

Quality assured image file format migration in large digital object repositories

Using various outcomes of the SCAPE project in the context of library preservation scenarios

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ABSTRACT

This article gives an overview on how different components developed by the SCAPE project are intended to be used in composite file format migration workflows; it will explain how the SCAPE platform can be employed to make sure that the workflows can be used to migrate very large image collections and in which way the integration with a digital object repository is intended.

Two institutional image data migration scenarios are used to describe how the composite workflows could be applied in production library environments. The first one is related to the British Newspapers 1620-1900 project at the British Library which produced around 2 million images of newspaper pages in TIFF format. The second is a large digital book collection hosted by the Austrian National Library where the book page images are stored as JPEG2000 image files.

1. INTRODUCTION

Several memory institutions in the SCAPE project, such as the British Library, the National Library of the Netherlands, and the National Library of Austria are using the JPEG2000 image file format for storing images of digital newspapers, books, or other image collections.

In this context the SCAPE project (SCAlable Preservation Environments), partly funded by the European Com-

mission, is doing research and providing solutions that help memory institutions in performing preservation at scale. The project develops an execution platform together with preservation tools and advanced services for preservation planning and watch. Development is driven by institutional requirements and tested in real world institutional environments in order to ensure that the solutions are really applicable on diverse data sets and on a large scale.

This article will give an overview in which ways different components developed by the SCAPE project are intended to be used in composite file format migration workflows, explaining how the SCAPE platform makes these workflows scalable so they can be used to migrate very large image collections. Furthermore, it will discuss the implications that the use of the SCAPE platform has on development and integration of the different components.

We start by explaining the institutional image migration scenario in more detail. We then outline the SCAPE components used in the composite workflows, before presenting the composite workflows themselves. Finally, we conclude the article with a summary and outlook.

2. THE INSTITUTIONAL SCENARIOS

Our first scenario is a real world use case of the British Newspapers 1620-1900 project at the British Library which was funded by the Joint Information Systems Committee (JISC) and produced around 2 million images of newspaper pages in TIFF format¹. In order to reduce the storage cost of these images, the British Library undertook a migration of the items to the JPEG2000 format prior to ingest into the Digital Library System.

¹http://www.jisc.ac.uk/media/documents/programmes/digitisation/digitisation_brochure_v2_overview_final.pdf

Our second scenario looks at a large digital book collection hosted by the Austrian National Library where the book page images are stored as JPEG2000 image files and serve as master and access copies at the same time. With this scenario we are showing how an image migration workflow is supposed to work with a digital repository.

For both of these scenarios it is clear that a system capable of migrating millions of images from one format to another is required. Workflows executed on this system must include steps that validate both original and migrated image files and provide assurance that migration was successful and produced equivalent migrated images and valid instances of the new format.

In the following section we describe the SCAPE tools that are used in the composite workflow and which are essential to fulfilling the requirements listed above.

3. PRESERVATION COMPONENTS

As briefly mentioned in the introduction, the SCAPE project is developing new components, extending and improving existing tool implementations and providing means for integration of new tools into the SCAPE preservation platform.

In order to give a complete picture about how software components of different types can be put together in a composite workflow, we make use of two tools developed in the SCAPE project which will be described in more detail in the following sections.

3.1 Jpylyzer

Jpylyzer [8] is a validator tool for the JP2 (JPEG 2000 Part 1) still image format. It was developed to do the verification of whether an encoder produces standard-compliant JP2s, to detect JP2s that are corrupted (e.g. images that are truncated or have missing data), and to extract technical characteristics and metadata.

Although some of the above features are also provided by other software tools, these either provide limited or incomplete validation functionality, partial coverage of JP2's feature set, or produce output that is difficult to interpret. The main philosophy behind Jpylyzer was to create a tool that strictly adheres to the JP2 format specification, is lightweight, simple to use and scalable. The validation procedure includes a verification of the general file structure, tests on the validity of individual header fields, and a number of consistency checks.

3.2 Matchbox

The Matchbox tool was designed for content based image characterization and comparison. It is based on robust detection and invariant description of salient image regions using the Scale Invariant Feature Transform (SIFT) [5]. Categorization of image content uses the Bag of Features (BoF) approach [2] which is inspired by the bag of words approach in information retrieval. In the BoF approach scanned book pages are characterized by compact visual histograms referring to visual words contained in the BoF. The BoF itself is constructed for each collection, i.e. a book scan, using machine learning. Once the BoF is created, image comparison becomes an efficient comparison of histograms. Matchbox also implements detailed image comparison based on the estimation of a geometric transformation between pairs of images followed by the estimation of a perceptual measure of Structural Similarity (SSIM) [9].

