Transparent Format Migration of Preserved Web Content

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Abstract

The LOCKSS digital preservation system collects content by crawling the web and preserves it in the format supplied by the publisher. Eventually, browsers will no longer understand that format. A process called format migration converts it to a newer format that the browsers do understand. The LOCKSS program has designed and tested an initial implementation of format migration for Web content that is transparent to readers, building on the content negotiation capabilities of HTTP.

1 Introduction

Eventually, any format in which digital content might be stored will become obsolete. A format is said to be obsolete when current hardware and software are no longer able to render information represented in it understandable to readers. The design of digital preservation systems must anticipate this obsolescence, and incorporate a strategy by which the content they preserve will still be understood by readers after multiple generations of formats have become obsolete. Two such strategies have been identified:

Emulation in which the content is both preserved and presented to readers in the original format [10].

Migration in which the content is presented in a current format; it may be preserved in a succession of current formats or in the original format which is transformed on request into the current format for presentation [9].

Some software business models depend on a rapid upgrade cycle. In these areas rapid format change is normal; users who do upgrade produce a format users who have yet to upgrade cannot interpret. This is a powerful motivation for further upgrades, and thus a powerful income generator. But note that rapid format change doesn’t imply rapid format obsolescence. An upgraded application that didn’t accept old formats would not be an effective income generator.

We provide an overview of the problem of format obsolescence as applied to Web content and, in this context, examine possible implementations of the two strategies. We identify the practical difficulties that face any implementation of emulation; they led us to choose the migration strategy. We describe the design and implementation of a transparent, on-access format migration capability for the LOCKSS system for preserving Web content.

Our implementation is capable of transparently presenting content collected in one Web format to readers in another Web format, with no changes needed to browsers. The reader need take no special action to cause this to happen, nor even be aware that it is happening. This appears to be the first time that a production digital preservation system has demonstrated transparent format migration of live content collected from the Web for end-users.

2 Format Obsolescence of Web Content

A Web format may be said to be obsolescent when widely-used browsers are no longer able to present content in the format to their readers.

To the casual observer it may appear that the format in which Web content is supplied is solely determined by the Web server, possibly by the file name extension. In fact, the format is determined by one of a set of mechanisms for content negotiation defined in Section 12 of [5] which are capable of negotiating format, language, and encoding. The mechanism for format negotiation uses the Accept: header defined in Section 14.1 of [5]. A browser sends this to the server with a list of acceptable Mime-Type values, each with

1LOCKSS is a trademark of Stanford University. It stands for Lots Of Copies Keep Stuff Safe.
a numeric preference value between 0 and 1. If it is capable of supplying the requested content in multiple formats the server MAY decide on the basis of this list and its preference values which format to supply. Browsers determine the format in which the server has decided to supply the content they requested using the Mime-Type: header.

In practice, a browser does not know when it issues a request for a URL whether it refers to text, audio, video or some other class of object. Browsers therefore send a default Accept: header on most GET requests specifying their preferred Mime-Type values. These lists typically include a low-preference default */*;q=0.1 saying, in effect, “if you can’t give me what I want, give me what you have”. Because browsers indicate in this way their willingness to receive any format, there is some difficulty in determining when obsolescence has occurred.

In brief, the problem of format obsolescence for a system preserving Web content is that of what to do when it receives a request for some content that was collected in format F/G, say image/gif, whose Accept: header indicates F/G is not an acceptable format.

In the light of the */*;q=0.1 usage, there are two ways in which this can happen; the browser can explicitly signal it or the server can be configured to assume it. Although Section 12 of [5] does not define the semantics of a 0 preference value, it appears that servers treat this as an instruction not to send content in that Mime-Type. Thus even a browser that uses */*;q=0.1 can flag a format as unacceptable by F/G;q=0. Alternatively, a server could be configured not to recognize F/G as matching */*.

Fortunately, since Web browsers and their plug-ins are normally free, there are few incentives for rapid format change and particularly obsolescence. No-one clamors to remove support for an old Web format; it is valuable so long as there is content on Web servers that has not yet been migrated to a current format. There are no good ways to motivate small Web sites to perform this migration, so old Web formats die a very slow death. From the viewpoint of digital preservation, this makes Web content easier to handle; there will be plenty of time to implement a format migration.

