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Moving Image Indexing: Theory and Technology

1.0 Introduction

Indexing of moving image elements is becoming an increasingly more important issue for the disciplines of indexing and information architecture, in both traditional bibliographic venues and online, as moving image content not only grows in its production but also grows in the variety of uses it is put to and the places in which it is available. This paper will touch briefly on the implications, for user discovery and retrieval, of locating large amounts of video or digital moving image content on the web in catalog sites such as Google Video, Yahoo Video, Youtube, Castpost, and Clesh. How the material is displayed and arranged will be discussed, and posed against, in the second part of the paper, more detailed and granular methods for indexing and retrieval used in other environments, such as television news studios to control large amounts of moving image material.

2.0 Google and Video in the Internet Environment

Tapping into both the high and low culture impulse and fascination with video, coupled with the cheaper and more ubiquitous methods of making and migrating digital video, Google has launched its own video platform service (VPS), Google Video.

The public as well as private collections can upload and allow free viewing or display for purchase. Granted, the vast majority of titles are emulations of reality TV shows, there are also teaching modules for corporate and distant learning services, stock footage, and a host of unintentional anthropological and ethnographic work from birthday parties to municipal and religious proceedings. If one wishes to sell their content one can set their price for purchase, but many are starting at prices to compete with iPod downloads (99 cents or $1.99). With specific titles for sale, Google has the right to take a cut of the sales, if traffic and download purchases go up for that title. There is not a minimum, or maximum amount of video time that one could upload (or if there is a maximum amount of time they don't say). Larger content providers such as CBS, the NBA, and PBS's Charlie Rose have taken the plunge and offered content to be downloaded for a price. Google terms these "major producers" and makes the distinction between them and the average producer at the level of volume to be ingested: if you have more than 1,000 hours of material to offer Google, then you are a major producer. But Google's ulterior motivations are not clear. By comparison, Yahoo also has its version of a video platform service but at this time is not taking material unconnected to a website, which is a major difference in ownership, and has implications for indexing and retrieval as well. Yahoo video points to sites where the video exists, much like Google's Image search. However, in the case of Google's Video, their Terms of Service state a licensing

situation which seems to grant them a piece of free content (your contributed video) for them to use freely (potentially in the future if they wished to do so) simply by way of their reformatting the video.

3. Use of Content.
By accepting this Agreement and uploading Your Authorized Content to Google, you are directing and authorizing Google to, and granting Google a royalty-free, perpetual, non-exclusive right and license to, host, cache, route, transmit, store, copy, distribute, perform, display, reformat, excerpt, analyze, and create algorithms based on the Authorized Content in order to (i) host the Authorized Content on Google's servers, (ii) index the Authorized Content; and (iii) display the Authorized Content, in whole or in part in the territory(ies) designated in the Uploading Instructions, in connection with Google products and services now existing or hereafter developed, including without limitation in products developed for syndication.[1]

To stream the content through a Flash based player, Google has used DivX technology for encoding, compression, and digital rights management. To view purchased content one must have downloaded the Google viewer and be connected to Google through the internet. This course of access irks some people as they complain that the need to link to Google to get a Google reauthorization for each viewing can be a limitation not only of privacy (users should be able to watch whatever they want, wherever and for however many times they wish, some argue), but of equipment and hardware as well. Many suggest that Google has simply added another proprietary viewer to the many incompatible and non-universal ones (Windows Media Player, Real, QuickTime, etc) out there and has not truly solved the access issue.

Options for end use and delivery are one aspect of the developing online video environment, but indexing, search and retrieval are another. As we will see, online capabilities for representing and finding video content are different then those used in

[1] http://video.google.com/support/bin/answer.py?answer=31704&topic=1490

existing programs which allow for some degree of shot listing, or, in test-bed software being developed, to scan through video on a deeper level.

