Using the Semantic Grid to Build Bridges between Museums and Indigenous Communities

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Abstract. In this paper we describe a Semantic Grid application designed to enable museums and indigenous communities in distributed locations, to collaboratively discuss, describe, annotate and define the rights associated with objects in museums that originally belonged to or are of cultural or historical significance to indigenous groups. By extending and refining an existing application, Vannotea, we enable users on access grid nodes to collaboratively attach descriptive, rights and tribal care metadata and annotations to digital images, video or 3D representations. The aim is to deploy the software within museums to enable the traditional owners to describe and contextualize museum content in their own words and from their own perspectives. This sharing and exchange of knowledge will hopefully revitalize cultures eroded through colonization and globalization and repair and strengthen relationships between museums and indigenous communities.

1 Introduction

Many museums, archives, libraries and cultural institutions throughout the world hold large collections of objects that are of cultural or historical significance to indigenous communities. Because many of these objects were collected without the consent of the traditional owners, the custodial organizations are now facing the challenges of determining ownership, seeking direction from the traditional owners on the future of such objects and either repatriating them, storing them or exhibiting them appropriately as requested. This process is made more difficult because colonization has caused many indigenous communities to become dispossessed of their lands and widely dispersed geographically. New collaborative interactive software tools, high-speed networks and emerging Grid technologies that facilitate communication and the sharing of resources and knowledge between geographically dispersed groups, appear to offer an infrastructure that is ideally suited to the implementation of such digital and physical repatriation programs.

Within this paper we describe the software that we are developing specifically for such an application, within the Smithsonian's National Museum of the American Indian (NMAI). In the United States, the Native American Graves Protection and Repatriation Act (NAGPRA) specifies the types of objects and sites to be protected and/or repatriated. Going beyond the requirements of NAGPRA, the NMAI has established a Culturally Sensitive Collections Care Program to respond to areas of concern of Native peoples with regard to the maintenance, presentation, and disposition of sensitive materials and information in the collections of the museum. Past experience has indicated that many tribal communities want access to the records of all objects in museum collections associated with their community and that after reviewing these, some will be satisfied with digital surrogates and access to physical objects when requested. The objective of the application described here is to provide the cyber-infrastructure to support such a program.

Within the FilmEd project [1], we developed the Vannotea system to collaboratively index, annotate and discuss digital film and video over high bandwidth networks. Vannotea has been extended to support the sharing, indexing and annotation of high-quality images (JPEG2000). Within the Indigenous Knowledge Management project [2], we developed software tools to enable non-collaborative indexing, annotation and rights management of indigenous collections. In this paper we explain how we have amalgamated software developed within these two projects to produce a system that enables collaborative indexing, discussion, annotation and rights management of indigenous collections via access grid nodes. We have done this by extending the Vannotea software through the addition of:

- Fine-grained rights management components specifically required for Indigenous Knowledge;
- Support for the sharing, indexing and annotation of 3D digital objects.

The remainder of this paper is structured as follows. The next section describes related work and the background and objectives to the work described here. Section 3 describes the architectural design of the system and the motivation for design decisions that were made. Sections 4 describes the issues involved in integrating Indigenous knowledge management requirements and adding support for 3D objects, respectively. Section 5 provides the conclusion and describes plans for future work.

2 Related Work and Objectives

Developing a system to collaboratively index, annotate and discuss high quality images, videos and 3-D objects within the context of indigenous collections involves research across a range of disciplines:

- Multimedia indexing, search and retrieval;
- Annotation tools for digital multimedia documents;
- Collaborative application sharing and document sharing tools;
- Authentication, authorization and digital rights management for Indigenous collections.

In the next four sub-sections we describe relevant, related work in these areas.

2.1 Multimedia Indexing, Search and Retrieval

There has been considerable work on the indexing, searching and retrieval of images and video content. Many automatic tools have been developed to extract low level features [3-6] and various sophisticated content-based retrieval methods have been developed (e.g. Query- by-Example, Sketching interfaces, etc.) [7-9]. A number of tools have also been developed to enable the manual attachment of semantic descriptions to be manually attached to video [10-13] and image [14, 15] content using free text, controlled vocabularies or ontologies. Other research groups are attempting to "bridge the semantic gap" [3, 16, 17] by automatically generating semantic descriptions using machine-learning techniques.

