SESSION 6: Digital Practice Applications—Education

Integrating Digital Educational Content Created and Stored Within Disparate Software Environments: An Extensible Markup Language (XML) Solution in Real-World Use

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Objective: To provide a standardized and scaleable mechanism for exchanging digital radiologic educational content between software systems that use disparate authoring, storage, and presentation technologies. **Materials/Methods:** Our institution uses two distinct software systems for creating educational content for radiology. Each system is used to create in-house educational content as well as commercial educational products. One system is an authoring and viewing application that facilitates the input and storage of hierarchical knowledge and associated imagery, and is capable of supporting a variety of entity relationships. This system is primarily used for the production and subsequent viewing of educational CD-ROMS. Another software system is primarily used for radiologic education on the world wide web. This system facilitates input and storage of interactive knowledge and associated imagery, delivering this content over the internet in a Socratic manner simulating in-person interaction with an expert. A subset of knowledge entities common to both systems was derived. An additional subset of knowledge entities that could be bidirectionally mapped via algorithmic transforms was also derived. An extensible markup language (XML) object model and associated lexicon were then created to represent these knowledge entities and their interactive behaviors. Forward-looking attention was exercised in the creation of the object model in order to facilitate straightforward future integration of other sources of educational content. XML generators and interpreters were written for both systems. **Results:** Deriving the XML object model and lexicon was the most critical and time-consuming aspect of the project. The coding of the XML generators and interpreters required only a few hours for each environment. Subsequently, the transfer of hundreds of educational cases and thematic presentations between the systems can now be accomplished in a matter of minutes. The use of

algorithmic transforms results in nearly 100% transfer of context as well as content, thus providing "presentation-ready" outcomes. **Conclusion:** The automation of knowledge exchange between dissimilar digital teaching environments magnifies the efforts of educators and enriches the learning experience for participants. XML is a powerful and useful mechanism for transferring educational content, as well as the context and interactive behaviors of such content, between disparate systems.

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A MIGRATION is underway towards digital teaching files and away from "legacy" collections of film-centric educational material. Some advantages are easily seen. Digital material can be more easily edited and simultaneously accessed when compared with hard-copy material. However, hard-copy teaching files are immune to some problems in the digital world. For example, both the storage media and "user interface" employed in film-based teaching files are universally compatible with all radiologists because radiographic films (or 35-mm slides) are the media, and a viewbox (or a 35-mm slide projector) provides the user interface. There is no guarantee that content maintained in a digital teaching file created by one institution or organization will be compatible with the teaching-file software used at another. Often the opposite is true. We describe a technique for integrating disparate digital collections of educational content, such as radiologic teaching files, by using an emerging standard known as extensible markup language (XML). XML is rapidly gaining popularity as a framework for structuring and giving context to digital data intended for exchange between disparate database systems. XML can also provide a standardized and scaleable mechanism for exchanging digital radiologic educational content between teaching-file systems that use disparate authoring, storage, and presentation technologies. We describe a working model in which XML is used to exchange educational radiologic content between two different systems.

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<CASE NAME="ULCERATED GASTRIC ADENOCARCINOMA" ID="127">
  <NODE NAME="History" ID="127" CAPTION="127.TXT">
    <NODE>
      <NODE NAME="Diagnosis and Classification" ID="127" CAPTION="127.TXT">
        <NODE>
          <NODE NAME="CT" ID="126" CAPTION="126.TXT" IMAGE="126-0.jpg" THUMB="126-1.jpg" ANNOTATION="126-1.jpg">
            <NODE>
              <NODE NAME="CT" ID="127" CAPTION="127.TXT" IMAGE="127-0.jpg" THUMB="127-1.jpg" ANNOTATION="127-1.jpg">
                <NODE>
                  <NODE NAME="UGI" ID="128" CAPTION="128.TXT" IMAGE="128-0.jpg" THUMB="128-1.jpg" ANNOTATION="128-1.jpg">
                    <NODE>
                      <NODE NAME="Correlative Case 1" ID="129" CAPTION="129.TXT" IMAGE="129-0.jpg" THUMB="129-1.jpg" ANNOTATION="129-1.jpg">
                        <NODE>
                          ... (Specifications for remaining correlative cases associated with this case)...
                        <CASE>

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Fig 1. XML specification employed for representing a case (see Figs 2-5) in our implementation. Text accompanying child elements (ie, child nodes) is stored in a separate file conveyed by the CAPTION attribute within each node. The NAME attribute conveys the context of the node. All images associated with a node, such as thumbnail images and full-sized images without and with annotations, are conveyed as attributes within a node. Images are grouped within our object model as "collections" in order to facilitate the association of a variable number of images with the primary case and each of its correlative cases.