Though the result is similar, the particulars of Google's and Yahoo's services show a difference not only in content, but in how that content is acquired and how a user can search the holdings. Yahoo does not solicit videos, nor do they intend to, at this time, host any solicited material. Yahoo will accept suggestions for content but it must already exist in a site that is able to be referenced through pre-existing links. Google on the other hand openly solicits video and will show it isolated from any other contexts; however, further information about who is participating aside from the large corporate names previously mentioned is hard to come by. Perhaps museums, and other cultural repositories with moving image content are waiting to see how the Google interface and use-trends develop. There is also the question of whether those institutions want to enter into licensing agreements with a company that once was a search engine and now is a content provider and is posed to possibly serve itself through its own owned and run IP networks.[2] Yahoo is much more transparent to the public about how it searches and how the public can better produce content to be found by Yahoo's crawling methods. Yahoo advocates using Media RSS methods to promote discovery of content.[3] Media RSS follows on RSS 2.0 as a method of syndicating content through linking. Multimedia content tagged in and supported by Media RSS will enable web search engines and their crawlers to discover key words and, more importantly, meta data about the multimedia object, specifically screen size, player, format, frame or bit

[2] http://business.timesonline.co.uk/article/0,,9075-2023600,00.html

[3] "Much of the multimedia content on the Web can be difficult for automated crawlers to access. It is often hidden behind JavaScript or tied to site-specific "pop-up" video players. Our support for Media RSS gives publishers a way to ensure their video content is discovered and indexed by search engines that support Media RSS", http://search.yahoo.com/mrss/mrss

rate, and sampling rate, details which will hopefully also make playback of these objects less frustrating.[4] In the case of Google, they are far less transparent in the FAQ's about their search and crawl methods and therefore have less to say to the consumer about how the consumer-producer can best profile and utilize the various codes and protocols available. Google's search for video is not as precise as their searches for text based web pages and content. Even their image searches, though riddled with wildcard finds, usually produce more precise hits. The reason is that video, or moving image and audio content is not a text and not a photo. The essence is different and therefore the data representation of it will also be different. Video, as another form of content, which can be diversified and disseminated in a similar way as text, but, in addition, has inherent qualities which effect its discovery (indexing), and routing (formats). A video file, greatly compressed as an online version (as a .mov, .avi, or mpeg file, the DivX codec being an MPEG 4 file) is a different content entity than the .pdf or .tiff file of a text sample from a book. Video files can be much larger and are time based. All information is not self evident in one display, and the potential ways of cataloging the item online are greatly expanded if one uses the video's metadata properly. A common complaint is that Google doesn't, but should[5] adopt for its video searches, tagging methods already prevalent through folksonomies in the social search communities.

Unlike in the print world, there is an established peer-to-peer micro-community sharing home grown, self produced video and photographs in a non-commercial mode. This type of production and circulation community does not have quite the same equivalent

[4] http://search.yahoo.com/mrss
[5] http://www.jasonsalas.com/2005/12/google-video-needs-to-adopt-flickr.html

for music makers. Though these music based micro-communities exist, the commodification of the song as a product is different and stronger, and has preexisting models outside of the internet with histories going back to brick and mortar times. Photography and video are a bit more rogue in their free circulation and are still oddities of sorts and have not yet created for themselves strong online markets, with the exception, perhaps of pornography. These photo and video micro-communities are based on the many-to many, or peer-to-peer, youth culture technorati who have built and inhabit sites such as del.icio.us, Friendster, Myspace, Flickr, Youtube, Clesh, Dodgeball, Librarything, and countless photo, video and opinion blogs. These sites are by fits and starts developing intuitive and flexible models for categorizing content by subject, based on ideas of thesauri and controlled vocabularies. Clay Shirky, among others, has focused this issue and well articulated the forces at work beneath it.[6]

3.0 The environment is built by the needs of the producers and users and those needs determine how content will be ordered, stored and retrieved.

Streaming content as is provided by Google et al.is only one environment where video indexing comes into play. There is also the offline digital archives of news networks that need to manage and retrieve their own previously created content, for re-use in contemporary news stories. In addition to the commercial broadcasting realm there are also digital libraries associated with stock footage houses or museums, or national

[6] See particularly: http://many.corante.com/archives/2005/01/07/folksonomies_controlled_vocabularies.php, and http://www.itconversations.com/shows/detail470.html, and http://www.shirky.com

moving image archives, the former needing to organize their material for re-sale, the latter needing to organize and present their material to enable access to researchers, students and scholars. The end-use of the content will also determine the type of indexing needed. A non-profit museum may not use the same software that a network newsroom would or a commercial for-profit stock footage library. As video indexing is still evolving, the depth and quality of the indexing is still developing with various software packages offering more or less operability for the data managers as well as the user community.

