An Evaluation of Three Methods for Visualizing Uncertainty in Architecture and Archaeology

Scott Houde* Sheila Bonde † David H. Laidlaw ^

Brown University

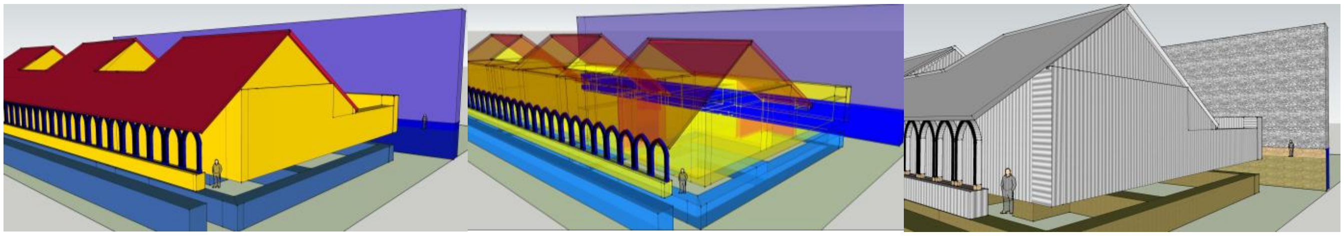

Figure 1: The three variants of the model generated in this project: from left to right, color, transparency, and texture. Online at https://goo.gl/Wj8Q4G

Abstract

This project explores the representation of uncertainty in visualizations for archaeological research and provides insights obtained from user feedback. Our 3D models brought together information from standing architecture and excavated remains, surveyed plans, ground penetrating radar (GPR) data from the Carthusian monastery of Bourgfontaine in northern France. We also included information from comparative Carthusian sites and a bird's eye representation of the site in an early modern painting. Each source was assigned a certainty value which was then mapped to a color or texture for the model. Certainty values between one and zero were assigned by one subject matter expert and should be considered qualitative. Students and faculty from the fields of architectural history and archaeology at two institutions interacted with the models and answered a short survey with four questions about each. We discovered equal preference for color and transparency and a strong dislike for the texture model. Discoveries during model building also led to changes of the excavation plans for summer 2015.

Keywords: uncertainty visualization, 3D models, architectural history, archaeology, Bourgfontaine, qualitative data.

1 Introduction

Representing uncertainty in 3D visualizations is a continuing challenge. This work saw the collaboration of a computer scientist with an architectural historian/archaeologist to present qualitative uncertainty. By qualitative we mean that our certainty levels were not assigned by a discrete measurement, but instead were chosen based on our prior knowledge. We feel that visualizing uncertainty has been under explored. Architectural historians and archaeologists can benefit by utilizing visualizations, especially early in the research process.

The research site for this project is the charterhouse of Bourgfontaine, a Carthusian monastery north-east of Paris that was built in 1323-1325. Several of the structures on the site survive intact, but the great cloister with all the individual cells has disappeared. GPR was performed during the summers of 2013 and 2014 in the area of the great cloister, the zone of planned excavation in 2015.

2 Related Work

Much work has been done on uncertainty in 3D visualizations; a call for a framework for doing so was issued by Johnson and Sanderson in 2003 [1]. Our intention is to find a way that allows the researcher and audience for scholarly publications to apprehend clearly the various levels of uncertainty in archaeological research.

Research has been done on providing a complete rendering package to create visualizations that are animated to show changes to archaeological sites over time [2]. They restricted their representations to the use of transparency and wireframe, and performed no evaluation. One co-author [3] has done prior work on displaying various levels of uncertainty for the reconstruction of the largely destroyed monastic church Saint Jean-des-Vignes, Soissons. We build on that work by having more visual levels with three variants and conducting a user survey to determine preference. In distinction to all previous work, the current project models uncertainty in reconstructing 3D architectural models before the start of excavation. In this way, assumptions about the architecture are foregrounded during the research process.

The GPR data slice was a result of work done by A. Saintenoy et al. [4] which was performed at Bourgfontaine in 2013 and 2014. We focused not on displaying the GPR cube data, instead extrapolating out actual foundations and walls above them from the provided slice.

3 Methods

Our work took various pieces of data and brought them together in one 3D model of the three cloister cells that are going to be excavated in the summer of 2015. For our base we have a surveyed site plan, with one slice of GPR data added in scale. To construct the walls and roofs, we used various sources. One particular image, a painting by Louis Licherie of the 17th century [5] was our primary source, although we also consulted images and plans of comparative Carthusian sites.

We used free modeling software, SketchUp, since the intention was for our models to be used easily in the field. We constructed a master model to scale based on a scan of the site survey with GPR data overlaid. These two elements had the highest certainty. We selected seven levels of certainty with our highest being .95 (the existing but ruined external wall) and the lowest value of .25 (the roof which was certainly present, but whose exact design, style and pitch are unknown.)

After we constructed the model, we generated three variants: a color, a transparent and a textured version. In the color version, each color indicates a different certainty level. The colors were chosen using the triad rule on a color wheel where the most common level was the primary color. (Green was avoided since our ground plane was green.) For the transparent version, we

* e-mail: Scott_Houde@brown.edu
† e-mail: Sheila_Bonde@brown.edu
^ e-mail: David_Laidlaw@brown.edu

used the same colors as the color model, but the opacity of each class was set to its certainty level. The texture variant used simple neutral colored textures that were chosen from the default SketchUp library.