2.1 Emulation of Obsolete Web Formats

The goal of the emulation preservation strategy is to avoid the loss of fidelity that is likely to result from converting content from one format to another. If the content is preserved in its original format and presented to the reader in that format, no conversion is needed. What is needed is the ability of a future reader to run the software the original reader would have run to experience the content. The emulation strategy seeks to provide that by preserving the original software as well as the content, and providing the future reader with a software emulation of the environment needed to run the original software to interpret the preserved content in its original format. In a suitable context the emulation strategy is attractive; it is being pursued, for example, by a collaboration between IBM [7] and the Koninklijke Bibliotheek (KB, Dutch National Library) [11] which has built a PDF interpreter that runs on a Universal Virtual Computer (UVC, a virtual machine designed to be easy to port to future environments). The terms under which the KB preserves content make this appropriate; they mandate that it be accessed only at the KB, where deployment of the UVC is easy.

In the Web context emulation means that a future reader wishing to read a preserved Web page that contains some content in an obsolete format must somehow find out the approximate date of the original content, then locate a preserved browser or plug-in of that date, and the appropriate emulation needed to allow that preserved browser or plug-in to run in the reader’s current computing environment. The reader must then invoke this emulation to run the preserved browser or plug-in to view the Web page.

Since in the emulation strategy all these activities take place in the reader’s environment, there is little the preservation system can do to enable them. It has no control over the reader’s environment. Indeed, if it is disseminating the preserved content by acting as a Web server, it will have almost no knowledge of the reader’s environment. Although the effect of a successful emulation strategy would be to prevent the preservation system ever seeing a request with F/G;q=0 in its Accept: header, the practical difficulties in implementing both the emulation of instruction sets, operating systems, etc. and in deploying both the appropriate emulation and the appropriate preserved browser or plug-in to the appro-
priate reader are formidable.

2.2 Migration of Obsolete Web Formats

Migration of Web content from an obsolete format to a current one can take place at any time between the point at which the content is collected to the point at which the reader requests access to it. We examine three points that have been implemented, from the earliest to the latest.

2.2.1 Migration On Ingest

The National Archives of Australia (NAA), faced with a requirement to preserve vast volumes of government information in a wide variety of mostly proprietary formats, chose a strategy of migration on ingest [6]. They pre-emptively migrate the content they receive into one of a small number of carefully chosen formats before preserving it. If their choices turn out well, this pragmatic approach has significant advantages:

- It can postpone the need for future migration for a long time, allowing both economies in operation and the use of better, future technology for performing the next migration.
- It can greatly reduce the cost of eventual future migrations by reducing the number of formats to be migrated.

Both these advantages are greatly enhanced if the formats chosen are open standards and are supported by open source software, as they are in the case of NAA. Most of the material NAA handles is not from the Web, and most Web formats would meet their criteria without an initial migration.

The disadvantages of this approach are two-fold. First, it does not fully satisfy the requirements of archivists, because the content is not preserved in its original format ². Some potentially useful information may be lost in the initial migration. Second, it postpones the format migration problem but does not actually solve it. Even the chosen formats will eventually become obsolete.

2.2.2 Batch Migration

When a format in which some content is being preserved is thought likely to become obsolete, a batch migration process can be preemptively undertaken. The preserved content in the obsolete format is converted to a current format en masse. Some stand-alone tools for doing so have been developed [12] but they have yet to be integrated into a complete digital preservation system. When a reader requests access to the preserved content, the result of the conversion will be delivered.

The DAITSS (Dark Archive In The Sunshine State) is designed to use a batch migration strategy [4] ³. As a dark archive, one not intended to be accessed by readers but maintained in a controlled environment, this is an appropriate solution. The archive has total control of the environment and no urgent demands from end-users to satisfy.

2.2.3 On-Access Migration

The alternative migration approach, migration on access, postpones format migration until the reader actually requests the preserved content. It avoids the disadvantages of the other migration strategies by preserving the content in its original formats. When a format is thought likely to become obsolete, the digital preservation system is enhanced with the ability to present the reader, upon request, with the requested content in a current format. In effect, the migration tool is integrated into the dissemination pipeline of the preservation system rather than being applied to the preserved content.

This approach requires the ability to convert dynamically from the obsolete to the current format, but it offers significant advantages:

- Content is preserved in its original format, satisfying the archivists’ requirements and avoiding the risk of information loss from buggy format convertors. This risk is clearly enough to motivate systems using other migration strategies to hedge their bets by preserving the original format too.
- Preserved content is migrated by the most recent, and presumably best, technology available at the time the reader requests ac-

²NAA actually does preserve both the original and the migrated format but expects that access to the original will be an exception

³DAITSS also preserves both the original and the migrated format
Preserved content is rarely accessed, thus delaying format migration until it is actually required reduces the resource cost of the process by the proportion that is never accessed, and by the decreasing cost of technology through time.