4. EXECUTION PLATFORM

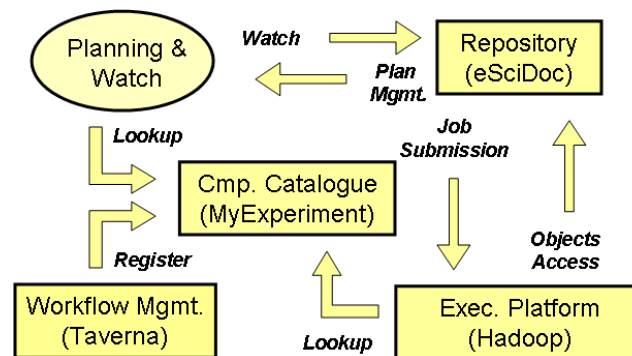


Figure 1: Components and services of the SCAPE Preservation Platform. The available software components provide support for workflow design and description, registration and lookup of preservation components, scalable storage and execution, and digital object management and efficient access. Integration with the SCAPE Preservation Planning and Watch components is supported through the Component Catalogue Lookup API and the Repository Plan Management and Watch APIs.

The SCAPE Preservation Platform [6] provides an infrastructure that targets the scalability of preservation environments in terms of computation and storage. The goal is to enhance the scalability of storage capacity and computational throughput of digital object management systems based on varying the number of computation nodes available in the system. A platform instance is based on existing, mature software components like Apache Hadoop², the Taverna Workflow Management Suite³, and the Fedora Digital Asset Management System⁴. The platform implements a set of additional services on top of these software components to specifically support scalability and integration with digital preservation processes as well as to integrate with other SCAPE components, such as the SCAPE preservation watch system, SCOUT [1]. Figure 1 provides an overview of the main software components of the SCAPE preservation platform and shows their interactions.

A key challenge of the platform is the development of methodologies to integrate preservation tools with its parallel execution environment. The automated deployment of preservation tools such as Jpylyzer, described in section 3.1, is based on software packages like those maintained by the Open Planets Foundation⁵ and a Linux based software package management system (presently based on Debian). Complex software environments like pre-configured platform nodes can be deployed on virtualized hardware using virtual machine images[7]. The platform provides support for migrating existing and sequential preservation workflows and applications to the parallel environment covering different aspects like data decomposition, tool handling, workflow support, or repository interaction. However, the strategy

²<http://hadoop.apache.org>

³<http://taverna.org.uk>

⁴<http://http://www.fedora-commons.org>

⁵<http://deb.openplanetsfoundation.org>

used to parallelize an individual workflow depends on the use case it implements and may be selected on a case-by-case basis. Section 4.2 discusses basic parallelization approaches with respect to the example workflow discussed in this paper. A flexible mechanism for the integration of existing digital repository systems is provided by the SCAPE Data Connector API. This generic interface supports the efficient exchange of data sets between the execution platform and digital object management systems, as described below.

4.1 Digital Object Repository

The SCAPE platform provides a Digital Object Repository to allow storage and management of digital objects. The repository offers several APIs to integrate with the SCAPE platform and other SCAPE components like Planning and Watch. Preservation actions running on the execution environment are able to interact with the repository via a RESTful service API. This Data Connector API allows ingest, retrieval, update and query of a repository's content.

A Digital Object Model has been defined to allow different SCAPE components to exchange data in a standardized way. This model is based on METS⁶ as a container format, along with other metadata formats like Dublin Core⁷, Marc 21⁸, PREMIS⁹ and other technical, administrative and rights metadata. The data we are focusing on is already provided in a METS format and can be ingested into the repository via the SCAPE Loader Application, a Java-based client application supporting different input source options. (local or distributed file system). Its intended use is for ingesting a large amount of digital objects (represented as METS) into the repository using the REST endpoint defined by the Data Connector API. It monitors and logs the ingest process, e.g. retrieves the life-cycle status of each digital object of the repository.

4.2 Scalable Processing

The SCAPE preservation platform utilizes the Apache Hadoop framework as the underlying system for performing data-intensive computations and consequently relies on MapReduce [3] as the parallel programming model. In SCAPE, preservation scenarios are typically developed as sequential workflows using desktop tools like the Taverna workbench. Such conceptual workflows, which will be explained in more detail in section 5, define the general logic of a preservation scenario and must be migrated to the parallel environment before they can be executed on the SCAPE preservation platform at scale.

Depending on their complexity, preservation workflows (or activities within a workflow) can be turned automatically into a parallel application that runs on the platform to a certain degree. An example is the execution of preservation tools against large volumes of files which can be performed on the platform using a generic MapReduce tool wrapper. The SCAPE tool specification language supports users in selecting a particular tool and parameter configuration used during the execution. SCAPE has also developed a model allowing a workflow designer to describe preservation activities following a defined component specification and register them to the SCAPE Component Catalogue (c.f. figure 1).

⁶<http://www.loc.gov/standards/mets/>

⁷<http://dublincore.org/>

⁸<http://www.loc.gov/marc/bibliographic/>

⁹<http://www.loc.gov/standards/premis/>

The platform makes use of this approach to discover runtime dependencies of workflows, like dependencies on pre-installed software packages, which must be resolved prior to workflow execution.

However, as discussed in this paper, it is typically required to migrate more complex workflows involving different activities, data flows, and decision logic to the platform environment. A simplistic approach is to instantiate and concurrently execute multiple instances of the sequential workflow on a range of cluster nodes. This strategy however comes with a number of restrictions as compared to an approach where the workflow language is fully translated into a native MapReduce program, a strategy which is also evaluated in the context of SCAPE.

