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1. Introduction

This document provides a high level, non-collection specific assessment of the JP2 file format with regard to preservation risks and the practicalities of preserving data in this format.

This format assessment is one of a series of assessments carried out by the British Library's Digital Preservation Team. An explanation of criteria used in this assessment is provided in italics below each heading.

1.1 Scope

This document will primarily focus on JP2 (JPEG2000 Part 1, core coding system) defined by ISO/IEC 15444-1:2000, but will reference other parts of the JPEG2000 standard(s) where context is necessary. A separate (or extended) assessment for JPX[1] and JPM[2], and indeed Motion JPEG2000 (Part 3), may be necessary depending on British Library needs. Issues of both preserving deposited JP2s and preserving JP2s created by the British Library as part of digitisation activities will be considered.

Note that this assessment considers format issues only, and does not explore other factors essential to a preservation planning exercise, such as collection specific characteristics, that should always be considered before implementing preservation actions.

1.2 JP2 Summary

JP2 is the file format described by the first part of the JPEG2000 standard, which effectively operates as a "basic" wrapper for a JPEG2000 codestream. As such it is a bitmap image format that offers advantages in both compression, where wavelet based lossy compression can be attractive for minimising file sizes, and in delivery where the profile of JP2s can be tailored to support streaming applications that deliver part of an image at a time. JP2 compression also offers lossless encoding, where it is possible to recover a bit-identical copy of image. Originally designed as an output format for digital cameras, but not widely adopted within that market, it has gradually begun to be used by memory institutions, primarily as a way of reducing short term storage costs for high volume digitised collections.

An overview is provided on the Library of Congress site, along with a list of useful references [1].

2. Assessment

2.1 Development Status

A summary of the development history of the format and an indication of its current status

JPEG, the Joint Photographic Experts Group [2] has been responsible for the development of the JPEG2000 standards: JPEG meets around three times a year to discuss and create the standards for still image compression. Specifically, the ISO/IEC JTC1/SC29/WG1 committee developed the first draft of Part 1 in 2000 [3][3]. The other Parts were developed primarily over the following decade, but the Committee is still active at the time of writing this document. Engagement with the Committee by the preservation community resulted in an amendment to JP2 in 2011 [4].

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1 JPX files are extended JP2 files that conform to the JPEG2000 part-2 (ISO/IEC 15444-2) specification. Extensions include support for extended colour space, mechanisms to combine several code streams as a composite or animation, and the possibility to use compression methods other than wavelet compression.

2 JPM files are extended JP2 files that conform to the JPEG2000 part 6 (ISO/IEC 15444-6_ specification, and enables multi-page documents with multiple objects per page.

3 This paper provides a description of the initial JPEG2000 development leading to the first draft of Part 1.

2.2 Adoption and Usage

An impression of how widely used the file format is, with reference to use in other memory organisations and their practical experiences of working with the format

JP2 is considered to be a niche format having failed to take off as a successor to the ubiquitous JPEG format. Rob Buckley notes that: "When we were developing JP2 in the late 1990's (JPEG 2000 was intended to come out in 2000), the application that most influenced the design was digital photography—JP2 was expected to be the next digital camera format" [4]. But JPEG2000 was not adopted by most camera manufacturers as Buckley goes on to describe: "After the release of the JPEG 2000 standard... digital cameras kept exporting the JPEG Baseline format; when they added a new export format, it was Raw and not JP2. The drive was toward more creative control rather than better compression when what they had was good enough". This goes a long way to explain the current status of the format and issues with it. Chris Adams states on the Signal Blog "I would argue that JPEG-2000 is currently in the unfortunate position of having limited use outside of a few niches and the majority of users depend on proprietary software but might not represent a sufficiently large market to support multiple high-quality implementations" [5].

The Succeed Project assessed existing digitisation recommendations and performed a survey of memory organisations that states: "The alternative master file format (to TIFF) is JPEG2000 Part 1 (Core) – JP2. The format is quite popular in existing recommendations (53%), but not so much in use in current digitization activities (14% of respondents of the Succeed survey use it for master files)" [6]. Since 2000 a number of memory organisations have begun to adopt JP2 in some circumstances. It has typically been used in high volume digitisation activities (sometimes referred to as "mass digitisation") where lossy compression is deemed to be attractive due to potential short term storage cost savings. The British Library has generated JP2 representations of some content from a number of its mass digitisation projects for exactly these reasons. The choice of JP2 for this content was a compromise between preservation and cost that might not have been as significant for smaller scale digitisation activities[4].

