularity at which we choose to provide support is essential to the usability of the software; and each percept, each intermediary interpretation, each piece of evidence used to support or invalidate a claim is potentially mutable.

The ambition of our ISS is to allow users to capture the information necessary to the reconstruction of the rationale that yields a given interpretation. Two difficulties in sampling the artefact and the interpretative thought process are: (1) to take advantage and to beware of the sense of scientific rigour that digitization conveys and (2) to allow the digital expression of uncertainty and mutability.

In this article, we present the theoretical framework in which, while attempting to digitize the act of papyrological interpretation, we strive to avoid spurious exactitude and to allow genuine uncertainty.

2 Digitization is both Sampling and Interpreting

The problem of digitization is a well-known one. It aims to capture digitally, and thus discretely, a continuous, or analogue, phenomenon. The approach usually adopted is to first observe the phenomenon, and then induce a model from it. The model helps to identify the discrete points that need to be captured; it encapsulate a theoretical and formalized description or behaviour of the phenomenon and therefore also provides rules on how, from the discrete points, to reconstruct the full phenomenon. The model always encapsulates tacit hypotheses and often takes, at least in a first instance, a reductionist approach to the understanding of the observed phenomenon through the study of its constituting parts (Frigg and Hartmann, 2006; Cat, 2009). Therefore digitization is not only sampling. The existence of a model demonstrates that some implicit interpretation of the phenomenon has already occurred; the expectations of the scholars are already impacting the digitization process, thereby making the process of digitization not only a sampling technique but also an important part of the interpretation process. In the theoretical and life sciences, measurement devices are developed to sample signals of interest. Then, based on an underlying model of the behaviour of the signal, on the discrete sampled signal, and on more general knowledge of signal processing and information theory (e.g. the Nyquist-Shannon sampling theorem), the continuous signal can be reconstructed with minimal deviation from the original signal. In that sense, the theoretical and life sciences do proceed to interpret and sample concomitantly. For example, most free-hand drawing pieces of software capture points along the curve that is being traced and infer the curve from a model imposing curvature constraints (smoothness of the curve), such as B-splines. The curve can then be reconstructed from the captured points. Associating a general model to a reductionist approach is a natural method to digitize a process; it allows to computationally label and store the digitized elements and to subsequently retrieve and process them. Digitizing the act of papyrological interpretation—i.e. digitizing the object to be interpreted and digitizing the interpretative thought process (or, equivalently, digitally recording it)—is no different. To facilitate digital papyrology, we have therefore adopted the model elaborated by Terras (2006), and we use it as a map to detail our approach to digitizing the act of papyrological interpretation. To build this model, Terras observed experts and identified ten levels of reading. These levels of reading are: (0)