How indexing moving images differs from indexing digital images such as photographs or art reproductions is also important to consider. The amount of original information due to the format is multiplied and the variety and breadth of indexable information is also multiplied

In their 1997article *Indexing the Content of Multimedia Documents*, Stephen W. Smoliar and Lynn D. Wilcox begin with a global view of indexing and "consider a description space for multimedia documents based on three 'dimensions' of a document, namely *context*, *form*, and *content*. "[7] This concept of a document or information bearing item existing in three dimensions they bring forth from John Seely Brown whose approach they see enables a better representation of the data item in question. The dimensions of form and content are traditionally known to the indexer and cataloger as available bibliographic elements. Context is an important dimension for users in retrieval that, depending on the search system, allows users to differentiate between returns. This

[7] http://www.fxpal.com/publications/FXPAL-PR-97-141.pdf.

dimension of context is closely related to the ratio of exhaustivity and precision in a search. The need for more fine toothed searches in moving image domains is accountable by the very multiplicity of images (bearing difference and similarity) and the exponentially increased need to differentiate within a data item between qualities of that data item.

Part of what is at stake in indexing moving images is linked to the technology of video and digital transport capabilities. But before getting into the physical properties of the "content" it would serve us well to understand how the "form" of video is being defined, keeping in mind that this will also be determined by the "context" of the indexing entity and the user community.

4.0 Part to whole, books versus tapes and reels: macro level format issues

By its constituent make-up, a moving image work is more complex a "bibliographic" entity than the traditional print and single image works. Subsequently, the methods of describing the multiple components of the moving image work can be as varied and complex as the components which make up the work. Again this is dependent on the level of precision needed by the home venue to describe and represent the work. Of course a moving image could be reduced to a very simple representation and treated as a book title with the same bibliographic elements recorded (title, author/director, date, place of production, running time) and depending on the user community that may be just enough. However, for user communities who need a greater degree of granularity in their content representation for research or re-sale footage purposes this level of

representation will not do. This type of conceptual assessing of the nature of moving image work is important to our earlier discussion of broad dimensions in which a data item can be described.

4.1 FRBR

To frame our discussion of indexing moving image work on the micro level, meaning scenes, shots and frames, it will be helpful to begin on the macro level and work down. Another way of looking at and relating content and structure issues when considering moving image and audio works is through the data model Functional Requirements for Bibliographic Records (or FRBR) that was put forth in 1998 by the International Federation of Library Associations and Institutes (IFLA)[8]. This conceptual framework proposes a new way of understanding data items in the bibliographic universe and their relations between each other. "Entities", as they are termed in IFLA's report, in the bibliographic universe are either related to the work (the intellectual realization) or the creator or owner or user of the work. Both sets of entities are pertinent for our discussion on the manifold nature of moving images. The first set of entities establish definitions for the work, the expression, the manifestation, and the item.

> The entities [are] defined as *work* (a distinct intellectual or artistic creation) and *expression* (the intellectual or artistic realization of a *work*) reflect intellectual or artistic content. The entities defined as *manifestation* (the physical embodiment of an *expression* of a *work*) and *item* (a single exemplar of a *manifestation*), on the other hand reflect physical form…..
> a *work* may be realized through one or more than one *expression*. An *expression*, on the other hand, is the realization of one and only one *work*. An *expression* may be embodied in one or more than one *manifestation*; likewise a *manifestation*

[8] http://www.ifla.org/VII/s13/frbr/frbr.htm

> may embody one or more than one *expression*. A *manifestation*, in turn, may be exemplified by one or more than one[9]

Though this conceptual ordering can at first seem to be too complex to make practical sense, when we consider the non-print entities created from the rise in audio-visual and digital technology we can be thankful that there is a systemization that is extensible for current and future media.[10]

4.2 Moving images on the macro-level, applying FBR, and alternate schema

This understanding of a work begins to match more closely with the actual real world result of many moving image productions. Increasingly, moving image archives are having to manage and account for the multiple stages a work goes through in pre-production and post production. For example, in the case of film or video documentary there can be various amounts of raw material that may or may not be used in the final work. Outtakes are an important category that are becoming more important as they provide another layer of evidence from which to view a work, another concentric context of what a work may have meant, had it been included in the final cut. In the instance of film there are many production elements which go into making a final version. There can be the camera original film and depending on whether or not the film was shot on positive or negative (reversal) stock one can have a pre-print generation (a negative which is usually the case) or a positive print ready to be projected from reversal stock. When a negative is generated the print must then be made from that. These elements are very important from a preservation standpoint as they are what one would go back