The Library of Congress' Format Sustainability Factors notes that: "a format that has been reviewed by other archival institutions and accepted as a preferred or supported archival format also provides evidence of adoption" [1]. Van der Knijff referenced this quote in a blog post from 2010 on JPEG2000 stating that this "certainly seems to be the case for JP2. But how relevant is this, really? Going back to the ICC profiles issue (see Section 2.10): the JP2 file format has been around for about 10 years now, and its acceptance by the archival community has been growing steadily over the last 5 years or so. Yet, this whole issue seems to have gone unnoticed in the archival community for all those years, and I think this is slightly worrying" [7]. Clearly a format's acceptance by other archival institutions does not provide strong guarantees of the suitability of, nor the identification of problems with, that format.

The National Library of the Netherlands (KB) adopted JP2 for storing digitised masters following a format assessment exercise. Van der Knijff (of the KB) subsequently stated: "The outcome of this was used to justify a change from uncompressed TIFF to JP2. It was only much later that we found out about a host of practical and standard-related problems with the format" [8], including issues with resolution metadata, and support for colour profiles, as detailed below.

The lack of comprehensive software support for JP2, which is both a contributor to and partly as a result of the current state of adoption, is discussed in more detail below.

2.3 Software Support

2.3.1 Rendering Software Support

An overall impression of software support for rendering the format with reference to: typical desktop software; and current support on British Library reading room PCs

[4] See also a preservation planning exercise from the Bavarian State Library that used the same process as the British Library, but came to very different conclusions as the requirements were different [36]

Software support for JP2 is not as strong as for other significant bitmap graphics formats, and browser support is minimal. The lack of open source (and in particular performant) decoders has frequently been noted as a concern in terms of sustainability and practical usage. Van der Knijff notes that there are three open source decoders (JasPer, OpenJPEG and JJ2000) but only OpenJPEG appears to be under active development [9; 10]. Chris Adams summarises: "The most common concern I've heard about JPEG-2000 is the lack of high-quality tools and particularly support within the open-source world. I believe this is a critical concern for preservation" [5].

Application support is somewhat mixed with reliance on the problematic open source decoders leading to patchy support for the full JP2 Part 1 standard but most of the well-known graphics manipulation applications such as ImageMagick, GIMP, Photoshop or IrfanView provide some degree of support. Notably, Adobe removed support for JP2 in Photoshop Elements and in 2007 expressed some concern about resources needed to support a format that does not appear to have high usage [11].

OpenJPEG has been identified as the most promising contender to mitigate this issue, and has recently been approved by the JPEG committee as an official reference implementation [12]. One hope is that this will "lead to higher interest for the project and wider adoption and usage of OpenJPEG libraries" [13].

Issues

Most JP2 renderers demonstrate a degree of tolerance to badly formed files, as is the case with many format/tool combinations. This tolerance can be seen as a useful property, particularly given the mixed degree in which encoders implement the JPEG2000 standards. However, it should be noted that it can be misleading, especially when manual, visual checks are made of specific images. The British Library encountered arbitrarily truncated JP2s generated from a faulty workflow process [14]. Where a large portion of a JP2 had been lost the image usually appeared obviously damaged, as in the image shown at the reference above. Where less of the image had been damaged, its appearance when rendered tended to look normal, until zooming into the image.

2.3.2 Preservation Software Support

An impression of the availability and effectiveness of software for managing and preserving instances of the file format

Format identification

Van der Knijff notes an issue where JPX files created by some applications, such as Photoshop, can be superficially indistinguishable from JP2. He states that the main risk is that "materials may be ingested that contain advanced features of JPX, even though identification tools will identify these as JP2. Since software support for JPX is still minimal, such files may not be rendered properly, and future migrations may result in loss of information (colour space information is particularly affected by this)" [15].

Validation and Detecting Preservation Risks

JHOVE1 provides validation support for JP2 and JPX [16] but parsing is minimal and several cases have been identified where seriously damaged or corrupted files [17] were not detected by JHOVE. Jpylyzer [18] performs a more in depth, even if not complete[5], parsing of JP2 files and was refined with a variety of test cases that were not met by JHOVE.

Conformance Checking

Jpylyzer enables JP2 files to be checked for compliance against a profile and is used by a number of organisations, such as the Wellcome Library, for this purpose [19].