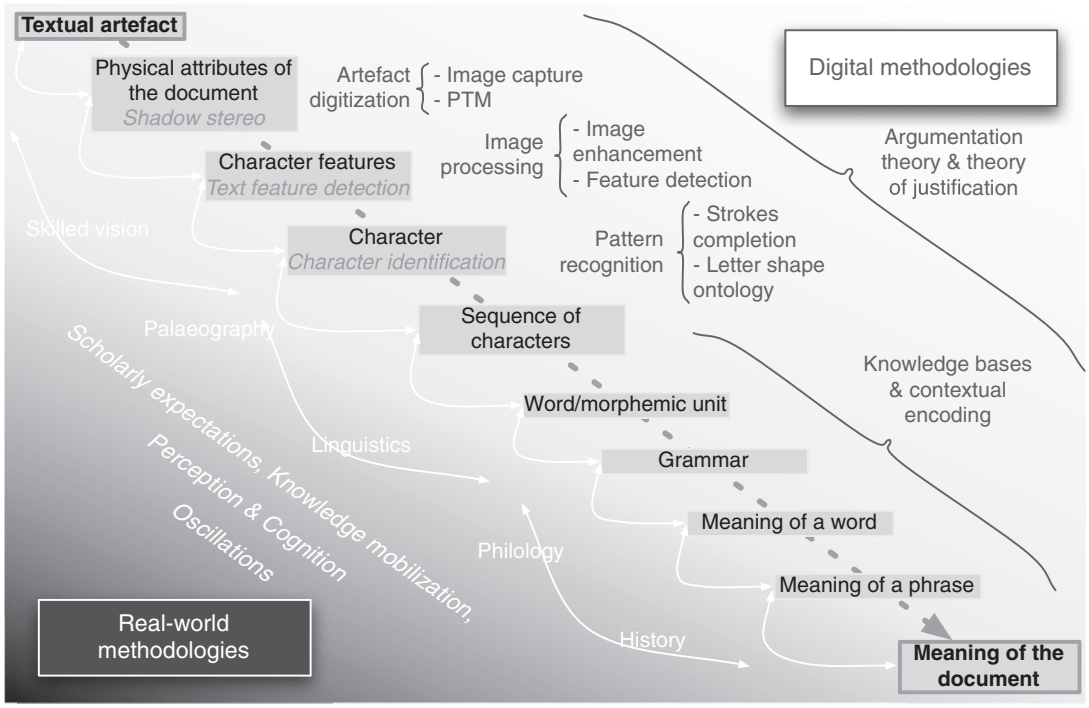


Fig. 1 From Artefact to Meaning, a model of the papyrological interpretative process and how real-world methodologies influenced the choices of digital methodologies. The various levels of reading of Terras's (2006) model are located along the diagonal arrow, middway between the real-world methodologies (deployed by the experts) and the digital methodologies. Importantly, despite the linear display of the levels of reading along the arrow, the interpretative process is strongly recursive and oscillations between the various levels of reading occur constantly (the white arrows). To implement our ISS, we have taken care to first identify the expert methodologies (lower left area) in order to find digital methodologies that can either form their digital counterpart or offer a digital support (upper right area)

archaeological or historical context; (1) physical attributes of the document; (2) features of a character; (3) possible character; (4) possible sequence of characters; (5) possible word or morphemic unit; (6) grammar; (7) meaning or sense of a word; (8) meaning or sense of a phrase or group of words; and (9) meaning of the document. Drawing on this model, we have identified some digital tools and methods that will enable to transfer real world tasks to the digital world (see Fig. 1). Based on further observation and analysis of the experts at work (Tarte, 2011), we have identified that perception and cognition are key elements that trigger the perpetual oscillations that occur between the various levels of reading. However, perception and cognition are both powered and hindered by uncertainty and mutability, which makes them elusive and difficult to capture. Our design choices are therefore always based on the observation of the experts at work to ensure that we do integrate (some of) their implicit/unconscious methodologies. It is through further ethnographic observation of the experts that we are attempting to add to Terras's model, in order to take into account the more holistic aspects of the act of papyrological interpretation, and in particular how the oscillations between the levels of reading occur.

3 Digitizing the Artefact: how to Avoid Spurious Exactitude

The problem of spurious exactitude is most prevalent at the stage where the text-bearing artefact is