Although the majority of multimedia indexing, search and retrieval systems target images and video, Rowe et. al [18] recently created a tool to capture, model, analyze, and query complex 3D data within an archeological museum context. Their focus was on feature extraction of 3D objects rather than on user annotations and only asynchronous, non-collaborative user access is provided.

However, none of the work carried out to date allows distributed groups to index and define the access rights policies associated with multimedia (images, video and 3D) objects collaboratively. Decision making within many indigenous groups is a group process, carried out by a council of elders. When describing cultural or historical objects and defining access rights, it's important that geographically dispersed community leaders can do this in collaboration with museum staff through real-time group discussions that will generate a legitimate consensus for future generations.

2.2 Annotating Digital Multimedia Documents

Existing annotation tools (which enable users to attach personal notes, questions, explanations, etc. to documents) can be categorized according to the media types which can be annotated (text, web pages, images, audio or video, 3D) and the extent of collaboration supported. This matrix in Table 1, gives an overview of the different products, tools, systems and projects according to these categories.

Table 1: Annotation Tools

	Non-Collaborative	Collaborative	
	private annotations	shared annotations (asynchronous)	Logged, live discussions (synchronous)
Text or Web pages	text processors like MS Word, Adobe Acrobat, etc.	Annotea [19], Cadiz et al [20]	Churchill et al. [21], Collaborative Information Browser [22]
Image	Adobe PhotoShop	PAIS [23], Photo Annotator (Annotea + SVG) [24]	mimio classroom [25]
Audio/Video		MRAS [26]	DTVI [27]
3D		Jung et al. [28]	

MRAS [26] is a web-based application designed to enable students to asynchronously annotate streamed lecture videos and to share their written and spoken annotations. Furthermore, MRAS supports fine-grained access control to annotation sets (e.g. public, private, specific user group) and even threaded replies. MRAS however, was not designed to be used within a collaborative video-conferencing environment. It does not support synchronous video annotation or the annotations of regions and only offers low–quality video (5-10 fps).

Other projects have aimed at providing concurrent annotation of 3D models [28]. Most only focus on allowing users to annotate the same model and view a list of annotations added by others asynchronously. Annotations to specific parts of the model are typically stored by capturing the users 'view' at the time of annotation rather than recording a specific point (x, y, z) on the 3D model. Selecting an annotation takes the user to the same view as the annotator. Jung et al. [28] prototype was implemented using VRML and Java 3D, two technologies commonly used for modeling and rendering 3D models. Current research in this area is focusing on usability issues in 3D environments e.g., how to prevent disorientation.

Mimio classroom enables real-time sharing of whiteboard notes between teachers and students who are viewing images collaboratively in a networked environment. But it doesn't support shared, real-time applications for browsing, viewing and annotating film, video or 3D objects.

Microsoft's Distributed Tutored Video Instruction (DTVI) [27] system enables students to replay and discuss videos of lectures collaboratively. However it does not support real-time synchronous annotations. It is based on a combination of Windows Media Player and Microsoft's NetMeeting [29], which uses the T.120 protocol [30] for application sharing. Because T.120 has been designed for low bandwidth and only supports low frame rates (e.g., 10fps), the capture and transfer of mouse events, keyboard events and screen update to the client display devices is too slow to adequately handle MPEG-2 video (24-30fps).

2.3 Collaboration - Application Sharing Protocols

The approach adopted by application sharing protocols such as T.120 (NetMeeting) or VNC-Protocol [31] makes them unsuitable for our application. In such protocols, the shared application runs on a master client or server, which receives the keyboard and mouse events from the participants and sends captured screen/window updates back to the participants. Although this approach provides a single framework that can be used to share different applications, these protocols were designed for low-bandwidth networks and can not handle the high frame rates required by video and 3D content. They also restrict the application sharing – only a single user can be in control at any one time. Because of our need to support high frame rates and MPEG-2, such ready-made application-sharing frameworks are unsuitable. We have had to build a collaborative environment from scratch, using .NET Remoting. This is described in detail in Section 4.4.