MATERIALS AND METHODS

Our institution uses two distinct software systems called Radiology Annotation and Publishing System (RAPS) and Education Delivered and Composed Through Internet Communication (EDACTIC) for creating educational content for radiology. The strategies employed for displaying content stored within these two systems are also distinct. RAPS is an authoring and viewing application that facilitates the input and storage of hierarchical knowledge and associated imagery, and is capable of supporting a variety of entity relationships. This system has historically been used for the production and subsequent viewing of educational CD-ROMs. For example, the Massachusetts General Hospital eCase CD-ROMs were created with RAPS. RAPS was developed using Visual Basic (Microsoft, Redmond, WA) and uses the "Jet" database engine. More recent generations of the software also support web-centric entry and display of educational content. EDACTIC is primarily used for radiologic education on the world wide web. This system facilitates the input and storage of domain expertise and associated imagery, delivering such content on the web as choreographed, interactive knowledge to simulate in-person interaction with an expert. EDACTIC is essentially two software applications joined at the database level. An authoring application was primarily developed in Visual Foxpro while a complementary web-delivery application was developed using Microsoft's Active Server Page technology running within Internet information server. Content created with the EDACTIC authoring system is viewed independently by an intended audience within a web browser. EDACTIC has been successfully deployed within teaching hospitals, radiologic organizations, and radiology web portals. The highest-volume site currently receives approximately 1 million page views per month and between 6,000 and 7,000 log-in sessions per day.

XML is a meta-markup language that provides a format for describing structured data (see <http://msdn.microsoft.com/xml/>). On the surface, XML looks like hypertext markup language (HTML). Unlike HTML, XML provides the capability to create one's own markup vocabulary or choose from a wide variety of markup vocabularies appropriate to an industry or project type. Entities called schemas are used to describe and document type

definitions (DTDs) are used describe these vocabularies so that a software module generating or interpreting XML will essentially have a dictionary available to define and give context to the data described by the XML. Vocabularies without formal definitions can also be used, as was our strategy; that is, our XML processing software takes advantage of built-in knowledge of our vocabulary in order to process the information within our XML implementation.

Both RAPS and EDACTIC support a case-based approach to inputting and retrieving data. In an effort to reflect the concrete world, our implementation uses a "case" to label the XML element that represents the fundamental entity transferable between the two systems. The XML generator will create an XML document that contains a structured representation of one or more cases. A case is specified by all content between opening and closing "case" tags. It was necessary to derive a subset of information entities common (and which could be directly mapped) to both systems. An

Fig 2. Top-level form for RAPS (A) compared to home page for EDACTIC as displayed in web browser (B). Both systems contain the same teaching-file cases in this demonstration.

additional subset of information entities that could be bidirectionally mapped via algorithmic transforms was also derived. For any case, these entities are represented as child elements of the case element within the XML (Fig 1). The child elements and their associated XML attributes thus comprise an object model for a case that represents the information entities therein along with any implied behaviors of these entities (eg, an automatically zooming thumbnail image). Among the information entities supported in our model are (1) the history, findings, diagnosis, and discussion for a case; (2) an unlimited number of automatically zooming (when clicked) thumbnail images representing the primary images in the case; (3) an annotated set of some or all of the same images with caption text; and (4) any number of so-called "correlative cases" comprised of sets of unannotated and annotated automatically zooming thumbnail images. In our implementation, correlative cases do not contain a discussion. Forward-looking attention was exercised in the creation of the object model in order to facilitate straightforward future integration of other sources of educational content. XML processing software was created to import the data, including references to image files, into each system.