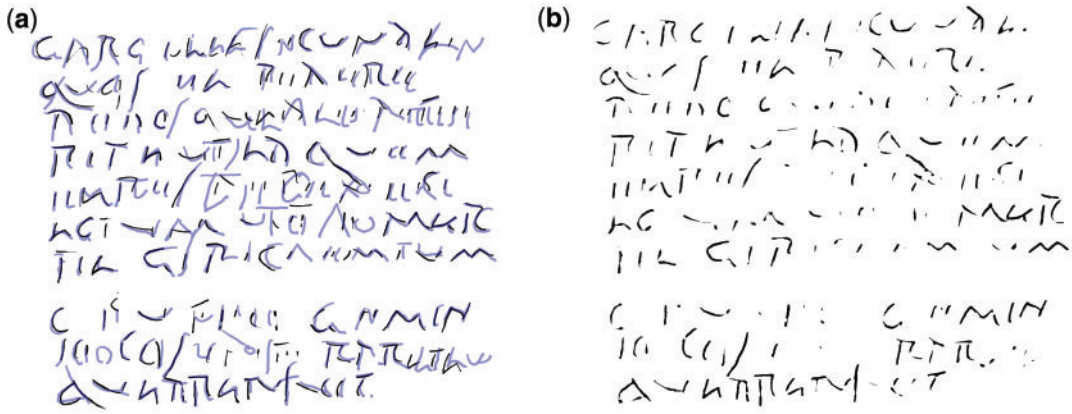
digitized. For Roman stylus tablets, for example, high-resolution pictures are not enough. The materiality of the artefact needs to be taken into account in a way similar to the way the experts exploit it in the real world. Indeed, when papyrologists have physical access to such an incised tablet, in order to see better the incised text, they lay the tablet flat on their hand, lift it at eye level and expose it to raking light while applying pitch-and-yaw motions to it. Similarly, orientalists working on cuneiform clay tablets are familiar with the play of light to enhance the visibility of the impressions left by the reed stylus. What the play of light achieves is to reveal the 3D nature of the text and exploit it; it is a signal enhancement strategy. It exploits the shadow-stereo principle by which stronger and more mobile shadows and highlights occur at the text than they do on the bare surface; the script is thereby accentuated. The guiding principle we thus choose to follow in this context is mimesis. Digitally imitating the real-world process and thereby integrating the shadow-stereo interpretation strategy in the sampling of the artefact, we capture series of images of incised tablets with varying light positions (Brady *et al.*, 2005; Tarte *et al.*, 2010). Users can then reproduce digitally the visual phenomenon they naturally exploit in the real world. The set-up consists of positioning a digital camera above the text-bearing artefact and to snap a picture for a range of light positions around the tablet (with a marked preference for raking light). A mathematical model of the influence of the light position at each pixel allows us, from the images with recorded light position, to simulate images with light positions that were not recorded (Malzbender *et al.*, 2001; Goskar and Earl, 2010). A piece of software[2] then allows users to interactively visualize the artefact in various lighting conditions. Similarly to what the life sciences do with signal measurement devices, we adopt a digitization procedure that is already part of the interpretation process. The intention behind artefact digitization, as well as the intention behind signal measurement, is always an implicitly set variable that affects downstream results. The advantage of such an explicit digitization strategy is that not only it imitates the real-world strategy, it also makes salient the fact that the digitization was made with a given purpose in mind. It is a way to support interpretation at the levels of reading in our papyrological model that are concerned with the physical attributes of the document and the features of characters (see Fig. 1). By making the artefact digitization process as similar as possible to the experts' real-world methodology, we significantly reduce the likelihood that users attribute spurious exactitude to the digital records and we make explicit one of their implicit and intuitive strategies.

4 Digitizing the Interpretation Process: how to Allow Genuine Uncertainty

An important aspect of digital papyrology—and a main aim of the eSAD project—beyond the digitization of the artefact, is to enable the digital capture of the thought process that builds interpretations of ancient and damaged texts. The aspects dealing with capturing the information at the levels of reading defined by Terras's papyrological model of reading have been described elsewhere: Roued-Cunliffe (2010) presents how she makes use of knowledge bases and contextual encoding at the word and group of words levels; and in (Tarte *et al.*, 2010) we present in more technical details the image capture and processing aspects of the research (see Fig. 1). The focus of this section is rather on what happens between the levels of reading and how it can be integrated in the design of our ISS. Previous research has already established that some of the triggers of the jumps between the levels of reading are: visual skills, scholarly expectations, and aspect shifting (Tarte, 2011). In other words, perception, cognition, and mutability not only have their role to play, they are inherent components of the meaning-building process.

4.1 Of the importance of uncertainty

One commonality between the triggers governing the oscillations between levels of reading is that they all possess an intrinsic and mutable uncertainty. Evidence of this uncertainty is presented in Figure 2, and stems from the case study of a Roman tablet that was interpreted twice (Vollgraff, 1917;



(c)

1917 transcription	2009 transcription
GARGILIUS SECUNDUS N(ummis)	ĢARǪ ỊỤLIA SECUNDAẸ
CXV A S[T]EL[O] RIIPERII	QUOS EA REDERE
BEEOSO VILA LOPETEI	ḌEḆO QUA DIẸ PEṬIE
RITE UTI L(icet) BOVEM	RIT AUT AD QUEM
EMI TESTE CESDIO C(enturion)I	EA RES PERTINEBI
LEG(ionis) V MUTO ADMETO	ACTUṂ VĪ Ḳ MAR
C(enturion)I LEG(ionis) I R(edhibitio) I(us) C(ivile) A(besto) EMTUM	TIA ĢIṚ.C.ḖMIUM
C FUUFIO GN MIN	C FUFḖǪ GEMIN
ICIO COS V [I]D(u)S S[EPTEMBRES] R(ebus) P(raestari) R(ecte) LILUS	IO COS ..T.RPR.TA
DUERRETUS VET(eranus)	QUADRATUS VIT