[5] The Jpylyzer documentation notes that compressed bitstream validation is not complete. For example, compressed codestreams are not parsed: [37]

Metadata Extraction

Both JHOVE and Jpylyzer enable extraction of key metadata.

Migration

As is the case with decoders, there are limited choices for open source JP2 encoders. Experiences from the British Library and elsewhere note issues with reliability and performance. Ed Summers notes issues with tools for creating JP2s: “We are heavily dependent on the closed source, proprietary Aware SDK for using JP2 files as the access copy of newspaper images in the National Digital Newspaper Program's Chronicling America web application. We just haven't found any opensource solutions that let us use the JP2 at scale. This is a big barrier to us making our software available to other NDNP partners” [20]. The JP2 Working Group's collation of JP2 profiles [21] indicates the software used at (primarily) national libraries, with most using Kakadu [22]. The British Library began using Leadtools [23], but has subsequently also adopted Kakadu for JP2 encoding/decoding. Research by the British Library, exploring the impact of 3 different software encoders and decoders on the quality of the resulting images, had to use a modified profile due to incomplete and broken support for a part of the JPEG2000 specification [24].

2.4 Documentation and Guidance

An indication of the availability of practical documentation or guidance with specific reference to the facilitation of any recommended actions

The JP2 (ISO) format specifications have been published. Other sources of documentation are not as abundant as with more commonly used formats such as TIFF, but some guidance is available. A number of references can be found on the LOC JP2 page [1].

Memory institutions have done a reasonably good job of sharing their understanding and key decisions in tailoring JP2 profiles to their needs. A number of JP2 profiles have been collated on the useful but somewhat dormant JP2K Working Group wiki (memory organisations) [21], and in depth discussions on the complexities of building a profile and setting an appropriate lossy compression level per image (typically based on PSNR) have been published [25]. Research conducted by the British Library has examined the impact of lossy compression and has questioned the need for images to be losslessly retained in digitisation works [26]. The work suggests that artefacts introduced by JPEG2000 compression at reasonable levels of lossy compression are no worse than the inherent variability or noise introduced by typical capture devices, but data is still irrecoverably lost and research into the effects of generational loss caused by JPEG2000 codecs shows, as to be expected, degradation in the image quality [24].

Ultimately, the use of lossy compression should be considered in conjunction with other requirements surrounding the preservation intent of the images.

2.5 Complexity

An impression of the complexity of the format with respect to the impact this is likely to have on the British Library managing or working with content in this format. What level of expertise in the format is required to have confidence in management and preservation?

In relative terms to other bitmap image formats such as TIFF, JP2 is one of the most complex and requires an in-depth understanding of the wavelet-based image compression schemes in order to facilitate its effective use as a digitised master, although this is less of a concern for deposited collections. Chris Adams provides, as “a rough estimate of the relative complexity”, details on the number of lines of code for two opensource JPEG-2000 implementations (OpenJPEG and JasPer) compared with the Python Imaging Library (“which supports several dozen formats as well as a general-purpose image processing toolkit”), indicating that OpenJPEG utilises ~2-3 times as many lines of code [5].

When adopting JP2, the British Library hired an external consultant to assess British Library needs and develop an appropriate profile for use as a preservation master of newspapers in a

mass digitisation initiative [27]. JP2 experience is not as widespread as with TIFF within the British Library, but has been developed through its use in the larger digitisation projects and programmes, particularly newspapers.

2.6 Embedded or Attached Content

The potential for embedding or attaching files of similar or different formats, and the likely implications of this

Not applicable.

2.7 External Dependencies

An indication of the possibility of content external to an instance of the file format that is complimentary or even essential to the intellectual content of the instance

None known.

2.8 Legal Issues

Legal impediments to the use, management or preservation of instances of the file format

The JPEG committee responsible for the JPEG2000 specifications recognises the importance for the core "baseline" standards to be free of the need to pay patent holders. It strived towards this by requesting patent holders to "issue a license for this use against the baseline implementation of a JPEG 2000 series standard without charge" [28]. Failure to obtain such an agreement results in selection of alternative technologies or, if none exist, removal of the feature from the baseline specification. With respect to JPEG2000 Part 1, a total of 30 declarations were submitted (up to December 2009) [29], from which all those believed to be essential can be licenced free of charge (under ITU-T's patent policy 2.1 [30]).