- Content can be migrated directly from the original to the current format, minimizing the effects of format conversion artefacts.
- The format converters, once developed, can themselves be preserved to document the original format. Note that a converter can be developed pre-emptively before the format goes obsolete and preserved against future need if the format’s longevity is suspect.
- As with other migration strategies, careful choice of the format to migrate to can greatly reduce the need for and cost of future migrations.

The disadvantages of the migration on access strategy are that dynamic format migration may impose significant delays on reader’s accesses to preserved material, and that it requires close integration with the dissemination pipeline delivering the digital preservation system’s preserved content to its readers.

3 Format Migration in the LOCKSS System

The LOCKSS system provides librarians with a simple, low-cost tool they can use to ensure their community’s continuing access to material published on the Web. It is designed to handle both for-fee subscription e-journals and open access material whose copyright is held by the publisher, not the library’s institution. Libraries run LOCKSS peers, low-cost PCs running free, open source software that:

- Collects the material to be preserved by crawling the publisher’s web site, after verifying that the publisher has granted suitable permission.
- Preserves the material by cooperating with other peers holding the same material in a mutual audit process by running polls to identify any missing or damaged content and repair it.
- Disseminates the preserved material by acting as a proxy cache, intercepting requests from the library’s browsers for the original URL from which the material was collected. If the publisher’s copy is still available, it is delivered. Otherwise the preserved copy is delivered.

The LOCKSS system was released for production use in April 2004 and about 80 libraries world-wide now use it. Publishers of over 2000 titles have endorsed the system.

3.1 Design

In the LOCKSS system it is natural to use the migration on access strategy. Preserving content in the original format greatly simplifies the mutual audit and repair process, and the LOCKSS system already implements the complete dissemination pipeline into which the migration process must be integrated.

The LOCKSS system is being enhanced to provide:

- An API for plug-in format convertors, by which they can register their input and output Mime-Type values, and by which the LOCKSS web proxy code can invoke them to perform on-the-fly conversion.
- A matching process which takes the Accept: header of incoming requests and compares it to the original format of the preserved content. If the original format is not acceptable, the matching process searches the table of registered format convertors looking for one which takes the original format as input and whose output format is acceptable. If a suitable convertor is not found, a 406 error is returned as required by Section 10.4.7 of [5].
- A distributed registry of convertors, similar to the distributed registry of the plugins that adapt the LOCKSS system to particular content. These registries treat Java classes exactly as other Web content; collecting them by crawling the Web and preserving them by mutual audit and repair.

3.2 Proof-of-Concept Implementation

To confirm the feasibility of this design, a proof-of-concept was implemented and tested. We chose an “obsolete” format widely used...
in actual content collected by the production LOCKSS system, and a suitable “current” format to replace it. The obsolete format was GIF, an old format for images. The GIF format has been deprecated by many open source advocates for reasons connected with intellectual property restrictions, and they have developed the PNG format as a replacement. This background makes our assessment less artificial, as the format migration in question has been actively solicited. Tools for converting from GIF to PNG are widely available, as would be expected if a widely used Web format were to become obsolete.

We did not implement the full Mime-Type matching process, but rather a configuration option that prevented image/gif from matching any Accept: header. The mis-match triggered a GIF-to-PNG conversion directly, delivering the content converted to PNG at the original URL but with Mime-Type=image/png.

3.3 Assessment

As can be seen from the before (Figure 1) and after (Figure 2) screen-shots, this format migration is not perceptible to the user. Nor does GIF-to-PNG format migration incur a noticeable delay in accessing the page.

4 Future Work

The next step is to replace the proof-of-concept implementation by a full implementation of the API for plug-in format convertors, and a broader set of convertors than just GIF-to-PNG. This implementation will need a more realistic-scale test, and we are arranging to conduct one.

Another approach would be to connect the API to a format migration service such as TOM (Typed Object Model). We are investigating this possibility.

The development of future format convertors will be significantly easier if more, and more reliable format metadata is available. We are working towards incorporating Harvard’s JHOVE format metadata extraction and validation technology to improve the quality of the format metadata in the LOCKSS system.

5 Conclusion

We have designed, implemented a proof-of-concept and demonstrated transparent for-
mat migration on access for the LOCKSS digital preservation system. By doing so we have validated one of the possible format migration strategies, and reassured the community of LOCKSS users that when the time comes the content they are preserving will remain accessible despite the obsolescence of the formats in which it was collected.

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