Fig. 2 Comparing two interpretations of the front of the Toslum tablet. The Tolsum tablet was first interpreted as a bill of sale of an ox, dated (with much uncertainty) 116 AD (Vollgraff, 1917); and, 92 years later, it was interpreted as a debt acknowledgement, dated (with little uncertainty) 29 AD (Bowman *et al.*, 2009). (a) Tracings of the text on the front of the tablet; in blue/grey, the 1917 tracing; in black, the 2009 tracing. (b) Commonality (strict overlap) between the 1917 and 2009 tracings of the front ot the tablet. It consists in 45.3% of the 1917 tracing, and in 60.6% of the 2009 tracing. (c) Transcripts of the text on the front of the tablet; letters in green/grey highlight agreement on the identification of individual glyphs as characters. Levenshtein distance between the two transcripts: 103 (strings of length respectively 200 and 163, including spaces). The proportion of characters in common (excluding spaces) consists in 43.6% of the characters in the 1917 reading and in 55.5% of the characters in the 2009 reading

Bowman *et al.*, 2009). The 2009 re-transcription was motivated by a wish to revisit the text to clarify its date using current imaging technology. As a result, not only the date was elucidated, but the whole tablet was entirely reinterpreted. The two editions now attribute to the document two notably divergent meanings: the 1917 edition interprets the text as a bill of sale of an ox dated 116AD; the 2009 edition interprets it as a debt acknowledgement dated 29AD. By comparing both tracings of the texts as well as both transcripts, we can attempt to identify how this divergence occurred and what role

uncertainty plays. The first striking observation is that, by overlapping the tracings (Fig. 2a), one can deduce that what was seen by both 1917 and 2009 editors is actually quite similar. The strict overlap of the tracings (Fig. 2b) shows that 45.3% and 60.6% of the respective full traces overlap; close inspection of the superimposed traces shows further that in many cases, the lack of overlap is only due to a shift, suggesting that the commonality between the tracings is even higher than that suggested by the strict overlap. It is through that shift that uncertainty is made visible at the palaeographical level. Similarly, at the character level of the script, one can compare how individual glyphs were read as the same character (Fig. 2c): 43.6% of the glyphs in the first reading are an exact character match to 55.5% of the glyphs in the second reading. The divergence appears unequivocally, although there is still quite some agreement as far as the actual letters are concerned. In fact, it is by revealing the certainty of some aspects of the tracings and transcripts that the uncertainty becomes evident. It is where there is uncertainty that the constraints imposed by the document on its interpretation(s) are the loosest and that there is room for the development of diverging interpretations. The grouping of the letters and the semantics of the text are where the gap between the two editions can further widen.

The tracing of the text and its transcript are two types of 'processed evidence' that are usually presented in an edition of an ancient document and that support its interpretation. Interestingly, they also are the reflections of the two types of strategies that the experts develop when tackling an interpretation: the kinaesthetic/palaeographical approach, which gives a predominant role to the shape of the text by drawing it as it is seen; and the cruciverbalistic[3]/philological approach, which gives a predominant role to the semiotic aspects of the text and proceeds to decipher it as one would solve a crossword puzzle. These approaches are not mutually exclusive, and experts resort to both methods, usually favouring the approach that relates best to their personal skills. These strategies were identified through an ethnographic study of experts deciphering a Roman incised tablet; details of this study are fully reported in Tarte (2011). The tracing and transcript are 'pieces of evidence' brought towards a given interpretation in the final edition. They are usually initialized when the interpretation task is started. They then mutate throughout the act of interpretation until they reach a point at which the experts are satisfied with them. It is therefore essential to integrate a counterpart to these real-world research strategies in our ISS.

4.2 The kinaesthetic approach to interpretation

One advantage of the kinaesthetic approach is that by drawing the text as a shape, one is not forced to make a decision as to which stroke belongs with which other stroke. One does not have to see a character in a group of strokes, and although one usually does so—'seeing and knowing are not two distinct operations' (Cohn, 2007)—there is no commitment to the identification of a group of strokes as a symbol. So by allowing users to draw without requiring strokes to be grouped into characters, we can allow the intrinsic uncertainty to be embedded in the action performed by the user. By regularly saving the iterations of the drawing of the text, one can see the evolution in the interpretation and potentially identify when a commitment to grouping strokes into a character is made: the drawing progressively reconciles the mental image that the expert has of the text with the actual digital image(s) of the text. In that sense, the act of drawing to inform and build interpretation inscribes itself in an embodied model of cognition, where active interaction with the physical world is an integral part of the cognitive process (Shapiro, 2010).