2.4 Indigenous Rights Management

One of the challenges that museums face when managing Indigenous collections is providing support for traditional laws related to the protection and preservation of sacred or secret resources. Attributes including a user's gender, tribal affiliation and status within the tribe are examples of the fine-grained access control that may be required. Physical artefacts may have special storage, orientation or preservation needs – known as tribal care constraints. Within the Indigenous Knowledge Management (IKM) project [2, 32] tools have been developed to enable traditional owners to define the specific rights requirements associated with digital objects and to match them against user profiles to control access. A number of other projects [33-35] have been developing software to support the management of indigenous multimedia collections but none provide the same level of granularity, flexibility, scalability and interoperability or are designed for real-time collaborative use.

Figure 1 shows the rights definition interface which is generated from backend XML Schema files which define the metadata schemes. A graphical user interface is also provided so users can customize the schema files to suit their particular community's descriptive and rights metadata requirements. A keyword web-based search interface is also provided so users may search, browse and retrieve resources that they are permitted to access. Our objective is to incorporate the fine-grained rights management components of the IKM software within the metadata schemas and search interface of the Vannotea system, essentially to enable the IKM software to be used by distributed groups of users, collaborating in real-time.

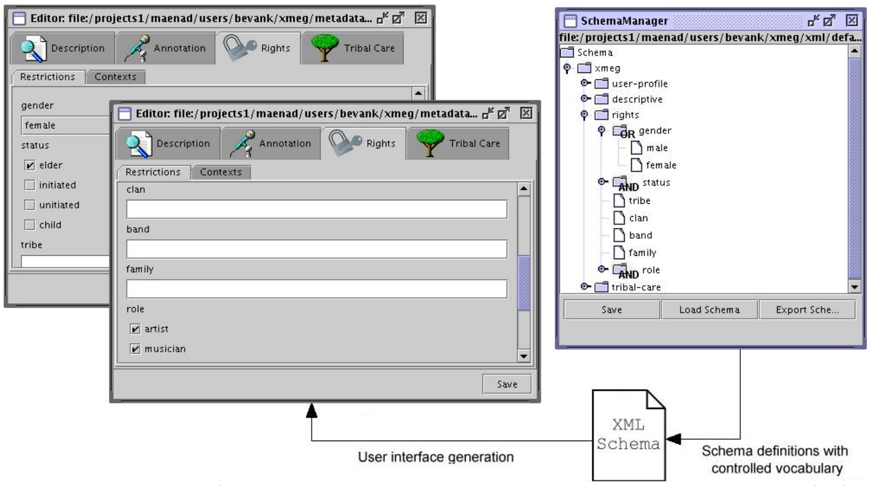

Figure 1: Rights definitions using Indigenous Knowledge Management Software

3 System Architecture

Figure 2 illustrates a hypothetical usage scenario of the Vannotea system - a live discussion between museum curators and traditional owners, communicating with each other using Access Grid Nodes and the Vannotea system over the GrangeNet broadband network.