Once the model variants were built, we loaded the models up to Sketchfab (https://sketchfab.com/) which allowed us to share interactive 3D models via a web browser. We constructed a survey which provided some background information on the site and our project and then presented responders with one model at a time along with four Likert scale (1-5) questions and space for comments. On each model page we had a short paragraph, a link to the online interactive model, a picture of the model and a legend explaining each color/texture. We also collected model rank (1 – 3), final comments, basic demographic data, and comparative certainty level information.

4 Results and Discussion

We received 21 responses to our survey and all were included in our analysis. The responses were evenly split between male and female (10 each plus 1 choose not to respond to any demographic questions) but the respondents were weighted towards the 18-25 age band, (52%), with 26-35, (33%), and 46-55, (10%), making up the balance. Differences between these groups are very slight and do not appear to be statistically significant ($t(58) = 0, p = 0.5$).

Looking at all the responses together the mode rank for Color and Transparency were both 1, but the average rank for Color was 1.71 versus 1.86 for Transparency. Texture had a mode rank of 3 and an average rank of 2.43 and was clearly least preferred.

For each model we asked four Likert scale questions. These questions can be reduced to one word each by which they are labeled as in Figures 2 and 3. The questions were: 1) The 3D rendering is simple to interpret (*simplicity*); 2) The difference in uncertainty among features is clear (*difference*); 3) The model is clear in representing uncertainties (*clarity*); 4) I would find a model like this one to be useful in my work or research (*useful*).

4.1 Color and Transparency Models

The color and transparency variants offer some more interesting analysis. Color was a slight favorite when only considering "Strongly Agree" responses but when including "Agree" it reveals that transparency was equal to or better than color in every question except simplicity. 81% agreed or strongly agreed that the color model was simple. Simple might not always be the best. In particular transparency has a lower variance in the difference question. Some insight into why is illustrated in this comment. *"This model* [transparency] *is more helpful than the last, but is much more effective in the 3D version than in the image above"*. Interestingly only one respondent commented on how the color and transparency variants would be difficult for a color blind user to interpret.

4.2 Texture Model

The texture variant was by far the least preferred of the three. One respondent commented *"The textures are extremely annoying to look at, and make the model seem as if it was made up out of thin air."* Those responding also felt that some of the textures were too similar making differences hard to distinguish. We purposefully choose neutral simple textures but unfortunately some of these textures indicated specific building materials and some responding knew that, which seems to have compounded their confusion.

5 Conclusion

Our respondents showed a clear preference for the color and transparency variants. Color was overwhelmingly chosen as

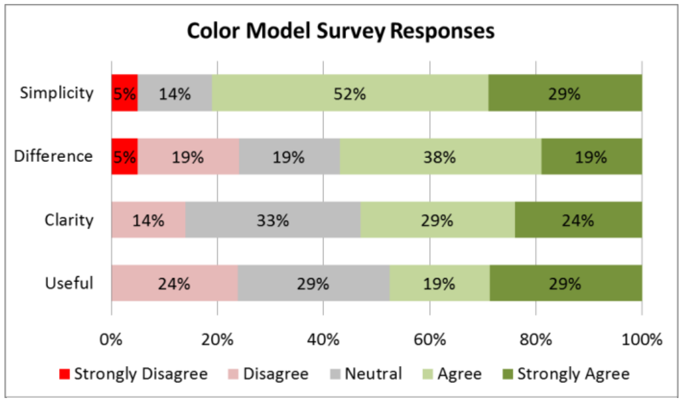

Figure 2: Survey responses to questions about the color model, N = 21

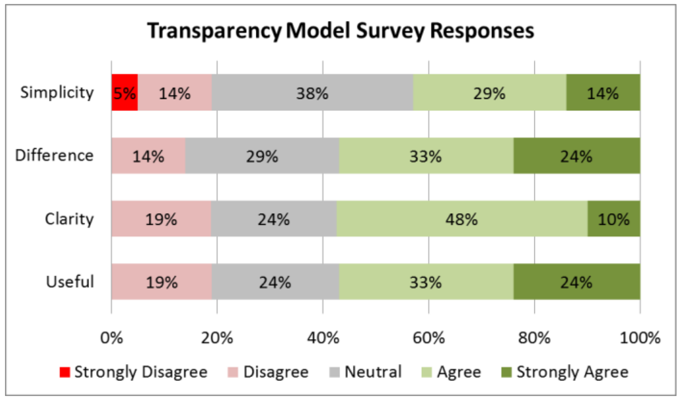

Figure 3: Survey responses to questions about the transparency model, N = 21

being simpler to interpret but we had several comments about how much better the transparency was as an interactive 3D model versus the transparency image. Despite their preference for these two variants several users found the colors too bright and garish. Variants were made using a more subdued color pallet.

Some open questions are: Would it be possible to display 7, or more, classes and be color-blind friendly? Use of textures would seem one way to be safe for color blind users. How many levels would display the most information clearly? How best to get across the most information without overwhelming the reader

Perhaps most usefully, the process of constructing the models and deciding upon uncertainty values led our co-author to several insights, and has guided the design of the excavation season during the summer of 2015. For example, the scaled model introduced some questions regarding the corridor width that resulted in a larger than originally intended dig area.

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