A new data model for digital preservation and digital archiving for the French Administration: VITAM model on NoSQL technologies

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ABSTRACT

The three ministries in charge of public digital archiving in France (Culture, Defence and Foreign Affairs) decided to build a specific system in order to preserve their digital information. The main challenge is the management of all the data and metadata produced by the French State which could be linked to Big data technologies. Since February 2013, these three ministries have done a large experiment (a proof of concept) based on NoSQL technologies, which ended in June 2013. In this paper, we describe our IT approach of this archivistic problem, our new data model and the results of this inter-ministerial study.

Categories and Subject Descriptors

C. Computer Systems Organization / C.4 PERFORMANCE OF SYSTEMS (Design studies, Fault tolerance, Modeling techniques, Reliability, availability, and serviceability)
D. Software / D.2 SOFTWARE ENGINEERING / D.2.10 Design (Representation)
E. Data / E.1 DATA STRUCTURES (Distributed data structures, Graphs and networks, Trees, Record)
G. Mathematics of Computing / G.2 DISCRETE MATHEMATICS / G.2.2 Graph Theory (Graph algorithms, Trees)
H. Information Systems / H.2 DATABASE MANAGEMENT / H.2.1 Logical Design (Data models)
H. Information Systems / H.2 DATABASE MANAGEMENT / H.2.4 Systems (Concurrency, Distributed databases, Query processing, Textual databases)
H. Information Systems / H.3 INFORMATION STORAGE AND RETRIEVAL / H.3.1 Content Analysis and Indexing (Indexing methods)
H. Information Systems / H.3 INFORMATION STORAGE AND RETRIEVAL / H.3.6 Library Automation (Large text archives)
H. Information Systems / H.3 INFORMATION STORAGE AND RETRIEVAL / H.3.7 Digital Libraries (Collection)

General Terms

Management, Measurement, Performance, Design, Economics, Reliability, Experimentation, Security, Human Factors, Standardization.

Keywords

Digital archiving, NoSQL, metadata.

1. VITAM, A JOINT PROJECT BETWEEN THREE MAJOR ARCHIVAL INSTITUTIONS IN FRANCE

The National Archives of France are in charge of archiving the documents produced by the French administration and government with the exception of two independent ministries: Defence and Foreign Affairs. The National Archives have decided to rethink their methods to collect, arrange, describe and preserve digital archives and to update their digital repository, CONSTANCE, which has been developed in the 1980's. There is an urgent need to build a new system in order to be able to meet the expectations of today's administration: adopting a "mass-production" approach has become a priority because of the exponential growth of digital information. CONSTANCE was set up at a time when the use of technology and technologies themselves were very different.

Thus, the National Archives launched a new project in 2011 called VITAM (the name of this project refers to the latin phrase *ad vitam aeternam*). As the National Archives are a department of the Ministry of Culture, they work closely with its IT Department; this collaboration is essential to build a solid model. Therefore, VITAM was included, as a strategic project, in the Ministry of Culture's IT outline plan in December 2011. From that date, the Ministry of Foreign Affairs and the Ministry of Defence, which are the only autonomous ministries allowed to keep their own historical archives, have joined the project. The three main archival institutions in charge of archiving the information produced by the French State are united around a common goal.

Controlling metadata: how to plan an intelligent access to digital information over the time?

VITAM's philosophy is directly in line with the legacy of CONSTANCE: simplicity, neutrality, durability, integrity. VITAM's functional model is based on the OAIS model [1] and also integrates records management standards (ICA-Req and MoReq [2]) in order to adapt the system to the needs of the French administration. The OAIS framework and vocabulary has been adapted for that purpose [3]. One of the major challenges of this new project is the description of digital archives and the capability to make requests in the new system over the time. In fact, the development of the information society has created facilities for copying, deleting, and editing documents, information and data produced by the public administration. However, data, as of paper archives, should be stored in specific conditions of integrity, security and authenticity. To meet these needs, it is necessary to assign to each given document or digital information many descriptive, archival and technical metadata.