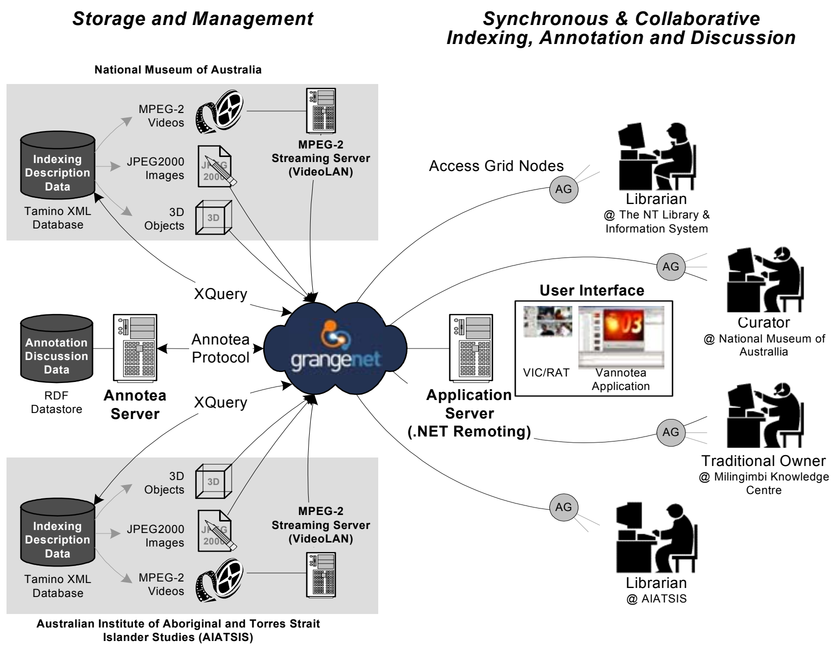

Figure 2: System Architecture

The Vannotea application enables the retrieval of high-quality images (JPEG-2000), MPEG-2 videos or 3D objects and real-time collaborative, synchronous indexing, browsing, annotation and discussion of the multimedia content. The architecture also reflects the assumption of two separate metadata stores:

- One (or more) databases for the search and retrieval of multimedia content based on objective metadata about the multimedia content. These databases are typically maintained by the custodial organization (museum or archive) or owner of the content.
- A separate metadata store that logs the shared personal annotations.

The different components are described in more detail in the next section.

4 System Components

Figure 2 illustrates the four major components of the system which are described in more detail below: User Interface; Indexing, Search and Retrieval; Annotation and Discussion Server; Collaborative Environment.

4.1 User Interface

A full-size screen capture of the interface, being used in the context of an access grid session, is available in Appendix A.

Figure 3: The three key components of the UI

The **Content Description** component enables the objective and authorized segmentation and indexing of the content, as well as search, browsing and retrieval.

In order to streamline the indexing and segmentation process of video content the Mediaware SDK [36] is used to perform the automatic shot-detection. The resulting shot-list is used for further hierarchical segmentation of shots to frames or aggregation of shots to higher-level segments (scenes). This hierarchical temporal structuring enables easy navigation and browsing through the video. The entire multimedia object, selected segments, or individual frames, can be described either by entering free text values or using controlled vocabulary/terms available through pull-down menus.

Different **Content Viewers/Players** were required to support the different high quality media formats: MPEG-2 for videos, JPEG2000 for images and Direct3D for mesh files. Microsoft Direct3D was chosen for its generic mesh file format and native C# API. Direct3D mesh files describe the model as a series of interconnected polygons. Utilities such as AccuTrans 3D [37] can convert a variety of popular 3D languages, including VRML, into this format.

The controls of each Content Viewer/Player vary depending on the format of the currently shared object. The Video Player features common video playback functionalities (play, pause, seek, stop). The Image Viewer provides tools such as panning, zooming and tilting and the 3D Object Viewer (Figure 4) provides controls to zoom, pan and rotate or change the current view.

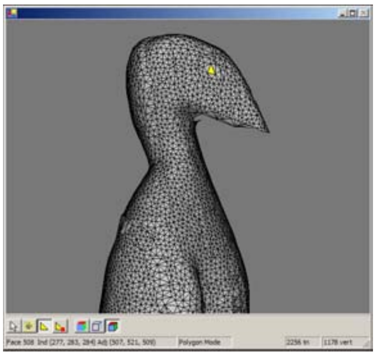

Figure 4: 3D Object Viewer

Users can attach annotations to selected regions within images, selected segments, frames or frame regions within videos, or areas within 3D objects. For 2D this is done through drawing simple shapes (line, rectangle, ellipse) on top of the image or frame. The frame number (for video), shape and the coordinates are then stored as context fields the annotation refers to. For 3D objects, annotations can be attached to a specific polygon or group of polygons in the mesh. A 3D technique called "picking" is used to identify a polygon based on a mouse click. Once annotated, the polygon(s) is/are highlighted to visually inform users that an annotation exists on that surface region of the model. Currently annotations can be either plain text or a URL. Within the Annotation & Discussion window, we not only list the annotations (details of who and when) for a multimedia document, but also implemented a search and browsing interface. Consequently, users can not only retrieve content based on the objective metadata, but also based on the subjective, personal annotations.