[9] Ibid

[10] FRBR concepts are even being transported into the XML realm of RSS and RDF protocols so as to be able to describe these entities in online cataloging and internet environments. See http://vocab.org/frbr/core

to if they wanted to make the cleanest set of new prints. In addition there may be ancillary material, again depending on the production, such as cutaway or B-roll material (used as background picture in news and documentary work), screen tests, location footage, or test rolls.

When a studio or film library decides to put out, say for example, a film on DVD, and that single initiating studio or film library does not have a good copy or print of the film they will look elsewhere across federated catalogs to see who may have the best existing materials (either a pristine print or original printing elements). This type of material is not always evident in a catalog. UCLA's Television and Film Archives, and the University of Georgia' Peabody Awards Archive are good examples of preservation conscious cataloging where MARC fields have been adapted to contain information on the specific film production elements that they have. This can be very helpful to drill down in a catalog to get exact holdings when a very particular data item (in this case film production elements) is needed. Here is an example of the detail or granularity depth of the content being lead by the search needs of a particular community of users, in this case other film archives and libraries.

Continuing from our example of the restored film, how is this new DVD release with special features (for example, with a longer "director's cut" version of the original work, with additional outtakes and deleted scenes, director and cast interviews, etc.) to be understood from a cataloging standpoint in the FRBR universe? If we take for example the 2001 re-issue of the 1979 Francis Ford Coppola film *Apocalypse Now* (152 min.),

with the altered title to denote another version, *Apocalypse Now Redux* (202 min.) we can start to determine on the macro level these entities as they take form in the bibliographic realm. *Apocalypse Now Redux* contains 50 minutes of additional footage, not included in the first cut, and some rearranged scenes. Because of the technology of DVDs (larger time capacity per disc versus video tape, multi sound and language tracks, and non-linear access points) our traditional filmic experience evolves and we begin to understand the film as a process in a continual context of past and present. Bibliographically speaking, our conception of the film also changes. Unfortunately, the re-issue DVD of *Apocalypse Now Redux* does not contain extra features such as deleted scenes, outtakes (there is reportedly a 5 1/2 hour rough cut bootleg version also floating around non-commercially, which makes yet another version), interviews, maps, archival news reports, or documentary work about the filming (Fax Barh and George Hickenlooper's *Hearts of Darkness*, 1991), all of which do exist. Enriching things further, however, it must be remembered that *Apocalypse Now* is takes its inspiration from the Joseph Conrad story *Heart of Darkness* from 1902. Though these are all not contained on the 2001 DVD, they are related entities in the bibliographic universe of *Apocalypse Now* 1979. There is a question as to why this additional material was not reissued on the DVD when it clearly could have been. Perhaps there were issues with rights clearances; or, perhaps this is the cut the director wants us to remember, as the first version was rushed to completion for release and he distinctly does *not* want the work cluttered with other bibliographic entities. Thus, we can say that the *work* (the distinct intellectual or artistic creation) is Coppola's property, in Hollywood jargon, *Apocalypse Now* 1979 (though an argument could be made that it is also Conrad's 1902 *Heart of*

Darkness). The *expression* is the filmwork that he shot from 1976 to 1979 on location in the Philippines. The *manifestation* is the film shown to the public in theaters in 1979. The *item* is the VHS video copy and now DVD of the 1979 film. *Apocalypse Now Redux*, 2001 can also be said to be a separate and new *manifestation* of the work, *Apocalypse Now* 1979 (or even, again, Conrad's 1902 *Heart of Darkness*), and the *items* are the new DVDs with or without their special features.

Martha Yee would consider this 2001 *Apocalypse Now Redux* manifestation of the original work as a *near-equivalent*[11] and from a cataloging standpoint would be described in somewhat the way a different edition of a book is.