RESULTS AND DISCUSSION

More than 200 cases have been transferred between the systems. The display engine for RAPS is distributed as a compiled Visual Basic application integrated with the CD-ROM product. Its user interface is markedly different than the hyperlinked, multipage web-centric delivery strategy used in EDATIC. Appropriate mappings were therefore necessary to represent the elements of a case in XML such that each system could import, store, and optimally display (within its own user interface) the elements of a case. For example, the top-level form for RAPS (Fig 2) displays a table of contents as an interactive hierarchical list, while the top-level (home) page for EDATIC displays a list of case categories, each category hyperlinked to the roster of cases within that category. In RAPS, the user interface contains an image display

Fig 3. RAPS user interface displays images in a viewing panel affected by clicking on thumbnail images below it and buttons below and beside it. (A) First image for case is displayed. (B) Clicking the appropriate button, the annotated version of the image is displayed. (C) Clicking third thumbnail from left, the corresponding full-sized image is displayed.

Fig 4. EDACTIC user interface displays primary case and its correlative cases as series of web pages. (A) Same case as depicted in Fig 3, displayed as unknown in EDACTIC. (B) Second page of case provides access to annotated versions of images. (C) Annotated full-sized version of the case's first image with corresponding caption text displayed by clicking on appropriate thumbnail image. (D) Third page of case with diagnosis and discussion.

panel (Fig 3) underneath which is a row of "clickable" thumbnail images that comprise all images for the case including images for any so-called correlative cases. The context of the thumbnail (eg, primary image v correlative-case image) is denoted by the color of its border. Additional buttons are available to display annotated versions of the images with captions, as well as the diagnosis and

discussion for a case. Cases are shown by design (Fig 2) as known diagnoses while in EDACTIC cases are displayed as unknowns. EDACTIC uses sequential web pages (Fig 4) to first show a case's primary images as a series of zooming thumbnails accompanied by a history, followed next by a page with zooming thumbnails of annotated images, which also carry textual captions, followed by a

Fig 5. First correlative case (which includes only one image in this instance) accompanying the primary case as shown in RAPS (A) and EDACTIC (B). Additional correlative cases are shown on subsequent web pages within the EDACTIC user interface.

page with the diagnosis and discussion. EDACTIC then uses as many subsequent pages as necessary to show all correlative cases, one case per page (Fig 5).

Deriving a bidirectionally compatible object model and subsequent XML vocabulary was the most critical aspect of the project. The coding of

the XML generators and interpreters required a few hours for each environment. Now literally hundreds of cases can be transferred between the systems in a fraction of the time that would be required to move the content between the systems manually. We have found that when a new author participates and submits a batch of cases composed his or her way, some minor adjustments to the XML processing software are sometimes necessary to overcome unexpected nuances in the way some cases are structured. This is more a consequence of our free-style authoring systems combined with our relatively informal XML specification rather than an inherent limitation of XML. Our decision to employ algorithmic transforms for certain elements (eg, annotated images with text captions, which are represented internally via entirely different mechanisms in the two systems) resulted in nearly 100% transfer of context as well as content, thus providing "presentation ready" outcomes. However, there are some elements that exist in one system for which analogous elements do not exist in the other, and thus XML specifications for such elements were not derived. For example, EDACTIC supports the authoring and display of dynamic interactive questions with active hyperlinks that provide real-time feedback while RAPS currently does not have this capability. RAPS has robust image manipulation features such as a floating magnifier and dynamic image resizing that are not supported within EDACTIC's web delivery technology.

The automation of knowledge exchange between dissimilar digital teaching environments magnifies the efforts of educators and enriches the learning experience for participants. We believe that XML is a powerful and useful mechanism for transferring educational content, as well as the context and interactive behaviors of such content, between disparate systems. The potential applications in radiologic education are manifold and exciting. For example, major radiologic organizations could conceivably cooperate to derive standardized XML specifications for exchanging many types of educational content such as teaching-file cases, manuscripts, and thematic review exercises. XML could play a helpful role in on-line, electronic peer review by providing a standardized data exchange mechanism for authors, reviewers, and publishers. Radiologists could use the software tools of their

choice for creating educational content as long as the software supported the export of its content into a format compatible with the XML vocabularies adopted as standards for representing such content. Radiologists and radiology departments could exchange such content with each other using a peer-to-peer mechanism over the Internet (eg, such as used by the popular Nabster website [www.napster.com] with digital music) were there XML vocabularies established

for representing their material. Furthermore, a standardized data-representation infrastructure would inherently be established to facilitate the hosting and publication of educational material on luminary, high-availability websites that could be provided by radiologic institutions or organizations, thus eliminating many obstacles often encountered by radiologists when using in-house facilities to set up and maintain their own web-centric educational content.