4.2 Indexing & Search and Retrieval Database

A key objective of the system was to provide simplicity and flexibility for users in their choice of metadata descriptions, whilst still supporting standards and interoperability and different media types. This required a design which could easily adapt to the different application profiles required by different communities.

We did this by providing a tool which enables users to define and edit XML Description Templates (Figure 5) – simplified versions of XML Schemas. The templates are directly mapped to the UI for entering the metadata. This flexible description architecture allows fast and easy customization of the system to support different indigenous community needs, as well as different media formats.

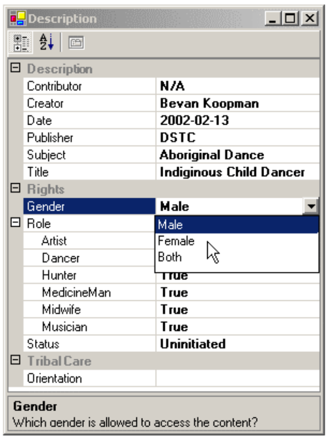

Figure 5: A metadata capture form generated from a Description Template

The actual metadata for each media file is represented as a Description DOM (Document Object Model) similar to the structure of the template, which makes it simple to transform to different standards like Dublin Core [38] and MPEG-7 [39, 40] or the IKM metadata format using XSL-Stylesheets. The metadata is stored in a Tamino native XML database and XQuery used to query the repository. However, the flexible description architecture and search and retrieval interface allows the integration of third party web-based search and retrieval tools such as provided by the IKM project described in Section 0. With very little modification to the HTML source (adding a JavaScript function calls) websites are able to communicate with Vannotea.

4.3 Annotation Server

The annotation database stores the annotations (which may be associated with regions of 2D images or 3D objects, video segments, keyframes, or regions within frames), as well as the source of the annotations (who, when, where). Currently either textual or hyperlink annotations are possible. We based the annotation component of our software on Annotea [19], an open source system developed by the W3C which enables shared RDF annotations to be attached to any Web document or a part of the document. We extended Annotea to support the annotation of other media types, such as audiovisual content or 3D objects through spatio-temporal fragment identifiers generated by extending URI's. For the annotation of regions on 3D objects we used unique polygon IDs. This was the simplest approach but may be problematic when the regions do not exactly match polygon boundaries.

This approach also allowed us to test prototypical annotation server implementations such as Zope [41] or the W3C Perllib [42] server. We experienced problems with current implementations of Annotea servers which also don't support fine-grained access control to annotations based on user profiles. Therefore we are currently implementing our own annotation server based on the same principles but with more flexibility enabling us to extend it towards our needs.

The flexible architecture of Annotea will also allow us to easily attach and store audiovisual annotations - small audio or video clips captured during the video conferencing discussion. However the current access grid node videoconferencing tools (*vic* and *rat*) prevent easy capture and synchronization of audio and video streams. Researchers from the ANU's Internet Futures Program are currently working on alternative videoconferencing tools [43] which will support easy capture of audiovisual streams from AGN sessions.

4.4 Collaborative Environment

Because Vannotea is implemented in C# within the .NET development framework, the most flexible, modular and integrated approach to application sharing was to develop it using .NET Remoting. .NET Remoting provides a framework that allows objects to interact with each other across application domains or on different servers through events.

Figure 6 illustrates the event-handling architecture of our application. In this example, the client-master is in control of the application, the remote clients are joining the session by connecting to the same server-application.

