Extracting Geometry from Digital Models in a Cultural Heritage Digital Library

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Abstract

This paper describes research to enhance the integration between digital models and the services provided by the document management systems of digital libraries. Processing techniques designed for XML texts are applied to X3D models, allowing specific geometry to be automatically retrieved and displayed. The research demonstrates that models designed on object-oriented paradigms are most easily exploited by XML document management systems.

1. Introduction

Much like a traditional library, a digital library can operate as a repository of objects that are identified using separate metadata records and subsequently disseminated as is. But more sophisticated digital libraries have evolved that are able to process objects both before and as they are delivered. The processes or "services" customize the document to the user.

Electronic texts are possibly the most frequently and most highly customized of objects disseminated by digital libraries. The Perseus Digital Library, for example, filters SGML- and XML-encoded documents through processes that automatically add links to lexical tools, named-entities, and citations (to name only a few of the customizations offered). Other library objects, too, can be customized. For example, much effort is being expended on new systems that index, search, and extract content from multimedia documents [1, 5, 9]. These systems are not widely available, however, and digital libraries often disseminate multimedia files without customization as a consequence.

2. Models and libraries

Digital models are characteristic of multimedia documents. That is to say, digital libraries typically treat models as immutable objects retrieved in toto on the basis of their cataloged metadata. If one assumes that a single model represents a logical whole, and that users will be interested in that whole, then in toto retrieval is a suitable method for model dissemination. These assumptions are not defensible, however, in the context of a cultural heritage digital library where the models' subjects themselves might not be complete and where user interest might be expected to lie solely in specific parts of a model [9].

The problem with in toto retrieval of digital models can be expressed in a paradigm. Imagine, for example, two digital models: one of a column capital cataloged in a digital library system as "Capital," and one of a peripteral temple cataloged as "Temple" — without additional reference to any component architectural blocks. Imagine, too, that the Temple model includes geometry for every architectural element, from the foundation blocks right up through the column capitals and the roof tiles (but note that this model could be constructed with less detail and only contain geometry for "platform," "columns," "roof," etc.). Now assume a user who is exclusively interested in models of column capitals to evidence research on shape development. This user is likely to retrieve the Capital model but is not likely to retrieve the Temple model, among the sub-objects of which are models of column capitals. Of course, had the creator of the Temple model simplified its geometry, the failure to retrieve it could have less significance to the user. But what might be done to identify undocumented geometry that has been individually modeled and incorporated into a larger construct? And what might be done to extract that sub-object from the larger construct automatically?

3. Models as texts

The paradigm illustrates the need for enhanced integration between digital models and the services provided by the document management systems of digital libraries. One might argue that more detailed cataloging of metadata is all that is necessary. But, while resolving the problem of sub-object identification, more exacting practices will collide with cost-benefit barriers and still not provide a method for sub-object extraction. A superior solution is to develop a way to parse the models and index their component geometry. The method proposed here is to masquerade digital models as XML (Extensible Markup Language) texts and to extend processing techniques that are already used by document management systems to these veiled models [8, 3, 7]. There are additional benefits to this approach; the method provides a basis for the integration of models with automatic linking services and has the potential to improve integration with 3D shape-matching services [5].

The proposed method is appropriate to models that have been stored in an ASCII format. For an object that is preserved in a cultural heritage digital library, the use of ASCII also makes archival sense [2, 6, 8]. Any structured ASCII format (e.g. IGES/STEP and DXF) for which an XML application might be composed is suitable. The research described here focuses on models encoded in X3D (Extensible 3D, ISO/IEC 19775), an XML application of VRML (Virtual Reality Modeling Language, ISO/IEC 14772).

The document management system of the Perseus Digital Library has multiple capabilities [10]. Chief among these are its ability to handle XML documents of any DTD (Document Type Definition), to extract structural and descriptive metadata from XML documents, and to deliver fragments of documents in well-formed XML. The system is based on abstract structures to which elements of one or more DTDs are mapped, and on indices of these mappings. The generation of the indices is automatic and can be configured to include descriptive content; this content is simultaneously extracted and stored in an RDF (Resource Description Framework) database to improve the discovery of resources.

In the extension of the Perseus document management system to X3D models, an abstract structure is proposed for each culturally significant object (be it a sculpture, vase, etc.). The following example illustrates the procedure using objects of Egyptian architecture. For one or more models of the site of Giza, the elements of the X3D Compact DTD are mapped to an abstract structure "Giza." And for one or more models of the Gizan tomb G 2110, the elements of the X3D Compact DTD are mapped to an abstract structure "Tomb G 2110." Although only one DTD is used, the abstract structure mapping is necessary for the document manager to handle instances in which there are multiple versions of a model encoded according to different DTDs (e.g. three models of tomb G 2110 with DTDs for X3D, XML-ized STEP, and XML-ized DXF defining the structure of one model each). The document management system generates for each model an index that includes the byte offset for **`<Group>`** elements (those that assemble sub-objects into meaningful hierarchies) and **`<Transform>`** elements (those that define meaningful hierarchies and describe associated coordinate systems). Additionally, each index includes the content from the **`DEF`** attributes, which name a model's sub-objects and sub-object groups. Using the indexed information, the document manager is able to open an X3D model, find the extents of a desired group, and read the embedded sub-object(s). The output is merged with additional tags to create a valid X3D document that is passed to an XSL (Extensible Stylesheet Language) transformation utility for styling into VRML; the result is displayed in an HTML page. Ultimately, when presented with a request for "Tomb G 2110," the document manager is not only able to return the geometry of the tomb model, but also that of the tomb sub-object in the Giza model.

4. Implications for model design

The treatment of digital models as electronic texts illuminates the need for well-defined and well-named geometry. Object-oriented modeling, a common paradigm among the tools designed for mechanical engineers and artists, is suited to these requirements natively [4]. Nested and related hierarchies of uniquely named components characterize models constructed with object-oriented tools. Layer-oriented modeling, the most common paradigm for tools targeted to Architecture/Engineering/Construction professionals, is suited to these requirements only with forethought. Since a component is identified by the name of the layer on which it resides, several components grouped on the same layer effectively have identical names. And since layers are not nested, layer-oriented modeling flattens the hierarchies that establish name inheritances crucial to the identification and extraction of geometry. If a layer-oriented paradigm is used, a separate layer with an appropriately specific name should be created for every component of the model. However, this practice contradicts various standard layer naming conventions, which currently do not accommodate the necessary specificity.

5. Conclusions

Research conducted thus far suggests that common XML text processing techniques can be applied to digital models successfully. The techniques facilitate the identification of geometry that has been individually modeled and incorporated into larger constructs. And they enable the extraction of sub-object geometry. Moreover, the application of XML text processing techniques establishes a framework for the integration or improved integration of digital models with additional services, such as automatic linking and 3D shape-matching. The achieved enhancements add value to the models, which are able to be tailored to the needs of specific cultural heritage research.

6. Acknowledgments

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7. References

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