4.3 The cruciverbalistic approach to interpretation

Complementing the kinaesthetic approach, the cruciverbalistic approach operates at the semiotic and semantic levels; this approach is more closely related to a connectionist view of cognition (McClelland and Rumelhart, 1981). It relies on clues given by the images of the text and the already identified letters (see Fig. 3). In the final edition, the uncertainties of the reading are expressed on a character-by-character basis via the Leiden conventions (van Groningen, 1932). Roued-Cunliffe (2010)

What character is this glyph:  ?
(glyph traced in white on the images below)

"Clues" (images) and "filled-in boxes" (characters)	*Hypothesis*	*Corresponding supporting evidence*
	Vowel	After QU
 Q U * D R * T U S	E	Vowel Read so in 1917
	A	Vowel Makes a known name
 * D Q U E M	L	Read so in 1917
	A	Occurs in legal documents
 * C T U M	L	Read so in 1917
	A	Occurs in legal documents

Fig. 3 A papyrological crossword puzzle. This table presents a part of the rationale that the experts developed in 2009 while working on the Tolsum tablet, and particularly on the identification of this letter form. The most robust hypothesis is that of the glyph being an 'A', and it was interpreted as such as can be seen in the transcripts in Fig. 2

presents how this is taken into account in her work, and what we are concerned with here is more with the theoretical formalisms that can serve as a backdrop to support the thought process expressed through these conventions. Note that in contrast to projects such as TILE[4] where both images and transcriptions already exist, in this project, the link between image and transcription is created while the transcription is being produced. Our ISS needs to provide a formal system as a backbone to support reasoning under uncertainty and make explicit some of the implicit mechanisms, however, excessive formalism and explicit formulation can become a hindrance and generate an overhead disruptive to the interpretation process; we need to find a balance between those two essential requirements (Shipman III and Marshall, 1999), and it is the understanding of expert methodologies that informs us on how to reach an acceptable compromise. When applying the cruciverbalistic approach, experts need to convince themselves that all relevant pieces of information have been taken into account and that ultimately the text makes some sense as a unit. A numerical approach to uncertainty such as Bayesian networks could have been adopted on a letter by letter basis with injection of information from known words , but quantifying uncertainty is always risky and usually presupposes that problems are complete, i.e. that all the alternatives to a given situation are known (Parsons and Hunter, 1998), which is far from being the case in a papyrological context. Instead, we have decided to turn to argumentation theory (Parsons and Hunter, 1998) and theory of justification (Haack, 1993), and combine them to provide a formal, yet invisible, epistemological framework that allows us to point out inconsistencies without forbidding them. Indeed, inconsistencies in an unravelling interpretation naturally occur; they are a natural consequence of uncertainty, and one of the sources of creative thinking that add to knowledge. Those tensions can be rooted either in the implicit expectations of the user or in the validity of the actual claims, and their resolution is at the core of knowledge creation (see Tarte (2011) for an account of an inconsistency that lead to the explicit revision of an implicit assumption). Justification theory concentrates on evaluating how good a piece of evidence is with respect to a given claim, where a claim is an interpretation of a character or of a group of characters or word. In a chain of reasoning, where a claim resulting from a reasoning process plays subsequently the

role of evidence towards or against another claim, evaluating the goodness of a piece of evidence eventually enables to evaluate the goodness of the whole rationale and to identify its weak points. In her book, Haack (1993) proposes a theory of justification in which three criteria enable to evaluate the goodness of an argument.[5] All three criteria come in degrees, and it is the combination of the three criteria that allows the evaluation of the goodness of an argument. They are:

(1) Favourableness: this criterion allows us to assign a degree of favourableness to a piece of evidence; it ranges from preclusive to conclusive, via undermining, indifferent (yet relevant), and supportive. Essentially, what the favourableness criterion relies upon is comparison with alternatives to the claim the evidence is brought to. The more conclusive the evidence, the less there is 'room' for the alternatives. Note that no notion of negation of a claim is used, but rather of alternatives (competitors) to a claim. This criterion enables to capture the mutability of the uncertainty as more clues (primary, like the image or shape of the text, or secondary like the identified characters) are uncovered and restricts the space of possible alternatives.
(2) Independent security: this is where papyrological and epistemological crosswords meet. The idea is that, like in a crossword puzzle, given clues and a partially completed grid which constitute the contributing evidence, the validity of a specific claim is not affected by the removal of one piece of evidence that directly supports it. In short, the whole argument does not collapse upon removal of a piece of evidence, the consistency of the system is intact even if it is weakened. In Figure 3, this criterion allows to state that the hypothesis of the glyph being an 'A' is the most robust one.
(3) Comprehensiveness: the comprehensiveness criterion is the trickiest criterion. It is evaluated on the basis of the consideration of all the relevant pieces of information towards a given claim. An argument that lacks in comprehensiveness is one that fails to take all relevant evidence into account. A parallel can be drawn here between the notion of comprehensiveness and the notion of complete problems. A comprehensive argument is one that does not fail to take all relevant pieces of information into account. Through this criterion, the mutability of uncertainty can also be expressed through the progressive accumulation of relevant evidence.