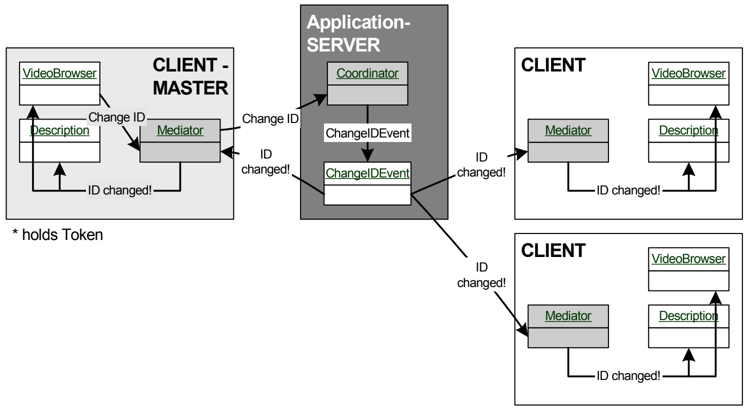

Figure 6: Event handling using .NET Remoting

The Mediator objects handle the communication between the clients and the server. They can call methods on the remote object (Coordinator). In return, the Coordinator can call methods on the Mediator by raising events that the Mediator has subscribed and listens to. To achieve a form of collaboration, selected events are simulated on all clients. Even mouse movement events can be handled in this way, resulting in several colour-coded mouse pointers within one application that can all be in control simultaneously.

The MPEG-2 videos are streamed using multicast over VideoLan [44]. VideoLan is controlled by the application server to ensure all clients are watching precisely the same content at the same time. Collaborative viewing of 3D objects can be implemented by:

- Either transferring the whole file and rendering it at the client. This is easier to implement; thin server; each client can have a different view. The major disadvantage is that computationally expensive rendering must be performed by each client.
- Or rendering it on the server and streaming the rendered result to each client. This is more efficient because rendering of complex 3D objects is computationally expensive. But it is more difficult to implement and to ensure that each client sees the same view.

One objective of the project is to evaluate users' behavior and obtain user feedback on the different levels of collaboration available during the image/video/object analysis and discussion and annotation processes. We may want to restrict access to shared application controls based on user profiles. Access management of content during collaborative sessions also presents a difficult problem. Participants might have different access rights to content, that is opened during a collaborative session. All participants have to log on to a collaborative session. Their user profiles are stored on the Application Server managing the session. If a user chooses to open a new multimedia object, the access rights of each user are compared with the access rights of the object. If one or more participants are not allowed to sight the object, the initiating participant is warned and has to choose if the object should not be opened at all or if restricted participants should be excluded from the collaborative session.

5 Future Work and Conclusions

In this paper we have described a system which combines high-speed networks, access grid nodes and collaborative document- and application-sharing software to facilitate the communication and exchange of knowledge between dispersed indigenous communities and museum staff. The aim is to deploy and test the software in collaborative projects between museums, archive and indigenous communities, to facilitate cultural repatriation programs. We are currently discussing a collaborative project between the Smithsonian National Museum of the American Indian (NMAI), the American Indian Higher Education Consortium (AIHEC) Tribal Colleges and American Indian communities which will use this system to facilitate the implementation of the NMAI's Culturally Sensitive Collections Care Program. It will provide a means for Native peoples to express and document their concerns with regard to the maintenance, presentation, disposition and repatriation of sensitive materials and information in the museum's collections.

In the immediate future we plan to complete the integration of the IKM software within the Vannotea system and carry out further testing, evaluation and usability studies using real groups communicating via access grid nodes. We also intend to investigate the following:

- Audiovisual annotations – capture of video/audio streams from access grid node sessions;
- Rights management of annotations;
- The use of Shibboleth and OpenSAML to implement user authentication and access controls;
- More intuitive search and browse interfaces e.g., GIS/map interfaces;

