DIGITAL RECONSTRUCTIONS: CONFIDENCE AND AMBIGUITY

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Abstract

Digital representations have progressed tremendously from the earliest wireframe images to realistic ray-traced renderings that are often indistinguishable from real-life. Yet, in many cases, in the fooling of the eyes, one should not also fool the brain. Especially in the reconstruction of the past, it may be useful for the visualization to also contain information about the certainty of the result. Methods exist to show what data was missing and is now restored and the confidence level of the reconstruction. This in-progress summary paper will discuss the overall usefulness of many of these techniques and list methods from architecture, archaeology, and other fields towards providing information beyond the visualization.

1. Introduction

There is no doubt that creating a reconstruction is an extremely valuable tool for visualizing what is, was, and could have been. Paleontologists start with a pile of bones embedded in rock or tar, jumbled together with multiple specimens and unrelated material. From that they separate out the fragments, put the bones together, and sometimes add copies from other skeletons of pieces that they lack. They may additionally "re-skin" the bones to produce museum quality displays. Knowledge is gained in the reconstruction - how big was the creature, what did it look like, how did the joints go together? Theories can be formulated: where did the muscles attach, what did the dinosaur sound like, how did it move, what were characteristics of the skin? Then additional reconstructions can be used to prove, disprove, or judge the likelihood of the new theories. There is danger in making an incorrect reconstruction (as demonstrated by the true story of the Brontosaurus and the wrong head), but one of the strengths of the scientific method allows for the adjustment of the theory as additional data is uncovered (see Novitski 1998 for another example).

Imagine for a moment the grandeur of ancient Troy on the big screen (the movie *Troy*) as envisioned by the production designer -- massive stone buildings and towering statues of gods, a place of epic proportions. But in Nigel Phelps' own words: "The reality is, Troy was quite a bit smaller than what we eventually designed – it's really quite contained," says the designer. "But you did have an outer wall and you did have an inner palace within the confines of the town. For the most part, all of the houses were single story and flat-roofed and made of mud. So we had to expand on that a little to make it more visually interesting." (Phelps 2004) Then consider what Heinrich Schliemann actually found in his excavations at Hissarlik, Turkey: scraps of ancient buildings, short stubs of broken walls, shattered pots -- a far cry from the imagined state. And was this even the Troy of Homer? Since Schliemann, other archaeologists have also tried piecing together fragments of information to provide a plausible reconstruction of Troy.

By attempting to create digital visualizations of historic structures, we have learned by experience what archaeologists have already known -- there never seems to be enough information available; inferences, educated guesses, and just plain wild speculation can make their way into a reconstruction. From the extremes of movie-making magic to diligent scholarship, opportunities exist to reconcile fiction with fact and speculation with reasonable conjecture to provide the viewer with an account of what is "true" or likely. This might be additional material distributed on a bonus DVD or summarized as footnotes in a published journal article. Even when the desire exists to provide the information, it is often difficult to decide upon methods that are

clear and instructive. This is not only an problem in architectural reconstructions. Many divergent fields, for example, art restoration, physics, statistics, and medical imaging can face similar problems. This in-progress summary paper attempts to provide a cross-disciplinary approach tabulating techniques for showing missing or reconstructed data and confidence about parts of a reconstruction.

2. Techniques for showing missing or reconstructed data

In most cases, the recreator needs to deal with the issue of what to do if there is not enough data to support any specific reconstruction. For example, it might be known that it is likely that windows were in a building, but there is no information suggesting where it would have been. Or a paleontologist discovering most of a skeleton of a dinosaur, but needing to reconstruct the rest. Although not unique, Historic St. Mary's City is one location where multiple techniques are used in the reconstruction of the buildings. In several cases, the actual archaeological remains were displayed. In others, they were left buried, but a reconstruction of the ruins was built above ground. In some locations where foundations were found or other evidence existed for the location of a building (like an old map), "ghost outlines" of buildings were constructed; these timber frames outlined the edges (full size) of places buildings were thought to have been. And other buildings and gardens were reconstructed full size. Several of these techniques were also observed recently at the Alamo in San Antonio, Texas.

There are numerous techniques for showing that information is completely missing or that what is shown is not an original; many of the methods can be expressed visually in two dimensions. For example, one can just leave the unknown areas empty, show one reconstruction overlaid on original data (see Staccioli and De Franciscus (Getty 2000) for examples of books that do this), label the missing piece with a question mark or text, visually show the reconstructed data as different (using colors, shades, black and white versus color, shimmering appearance, patterns, dashed lines, materials, rendering types, density of information, transparency, blurriness, fuzziness, Photoshop effects, and animation), show several alternatives (using more than one image, rollovers, projections (Ename 2005), QTVR, animations, morphologies, pop-ups), or use multiple methods. One can even aurally indicate the differences: leave the unknown area empty (put silence where sound is missing), use a "label" (put the "missing data" sound or noise in where appropriate), or change the volume or vibrato of a reconstruction versus original. Sometimes by context is enough to show what is "real" versus "reconstructed", but the viewer may still make mistakes. With some of these techniques, the invert can also be used -- for example a reconstructed artifact might be shown with more detail than the original, less transparent, brighter color, or even without it.