Additionally we are evaluating a methodology from Argumentation Theory called Schemes and Critical Questions (Walton, 2009). It establishes a framework in which modes of reasoning that cannot be tackled by inductive or deductive logics can be addressed by: (1) making some of the implicit assumptions explicit (dealing with enthymemes and uncovering fallacies); and (2) testing the strength of the arguments and evidence. A number of schemes fitting specific modes of reasoning have been identified (Walton et al., 2008), and the ones fitting best the case of papyrological reading and interpretation happen within dialogues that can be categorized as: persuasion, inquiry, negotiation and deliberation; they fall into schemes such as: practical reasoning, argument from analogy, argument from alternatives, argument from precedent, argument from sign and argument from expert opinion. For the purposes of our ISS, I intend to develop a specific scheme with its accompanying set of critical questions, fitting the particular case of (dialogical) argumentation about papyrological evidence and integrating Haack's (1993) approach to evaluating evidence.

This theoretical framework lays the grounds for the implementation of an intelligent digital counterpart to the real-world cruciverbalistic and kinaesthetic strategies in our ISS; it will also allow us to capture naturally occurring uncertainty.

5 Conclusion

Digital technologies can easily trick the mind into thinking that their use confers an exactitude to the results obtained with their support. It is however worth noting that in the sciences too, digitization is always made with an intention and expectations. When looking to sample a continuous signal, be it a

temperature as a function of time, or a thought process as a function of time, the sampling strategy is always adopted in the light of an intention encapsulated within a model. Digitization is not only a sampling exercise, it is an integral part of the interpretation process. To digitally record the continuous papyrological interpretation process, we have to identify clearly our final aim, and to adapt our sampling strategy to that aim. We have presented how mimesis is our constant guiding principle: (1) at the stage of the digital capture of the textual artefact, where we adopt a strategy that imitates the real-world actions of the experts; (2) and at the stage where one or more interpretations are unravelled. We have stressed how important the uncertainty is as a factor that powers the interpretation process and exposed how we propose to allow this uncertainty to by ported to the digital world by following our mimesis principle: experts draw; experts emit hypotheses and handle them as crossword clues and answers; analogously our ISS will allow experts to follow these strategies in the digital world. Our aim is to enable to record, reconstruct, back-track if necessary, the interpretation process by making explicit (some of) the epistemological evidence substantiating the interpretation in progress; a secondary aim, that comes as an added benefit to the software, is also that it will enable easier production of an edition of a text, as the evidence will have been laid out clearly. In that sense, the ISS we are developing can be seen as an addition to Ciula's (2009) work on palaeographical methods and to Cayless's (2009) linking of segmented images and text, as what we are attempting to capture is the workflow of the papyrological interpretation process. Capturing uncertainty is vital to the recording process, and being conscious that its very capture is also part of the interpretative task is crucial to allow the software to take on board the elements that are core to the interpretation task as a cognitive process.

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Notes

1 Project website: http://esad.classics.ox.ac.uk/

2 See for example the piece of software developed by Research at HP Labs: http://www.hpl.hp.com/research/ptm/ (accessed 6 April 2011).

3 The neologism 'cruciverbalistic' was coined in (Tarte, 2011) and inspired from the French term designating a crossword puzzle aficionado, 'cruciverbiste'—from the Latin nouns: crux-ŭcis,f: cross; and verbum-i, n: word.

4 TILE website: http://mith.info/tile/ (accessed 6 April 2011).

5 Note that throughout this article I use the terms 'evidence', 'argument' and 'pieces of evidence' interchangeably.

6 AHRC EPSRC JISC e-Science initiative website: http://www.ahrcict.rdg.ac.uk/activities/e-science/awards_2007.htm (accessed 6 April 2011).