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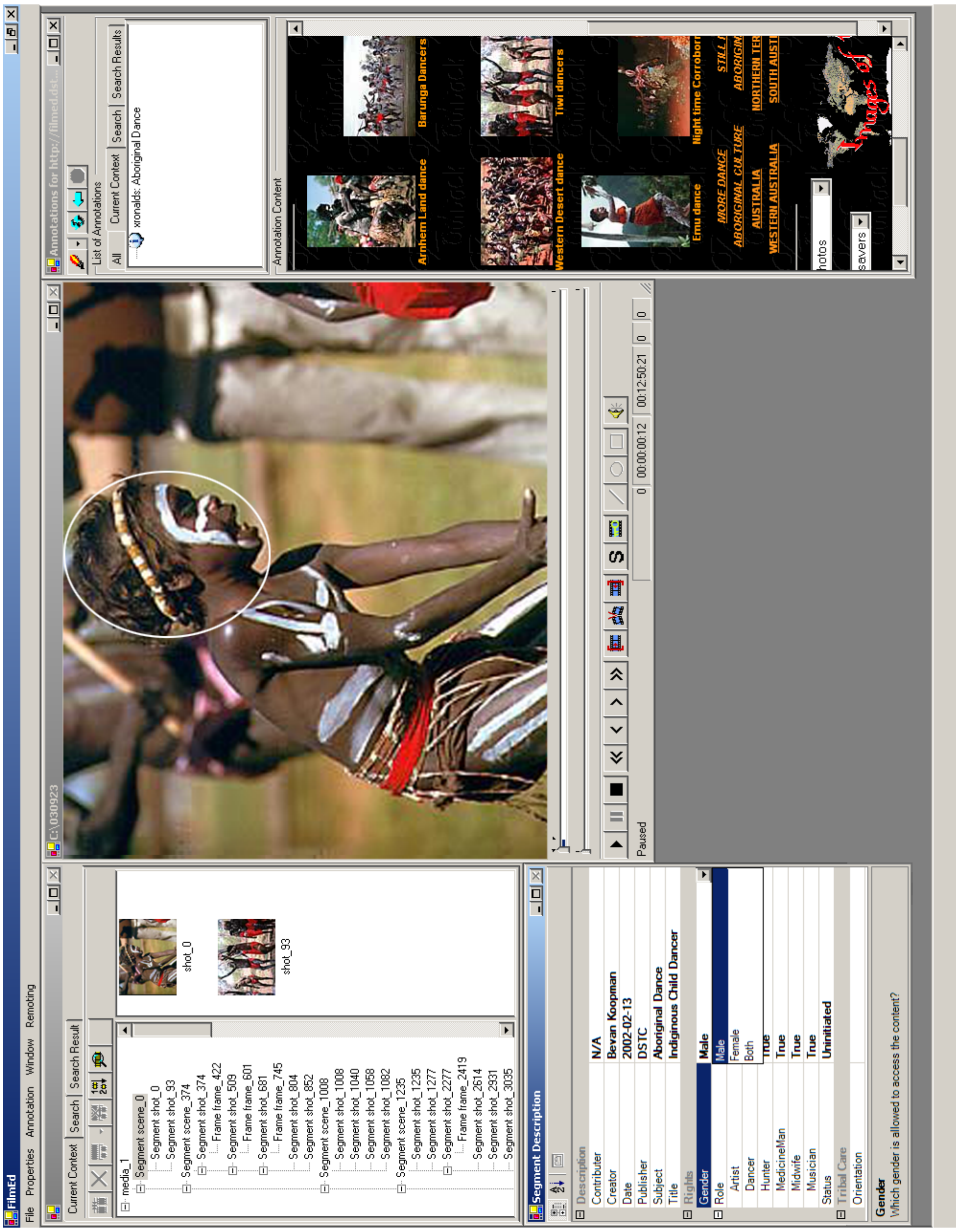
Appendix A


FilmEd
File Properties Annotation Window Remoting
Current Context Search Search Result
Segment Description
Description
Contributor N/A
Creator Bevan Koopman
Date 2002-02-13
Publisher DSTC
Subject Aboriginal Dance
Title Indiginous Child Dancer
Rights
Gender Male
Role
Status Uninitiated
Tribal Care
Orientation
Gender
Which gender is allowed to access the content?
Paused
Annotation Content
Arnhem Land dance
Barunga Dancers
Western Desert dance
Tiwi dancers
Emu dance
Night time Corroboree
MORE DANCE
ABORIGINAL CULTURE
AUSTRALIA
WESTERN AUSTRALIA
NORTHERN TER
SOUTH AUSTR