3. Confidence about the reconstruction

Assuming that a reconstruction is made, it is created with a set of assumptions that may be obvious to the reconstructor, but not those who later view the final project. As a simple example, an archaeologist who knows exactly where the foundations of the building are located, has some idea of the materials used for the construction of the walls, assumes from other excavations where the doors are located, but has a low level of confidence for the shape of the roof. How can she provide to the viewer a reconstruction and a graphic sense of not only the possible alternatives, but also her levels of confidence about the reconstruction?

Figure 1: Photographs from Historic St. Mary's City taken summer 2003 (KK).

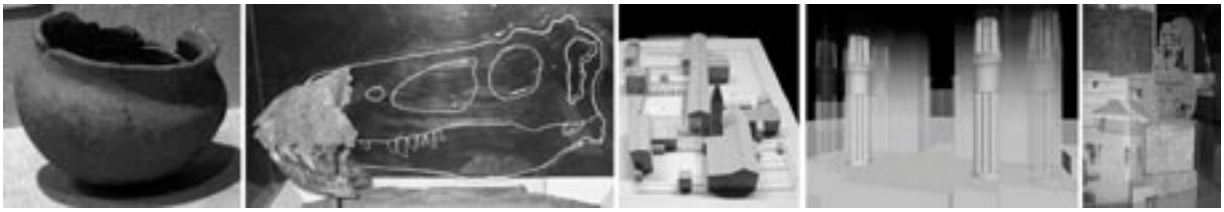

Figure 2: Show missing information with transparencies: don't show missing information (NHM/KK), dinosaur fragment (NHM/KK), convent model (JJ), digital model with varying degrees of transparency (KK), stelae (NHM/KK).

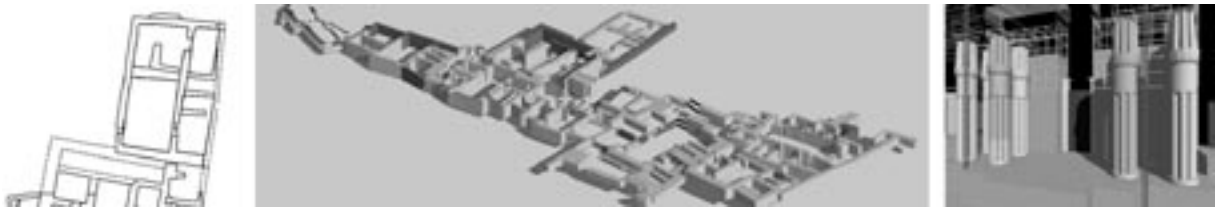

Figure 3: Show missing information with visual clues: dashed lines (JC/KK), color or shading (JC/KK), rendering type (KK).

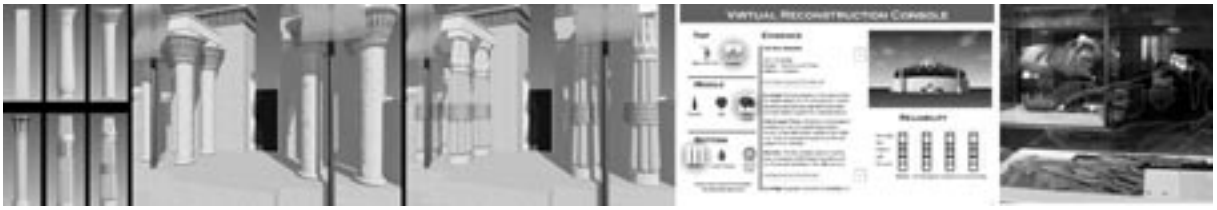

Figure 4: Show missing information using multiple techniques: multiple reconstructions (KK; Kensek, Dodd, Cipolla 2002); chose different components to create reconstruction (NC; Cipolla, et. al. 2004); use text, partial reconstruction, and full reconstruction (NHM/KK).

Many categories of methods exist to show ambiguity in the reconstruction: don't show it (the null case), use different visual methods to show the levels of confidence (color, transparency, rendering types, density, blurriness, error bars, graphic orbitals), provide text based information (written material, link areas to web sites, pop-ups (see example by Jepson, Snyder, et al. (2002)), percentages, rating system, statistical uncertainty, and sampling errors.), use sound (for example, on a rollover, a voice explains the certainty of the reconstruction or pleasant music plays during "confident sections" and cacophony during wild guesses), give tactile feedback, create multiple reconstructions with differing levels of assuredness (confidence slider, confidence bars, timing of images), and combine multiple techniques in a hybrid approach.

