Visualising uncertainty in archaeological reconstructions: a possibilistic approach (sketches_0546)

Maria Sifniotis* Ben Jackson Martin White Katerina Mania Phil Watten
University of Sussex, UK

Methodology

For the past decade, 3D archaeological visualisations have mostly been representing photo-realistic reconstructions of ancient monuments. While these can be constructive in a museum or tourist context, the archaeological community has long stressed the need for reconstructions showing where the actual remains end and the assumptions begin. Recent attempts to implement the latter approach are either limited to found/not found scenarios or marking of uncertain areas without any justification to the choice of colour/hue degradation etc. As a result, there is no system to represent the uncertainty involved in visualising archaeological data. The archaeologist interprets a site based on a limited amount of material remains and uses comparative evidence from other sites, written references, as well as speculation in order to create a reconstruction. Due to this varied range of data, he/she may have different levels of certainty on some areas of the reconstruction than others. If we are able to observe this uncertainty on the visualisation itself, it would provide us with a whole new range of uses for archaeological models, such as learning about archaeological hypotheses, comparing uncertainties across different models and highlighting cases where further research may be required.

Previous research has indicated that a fuzzy logic approach can represent the uncertainty of a complete archaeological reconstruction. However, fuzzy logic is specifically designed to deal with imprecision of facts – such as "the degree to which a fragmented tile belongs to the family of Roman tiles," rather than describing an archaeologist's interpretation confidence. Our approach uses possibility theory [Dubois and Prade 1988], an extension of fuzzy sets and fuzzy logic, to represent uncertainty in visualisation; it is a mathematical theory for dealing with uncertainty and an alternative to probability theory. While the latter works best with precise but varied knowledge, possibility theory does not expect such precise information – but we do hope for the greatest possible coherence from experts. Possibility theory has been used to describe human uncertainty in medical case studies with success and one of its strengths is the ability to provide both ordinal and numerical answers, whereas probability allows only for numerical. To briefly summarise its basic functions, let X be a variable for which we do not have full knowledge i.e. the shape of a capital missing from a Greek column, and Ω_x the set of values X can take (e.g. Ionic, Doric). A possibility distribution $\pi_x(\omega) \rightarrow [0,1]$ describes the extent to which it is possible that the actual value of X be Doric (ω). Let A be an event subset of Ω, so the possibility measure that A is correct is $\Pi(A) = sup_{\omega \in A} \Pi_x(\omega)$. $\Pi(A)$ expresses the level of possibility that the capital is one of the set associated with A. Possibility has also a complementary measure, necessity, which represents the possibility of the contrary event: $N(A) = 1 - \Pi(\neg A)$ Combination of the two measures aids in statement as: *I am quite certain that the column is probably Doric but I also accept the possibility that it can be Ionic.*

Based on the above, we have designed a system where the archaeological model is a composition of found and hypothesised parts. In order to derive the possibility degrees, the archaeologist is asked a series of questions about the unknown parts to which the responses are ordinal answers and the replies are fed into a possibility model. The calculated result is an uncertainty value assigned to every part, controlling its visualisation – as the uncertainty grows stronger the colour/hue/intensity changes. The user is able to choose from colour schemes which represent ordinal perceptually-ordered pseudocolour sequences [Ware 2000]. Pseudocolouring is a technique of representing varying values using a sequence of colours. If a value Y lies between X and Z, in an ordinal pseudocolour sequence the colours should have the same ordering scheme to allow perceiving the ordering of values. The colours change towards an opponent channel (black-white, red-green, yellow-blue) or by saturation; the crucial requirement is the change towards opponent colour space (Fig. 1). This approach can also allow us to retrieve uncertainty for an artefact or group of artefacts by calculating their combined uncertainty.

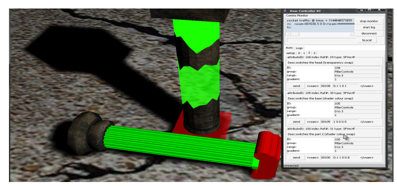

Figure 1: Representation of a column

In order to apply our design, we are using as a case study a Romano-British building, of either a religious or military nature. Our system uses X3D to display the site, with its uncertainty visualised by shaders. The system is composed of two distinct parts: visualisation, and control. Visualisation displays the model through which the user can navigate, and also sends and receives feedback from the control area. The latter allows the user to select different parts of the model in order to answer questions and assign values. Once all the objects in the scene have associated certainty values, the user can select a particular visualisation scheme to be applied to the model. These schemes are swapped by using X3D shaders. The underlying visualisation and communication services are supported by an author-friendly, run-time configurable X3D interaction system. The system supports network distribution to provide extensibility of processing requests and collaborative distribution of the visualisation.

Preliminary work strongly indicates that our design can be implemented to successfully present different pseudocolour schemes. A demonstration will be given at the conference. Further work will include a series of case studies as well as user evaluation for learning scenarios.

References

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*e-mail: m.sifniotis, b.j.c.jackson, m.white, k.mania, p.l.watten @sussex.ac.uk