In some cases the use of non-fee-free technology may be unavoidable or may offer significant advantages over the free alternative(s). Under these circumstances such technology may be included in the standards and made available on 'reasonable and non-discriminatory' (RAND) terms[6].

2.9 Technical Protection Mechanisms

Encryption, Digital Rights Management and any other technical mechanisms that might restrict usage, management or preservation of instances of the file format

Part 8 of the JPEG2000 standard describes a methodology for securing JPEG2000 code streams [31]. Applications include encryption of image content and metadata (including partial encryption of metadata, or encryption with different strengths), verification of source authenticity, and conditional access to portions of an image or its associated metadata (for example, allowing only viewing of low resolution images).

2.10 Other Preservation Risks

Other evidence based preservation risks, noting that many known preservation risks are format specific and do not easily fit under any of the sustainability factors above

Two significant preservation issues relating to the JPEG2000 standard were identified by Van der Knijff and flagged with the JPEG Committee [32]. These relate to the potential for missing resolution metadata and ICC colour profile restrictions. The proposed changes to the JPEG2000 standard [33] were subsequently accepted [34]. It should be noted that various encoders interpret the standard in different ways (a risk in itself) so created images should be carefully checked; however, several applications have already been updated to reflect these changes, including Kakadu [35].

[6] This appears to apply primarily to extension specifications, i.e. non-core specifications

2.11 Preservation Risk Summary

A summary of preservation risks and recommended actions (where possible)

The evidence referenced above identifies a number of risks in using JP2 for preservation purposes. JP2 is a niche format that has failed to see widespread adoption. As a consequence there is poor tool support and a number of issues have been reported, despite the low rate of adoption. Obvious bugs in both the format and in software were not fixed before the preservation community adopted JP2. Whilst it is hoped that growing use by memory organisations and associated experience in working with JP2 has led to the mitigation of most issues, other problems may remain.

- **Miss-identification of JP2s**
  - JPXs could be miss-identified as JP2
- **Lack of software support for JP2**
  - Reliance on a limited range of commercial software applications
  - Lack of performant/functional open source encoder/decoder
  - Different interpretation of the specifications by various encoders
- **Potential for unidentified preservation risks**
  - Lack of widespread usage means that there is a significant risk of yet to be discovered preservation issues
- **Missing properties/data in generated JP2s**
  - Key properties include: pixel data, colour profile, essential metadata such as source resolution
- **Badly formed JP2s**
  - Poor software support for the JPEG2000 standard can result in the creation of badly formed JP2s
- **Potential for the creation of JP2s that do not comply with a policy driven profile**
  - Incorrect compression choices could lead to incorrectly compressed images

3. Recommendations for Action

Recommended actions in usage and handling of the format. Recommend actions in the support or development of software applications that provide, or have the potential to provide, significant risk mitigation for the format. Note that these recommendations do not take into account other requirements such as those driven by specific British Library collections, or non-preservation issues such as resourcing.

If the benefits of JP2 (compression and delivery) are sufficient that it remains a desirable solution for storing digitised masters, use of the format must be considered a significant risk. Mitigation of this risk ideally requires investment in OpenJPEG to address the tool support concerns, and very thorough checking of all files in production settings. Mitigating JP2 preservation concerns comes with an associated cost, and this should be taken into consideration in preservation planning activities where storage costs savings are likely to be significant.

Handling Recommendations

Thorough testing of software components should be performed before use in a production environment. This is essential given the lack of confidence in JP2 software support. Once live, change management procedures should trigger further testing when software is changed or updated.

- For deposited collections:
  - Identify format (verify JP2/JPX distinction with Jpylyzer)
  - Validate and identify potentially damaged files with Jpylyzer
  - Manually check effective rendering of appropriate sample
- For digitised collections:

- Perform pixelwise comparison with source image using appropriate software.
- Verify colour table and resolution metadata has been retained with Jpylyzer
- Validate and identify potentially damaged files with Jpylyzer
- Check conformance to selected profile with Jpylyzer
- Manually check effective rendering of appropriate sample

Software Recommendations

- Ongoing support for Jpylyzer remains essential as it provides considerable JP2 risk mitigation
- Support for OpenJPEG would help to mitigate concerns about the poor software support for JP2

Monitoring Recommendations

Given the relatively low uptake of the format and the speed of recent advances in community understanding and recent changes to software, JP2 should be monitored on an annual basis with a reasonably high priority.

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