3D Visualization of Archaeological Uncertainty

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Abstract

By uncertainty, we define an archaeological expert's level of confidence in an interpretation deriving from gathered evidence. Archaeologists and computer scientists have urged caution in the use of 3D for archaeological reconstructions because the availability of other possible hypotheses is not always being acknowledged. This poster presents a 3D visualization system of archaeological uncertainty.

Methodology

Humans do not conform to the prescriptions of the probabilistic normative framework, therefore, we extend the visualization outcome of uncertainty models derived from fuzzy logic and conditional probabilities by introducing Bayesian probabilities and Possibility theory. Possibility Theory complements Bayesian probabilities using a pair of dual-set functions, known as Possibility and Necessity, instead of the single function used by Bayesian probabilities [Chen 1995]. The Possibility measure reflects plausibility, belief and its dual function, Necessity relates to certainty placed in an event reflecting a lack of plausibility of its opposite. We model the uncertainty of archaeologists when investigating evidence discovered on a Roman-British archaeological site in Sussex, UK. The structure known as Building 3 is located near the grounds of Fishbourne Roman Palace. Excavations of Building 3 turned up little evidence besides the stone foundations. There are two interpretations: its function was of a military nature or of a religious purpose. In the first scenario, more emphasis is placed on the functional use for the building constructed by ordinary materials. The religious significance suggests the use of more expensive construction materials or decorative items.

Formal discussions with three archaeologists who have worked on Building 3 excavations were held [Sifniotis et al. 2007]. The archaeologists were asked to list the available evidence in relation to each part of the building (if any), and report how confident they were concerning their subjective associations between the evidence and the suggested hypothesis. The outcome of these discussions formed a knowledge table employed when performing the Bayesian and Possibility calculations [Chen 1995]. Table 1 represents the resulting calculations for certain parts of the building and the possibilistic as well as probabilistic uncertainties associated with each part. The hypothesis visualized is the Military one. The higher a result turned to be, the higher the belief resulting in a Military interpretation, derived from the specific part.

	$Prob$	$Poss$	$Prob$	$Poss$
$NS\ walls$	0.636	0.71	0.37	0.43
$EW\ walls$	0.76	0.84	0.51	0.8
$Roofs$	0.30	0.125	0.12	0.11
$Stairs$	0.5	0.5	0.25	0.25
$Trusses$	0.72	0.81	0.47	0.66
$Prior$	$A\{0.5, 0.5\}$		$B\{0.75, 0.25\}$	

Table 1: *Subjective probabilities and possibilities for Building 3 Military hypothesis*

Examination of the results shows that the probabilistic and possibilistic uncertainties do not deviate more than ± 0.009 except in three cases: Roofs (0.5 prior), EW walls (0.75 prior) and Trusses (0.75 prior). In the first case, the evidence highly supports the Religious hypothesis, while in the others,, the Military one. This may suggest that in the face of extremely positive evidence, the possibilistic calculations might get overconfident (or under confident in negative) results while the probabilistic ones will not deviate that much. Figure 1 demonstrates the visualization of the uncertainty values as input in our system. It shows the specific parts of Building 3 using transparency visualization under Prior A. The left figure represents the probabilistic and the right the possibilistic values. More transparency indicates more uncertainty. The difference between the probabilistic and possibilistic values for the roofs is apparent, since the possibilistic figure shows much less confidence in the roof reconstruction. Varied transparency levels are assigned based on Bayesian and Possibility uncertainty calculations, with 100% opaqueness reflecting complete certainty.

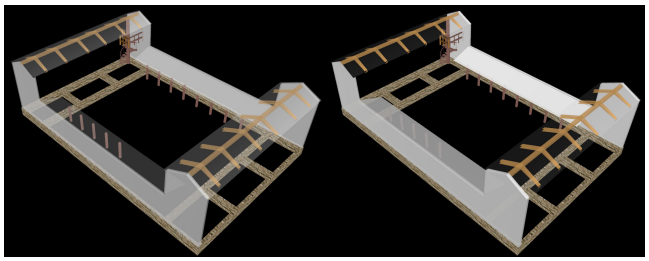

Figure 1: *Subjective Probabilities and Possibilities with a* $\{0.5, 0.5\}$*prior and a transparency visualization*

The 3D model of the building consists of hypothetical and recovered parts. A visualization framework supporting the mathematical modeling of uncertainty has been implemented using networked interactive X3D graphics to display the reconstructions.The visualization, control and communication services support multi-user inter-operation between the graphical and non-graphical components. The uncertainty engine that implements the Bayesian and Possibility theory calculations includes a user-interface. It captures the expert's input in relation to available evidence for different parts of the model, significance and associated confidence levels.

References

CHEN, Y. Y. 1995. Statistical inference based on the possibility and belief measures. *Transactions of the American Mathematical Society 347*, 1855–1863.

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