4. Future work and conclusion

This paper has listed different techniques for making visible missing data and incorporating confidence levels into the visualization. We are currently looking for more methods to include, especially from fields outside of the visual arts (Johnson and Sanderson 2003). Then these techniques will be transformed into other modes that can be used specifically for architectural reconstructions. There are other important issues that we also hope to research. These include what year to reconstruct to, appropriate use of the techniques, methods of linking data with images including GIS systems (Eiteljorg 2002; Forte and Siliotti 1996), and applications beyond visualization. And assuming that someone will reconstruct missing data, what techniques can that person use to do this?

A historic preservationist's creed might include preservation first, then rehabilitation, restoration, and finally reconstruction. By analogy, perhaps a digital reconstructor should show most prominently the real material, then attempt to fix minor details, patch major areas, and finally create missing parts, while clearly creating a visual "paper trail" of changes and assumptions. Consideration should be given to the best

and appropriate use of the methods especially with regard to the intended audience. Eventually we hope to give guidelines for which cases we think are most clear in different situations.

As a final point, a reconstruction need not only be optical. Although this paper concentrates on visual representations, one could recreate with an emphasis on other sensory inputs, with aural, tactile, gustatory, and olfactory characteristics: music as heard in the Parthenon, the texture of cobblestones through a Roman town, the taste of an Elizabethan feast, or the smell of a Gertrude Jekyll garden in the spring. Emphasis might also be shifted from producing "realistic" images to recreating an experiential feel, for example, of an Aztec temple from the point of view of the sacrificial victim (Serrato-Combe, 2001). Because people have a strong connection to how things look and computers can manipulate digital images, the emphasis has often been on renderings and animations. Although more difficult, there are no technological reasons that sound cannot be incorporated, and tactile feedback is possible -- taste and smell are also not beyond the reach of current researchers (USC 2004).

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Picture credit abbreviations

Juan Chen, Nicholas Cipolla, Pelin Herpilingirler, Jungwook Jang, Karen Kensek, Natural History Museum of Los Angeles County (NHM, part of permanent collections), Alex Pang.

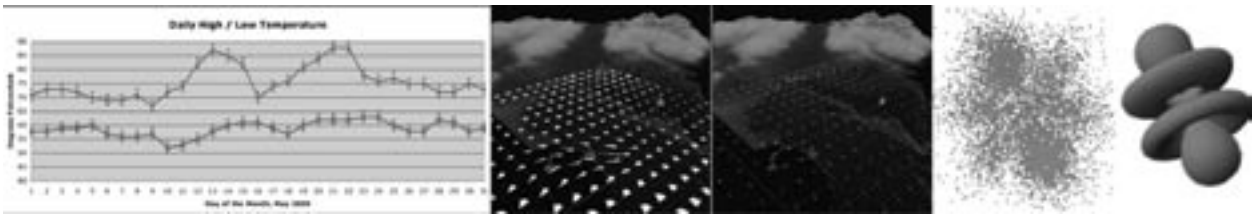

Figure 5: Show confidence: error bars (KK), uncertainty shown using direction glyphs (AP, Johnson and Sanderson 2003), electron position orbitals (Manthey 2005).

Figure 6: Show confidence: written material (NHM/KK), pop-ups on a Web site (PH), tolerance factor (KK).

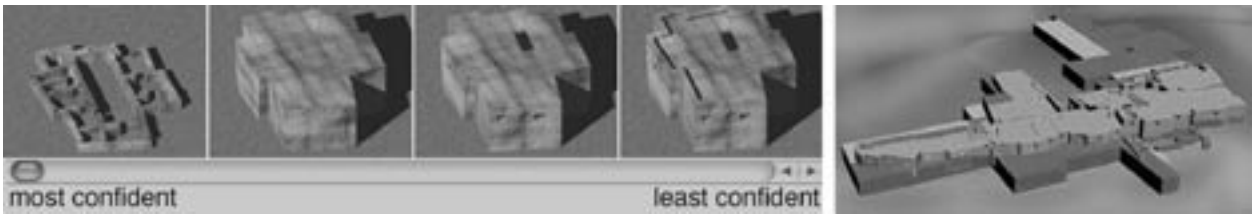

Figure 7: Show confidence: slider bars (KK; see Snyder and Paley 2001 for another example.), color (JC).

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Areas of interest: virtual reconstruction, digital rendering, ambiguity, uncertainty, solar envelopes