Also helpful as a real world exercise in clarifying the examples of expressions and near-equivalents comes from Andrea Leigh in her 2002 article on the television series *I Love Lucy*.[12] Leigh first describes the hidden layer of complexity in detailed (including not only full cast and production team, but writers and producers) cataloging or indexing episodes of television series over several years. She then goes on to point out that correct bibliographic representation (in her case MARC21 and AACR2) can be further complicated when episodes are collected (often out of original order of airing) on re-issue VHS or DVD compilations. Though she does not refer to FRBR entities, she makes a well balanced case for understanding the collaborative components of a

[11] see Martha M. Yee "Manifestations and near-equivalents: theory, with special attention to moving-image materials", *Library Resources and Technical Services* 38, no. 3, 1994, p. 227-255; and "Manifestations and near-equivalents of moving image works: a research project", *Library Resources and Technical Services* 38, no 4, 1994, p 355-372.
[12] See Andrea Leigh, "Lucy is 'Enciente': The Power of an Action in Defining a Work", Cataloging and Classification Quarterly, Vol 33, No. 3/4, 2002, p 99-127.

moving image production within a specific industry genre, the television sitcom, and how an understanding of these and eligible record fields by the cataloger can improve search accuracy and increase returns, delimiting false positives.

5.0 Moving images on the micro level: structure and content

Leaving the macro level of books, reels, tapes, and other such objects (or carriers) of content, and keeping with our moving image focus we can now go on to examine the micro level of the content, specifically the structuring of moving image work from a filmic and technical point of view.

As a media, both film and video operate on the segmentary principle of many still images shown successively at a certain rate to cause the effect of motion. This is known historically as “persistence of vision” and several pre-cinema apparatus such as the Zoetrope or Kinetoscope are based on this principle. Both film and video use frames. This is their most basic structural component. Both film and video’s frames lie on a strip of some sort of polyester or in early film from 1880 to 1950 a cellulose based compound. In the case of film one can see the frame and light projected through it, at 24 frames per second, is the mechanism of display. For video one cannot see frames yet they are arranged via and as coded electronic pulses controlled by a separate track that runs along the top of the video tape. For our purposes and in most real world

online/offline digital scenarios original film or video footage has been transformed to a digital code which is then re-asembled to represent the footage with new digital “frames” (sections of the re-assembled footage) in place. Digital frames may not represent the orginal format’s frames, because of the reassembling process of transcoding, but one can usually specify in the transcoding software what rate of re-assembling would best represent the frame-rate of the original footage. Sound is held in a separate “track” and is carried over when it exists in the original, to a similar track in the re-assembled digital file. With this understanding of the structure of frames as a section carrying content, we can now see the detailed level into which researchers or content managers may need to go. What used to go by in an instant and, depending on the playback technology, was unable to be reviewed or stilled is now open for examination.

6.0 The shot

James Turner has written much about the developing theory and technology behind shot analysis as it relates to indexing.

> For the purposes of cataloging, indexing, storage and retrieval of moving images, a scene can be described as a group of shots related to a common theme or that take place around a specific event or theme of a movie or television show. The shots play one after another in the edit sequence and can be considered as an intellectual unit used to advance the plot of a movie or to provide a unit of information in a television program.[13]

The analysis of moving image work (and determining its scenes and shots) for indexing purposes can be more or less complicated by whether the work is fiction or non-fiction.

[13] James M. Turner and Abby A. Goodrum, “Modeling Videos as Works” in *Works as Entities of Information*, ed. Robert Smiraglia, Hawthorn Press, 2003

When work is narrative in genre continuity of theme and content is more likely to be within a certain range of descriptors (semantic or temporal) that repeat or go through some alteration. The example of *Apocalypse Now* (either manifestation) will stay within the historical range of the Vietnam War, the geographical range of Vietnam and Cambodia and will not introduce out of genre objects or events. Therefore the scene descriptors will be limited in scope. There will be descriptors for the jungle and the military and actions therein, but not for other genres, no space stations, no man-eating sharks.

However, when the work is outside of fiction genres the need for specificity and comprehensiveness in indexing increases. Many moving image archives have reels and reels of unlabeled, unidentified film. If they have the appropriate playback material they can attempt a cataloging and/or indexing of the work. Many works in alternate film formats from the 1930s to the 1970s are being gone to for re-use now in documentaries. Historic footage, amateur and ephemeral films, industrials and educational films, archival and home movies could all conceivably be indexed for the purpose of revealing content that otherwise would not be known from a slip case, cover or description, or even original intetnion, for many of these works were produced in varying environments for different reasons.