5. WORKFLOWS

As already mentioned, Taverna [4] is used in the SCAPE project to build composite workflows using the components described in section 3.

Having created a single-threaded sequential Taverna workflow, as noted in the platform section 4, it is necessary to translate this into a suitable MapReduce program for execution on the SCAPE Platform. Performing actions like file migration using Hadoop is achieved by using one or more map jobs (made up of many map tasks) across a number of processing machines and few (if any) reduce jobs.

5.1 Taverna integration

The workflow in Figure 2 shows the steps required to migrate a TIFF to a JP2 and quality assure the results. It was designed to address the requirements of the British Library's TIFF to JP2 migration scenario. Input to this workflow is a list of TIFF files and the output is the migrated JP2s and a report giving details of the migration and quality assurance stages. The workflow consists of both sequential and parallel layers. For example, once the TIFF to JP2 migration completes (HadoopMigrate) then metadata extraction, feature extraction using Matchbox and profile validation using Jpylyzer can all operate on that JP2 at the same time. Similarly, while TIFF to JP2 migration is taking place, the workflow can also be extracting features from the TIFFs using Matchbox ready for comparison with the features extracted later from the JP2.

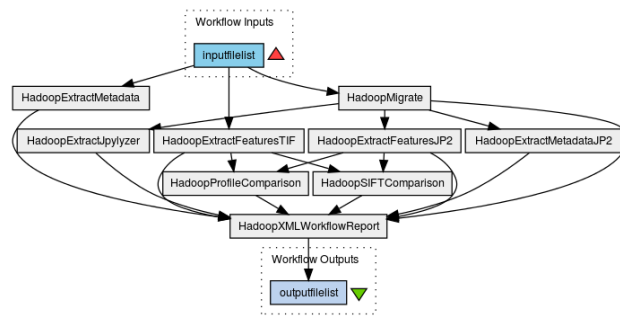


Figure 2: SCAPE Platform migration TIFF to JP2; <http://www.myexperiment.org/workflows/3400>

When translating a workflow like this we need to decide what each map task should do, and there are different options discussed in the following.

5.1.1 Vertically aligned workflow

Orienting the workflow with inputs at the top and output at the bottom, one option is to slice the problem vertically and execute the workflow from top to bottom for every input file. Here each map task calls the Taverna command line with a single input file and the workflow definition. Taverna is responsible for the order of execution within the workflow and runs steps in parallel, where possible, according to the workflow graph.

This vertical slicing has a number of advantages. Taverna preservation workflows that work well on single machines can easily be scaled using the SCAPE Platform. Workflow designers do not need knowledge of Hadoop and workflows can be re-used. This is the idea behind SCAPE components. We can also make use of Hadoop's robust design: should the workflow fail, that map task fails; Hadoop will handle retrying the map task and reporting the failure. Many workflows will create intermediate files on the processing data node. Doing all the work on a single data node avoids moving these files across the Hadoop cluster and managing their locations. Finally, Hadoop requires no knowledge of Taverna, and (unless using HDFS) the workflow does not need any knowledge of Hadoop.

5.1.2 Horizontally aligned workflow

Another option is to slice the problem horizontally and execute each layer of the workflow as a chain of map tasks. For the workflow presented in Figure 2 the TIFF to JP2 migration is performed over all files, one map task per migration. At the same time a second set of map tasks can be extracting the features and metadata of the TIFFs. Once complete another set of map tasks extract features from the JP2s and so on. It is clear that something is needed to manage this execution and for this we can use Taverna. However, this approach requires that the sequential workflow be re-written with knowledge of Hadoop.

5.1.3 Translation to MapReduce

A final option would be to translate the Taverna workflow to one or more native Hadoop jobs, using Taverna to design the workflow but not using it during execution. This strips away a layer of complexity.

5.2 Digital objects repository integration

The JPEG2000 to TIFF migration scenario using the digital book collection of the Austrian National Library provides a production environment for testing the large scale applicability for the digital objects repository integration.

In this scenario, digital book objects are ingested using SCAPE's Loader Application described in section 4. First, METS containers as the submission information packages (SIPs) according to the OAIS reference model, aggregates the digital book and book page entities (each book page consisting of an image, full text, and full HTML layout representation) with references to the physical files on the file server.

The goal is to find a performant way of doing ingest, migration, and finally adding a new representation to existing digital objects using the SCAPE Platform. Towards the end

of the SCAPE project, an evaluation will be made of overall system and component level performance indicators.

6. CONCLUSIONS

In this article we have presented several core outcomes of the SCAPE project along with preservation scenarios that give a better idea of how they can be used in an institutional context. We have also shown how tools can be used in workflows combining characterisation, migration, and quality assurance tasks.

According to the SCAPE project's mission to provide solutions that work on a large scale, we have discussed approaches to transform conceptual workflows into workflows which can be executed on the SCAPE platform and integrated with a digital object repository.

The development of these workflows will be pursued further this year; towards the end of the project, evaluations will give more insight into performance, runtime stability and organisational fit of the solutions presented in this article.

7. ACKNOWLEDGMENTS

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