Television news clips via station broadcasts have already been encoded with text (closed captioning for the hearing impaired) and this quasi-metadata can be used to

begin an indexing process. However, footage that originates outside of network news realms, historically on film and only recently on video does not benefit from this descriptive embedded captioning. This means that film must be indexed through non-automated means, usually by real time, full-length human viewing, an endeavor that can be resource consuming and cost inefficient for both non-profit archives and for-profit stock libraries.

The degree of granularity needed from video content can vary. Some stock libraries because of limited time and resources map a very shallow, general summary of titles which may in reality include several reels of film or videotape. Depending on at what stage this material resides (before or after digital ingestion) this may be very important. If a single title has 4 reels or 4 video tapes it would be that much more helpful from the user's standpoint to know which one of those reels or tapes has the sequence they are looking for. The search time is increased if one has to watch all the reels or tapes. As much as preservation issues are another layer on top of access and retrievability in moving image and audio content, for the purposes of this paper we will continue on the assumption that the work exists in a digital form (either digital tape as is the case with many television studios, or a complete digital file).

7.0 Automated Indexing

This is where the shot list comes in. A shot list can break scenes of digitized material further down into causal or a-causal linear sequences using descriptors to distill the actions, location, and agents, as they change or stay the same from shot to shot, of a

scene. This can be done either by a human recorder or via automation, to differing degrees of accuracy.

When describing moving image works there is an additional variable of time attached to the content and this also must be considered. Timecoding of some kind can also be embedded like closed captioning in the file and allow for a matching of frames to shots to scenes within the overall work. As it is time and cost inefficient to log hours of moving images by hand, programs are being developed to create controlled vocabulary, and to automate the analysis, segmenting and extraction process. But to do this, programs have to be taught what to look for, and how to distinguish changes in frames, shots, and scenes.

Video recognition and indexing applications are built on algorithms, or programs of code designed to compute certain values to perform a task, and then go on to another task to be fulfilled by computing another set of values. These algorithms will continue to run until a required end result or value is reached. To coordinate content, the algorithms are built to compare changes in iconic objects, colors, light and motion within a frame, and from frame to frame. Algorithms can also be run to pull text from footage that has closed captioning or from audio using speech recognition. The results of the analysis of shots are then coordinated and returned in some form of storyboard or visual/textual shot list in a graphical user interface. Programs that utilize these techniques are made by Fischlar[14], Virage (www.virage.com), and Pictron (www.pictron.com) for various news, commercial and post-production environments. In addition, many of these software

[14] http://www.cdvp.dcu.ie/, http://jodi.ecs.soton.ac.uk/Articles/v02/i04/Lee/,

suites offer editing and outputting features which allow the user to gather their search results (shots) and create a new file with only those chosen shots while the original file content (as it is digital) stays in the original file. This new compilation list of shots can then be transferred to tape if need be, though many news stations are evolving into 'tapeless' environments where a library and editing studio are merged as an enterprise system of data servers.

8.0 Conclusion

The field of digital moving image indexing is still evolving. There are no standards yet that are unified across the field and new methods are continuing to be tested and developed. Since 1994, the School of Computer Science at Carnegie Mellon University in Pittsburgh has been researching the video and digital indexing potential in a number of fields related to education and military endeavors. Informedia[15] is a multi-year, indefinite project with major funding from the university and the government, that hopes to further explore the potential of moving image indexing for uses outside the news and stock footage environments. As we discussed earlier, indexing via the internet is taking a different route from the offline environments, one that pays attention to not only the characteristics of the digital object, but also to the characteristics of the network on which it is stored, and retrieved. These issues of discovery and delivery over the internet are shaped by the necessities of that environment. Similar meta-data protocols and algorithms can be used for online indexing and retrieval, but at this point not at the same level of granularity that we find in the software used in offline environments. Also at this point, there is not that need for that level of discovery for video content online.

[15] http://www.informedia.cs.cmu.edu/

The operability models and the technology increase the potential for both exhaustivity and precision to come closer together in searches, allowing a wider net to be cast across a library or moving image repository with a higher degree of usable returns. But most definitely, the basic principles of indexing remain the same, and in great need whether on the macro level of the internet, or the micro level of the shot list.