Metadata has often much more value than data, information or original documents. They give meanings and make the archives intelligible. Moreover, in the context of increasing information sharing between different services, one must be able to hold this business details correctly. This fine archival description could not take place in the paper world due to lack of human resources sufficient to handle the mass of paper archives. However, information technology can multiply our processing capacity and allows us to consider keeping all these traces of digital information and ensuring their authenticity, integrity and intelligibility *ad vitam*. We have considered several solutions and we have built a specific model for metadata based on the National Archives experience and based on national and international standards.

Firstly, we will describe our IT approach and more precisely the use of a Big Data model to describe digital archives. Then, we will explain our model to describe and process metadata. Finally, we will present our experimental approach as a result of the Proof of concept we did for the IT director of the French State.

2. "BIG DATA" MODEL TO REPRESENT RECORDS AND DIGITAL ARCHIVES IN THE FRENCH ADMINISTRATION: OUR IT APPROACH

The team in charge of the development of this new system has particularly focused on archival description and metadata management because one of the major challenges is the description of digital archives and the capability to make requests in the new system over the time. One of the most important digital archives tested is mailbox and especially emails. Real examples of the Ministry of Defence and the Ministry of Culture were used to request the NoSQL database [4].

Digital archives lead to two difficulties: the number (and indirectly the raw volume) and the diversity. These two aspects are essential to ensure the performance and ease of interfacing of the solution [5].

Because of its volume and complexity, a platform for digital archiving leads to a significant cost. Two approaches have existed so far:

- **The vertical model**: each business archive theme is associated to one dedicated repository. This approach, functionally easy to implement, has the disadvantage of multiplying investment costs (one platform per business model). One main reason is the metadata format is different for each business, leading to a dedicated pattern of database model. Those solutions use the standard relational database model that provides performance, sometimes volume ability, but at the expense of absolute unification of the metadata representation model, leading to one dedicated silo per profession.

- **The horizontal model**: the platform is seen as a secure storage space but metadata are missing due to their diversity, hence their lack of control and completeness. These solutions use a simplified metadata format (mainly technical aspects) and therefore also rely on standard relational database model, deporting business record management to the relevant business applications. The advantage, compared to the vertical model, is the sharing of storage infrastructure and preservation method among various business domains. The disadvantage is the dissociation of storage and metadata, since the business metadata are kept on the business side.

In the VITAM project, we identified one core shared development part as the "back-office" managing all properties of an EAS (Electronic Archival System), not related to business or organizational aspects ("front-office" applications). However, in order to be effective and sustainable, this core must carry the indexing and search functions related to metadata, either on business, technical or archivistic fields. The main reason is metadata are just as important as the records themselves and must therefore be stored in the EAS too.

In addition, we have seen that the "front-office" need is not to store the metadata, but to know their structure (business model) and to have the ability to query them. Thus we propose to fully integrate the metadata query feature in the EAS, but to leave the control of the requested data (model) to the front-office. This leads to large data model variety capability.

In the context of "big" archiving system (several billion entries), another problem occurs, related to the ability to manage a huge database containing the metadata (several TB or even hundreds of

TB), while maintaining good performance, to ensure proper platform sharing, and of course the ability to grow as needed.

To meet these twin problems, but also to a single (either big volumes, either multiple data models), we proposed to study the use of document-store NoSQL database model [6] which has the main following properties:

- Ability to handle high volumes;
- Ability to handle flexible patterns (a table can contain multiple representations of the data in JSON-like format);
- Ability to provide high availability;
- Ability to provide high performances;
- Ability to handle custom queries;
- Ability to deal with full text requests.

3. A NEW DATA MODEL TO DESCRIBE ARCHIVES

The representation model is schematically presented as follows, inspired from MoReq 2010 [7].

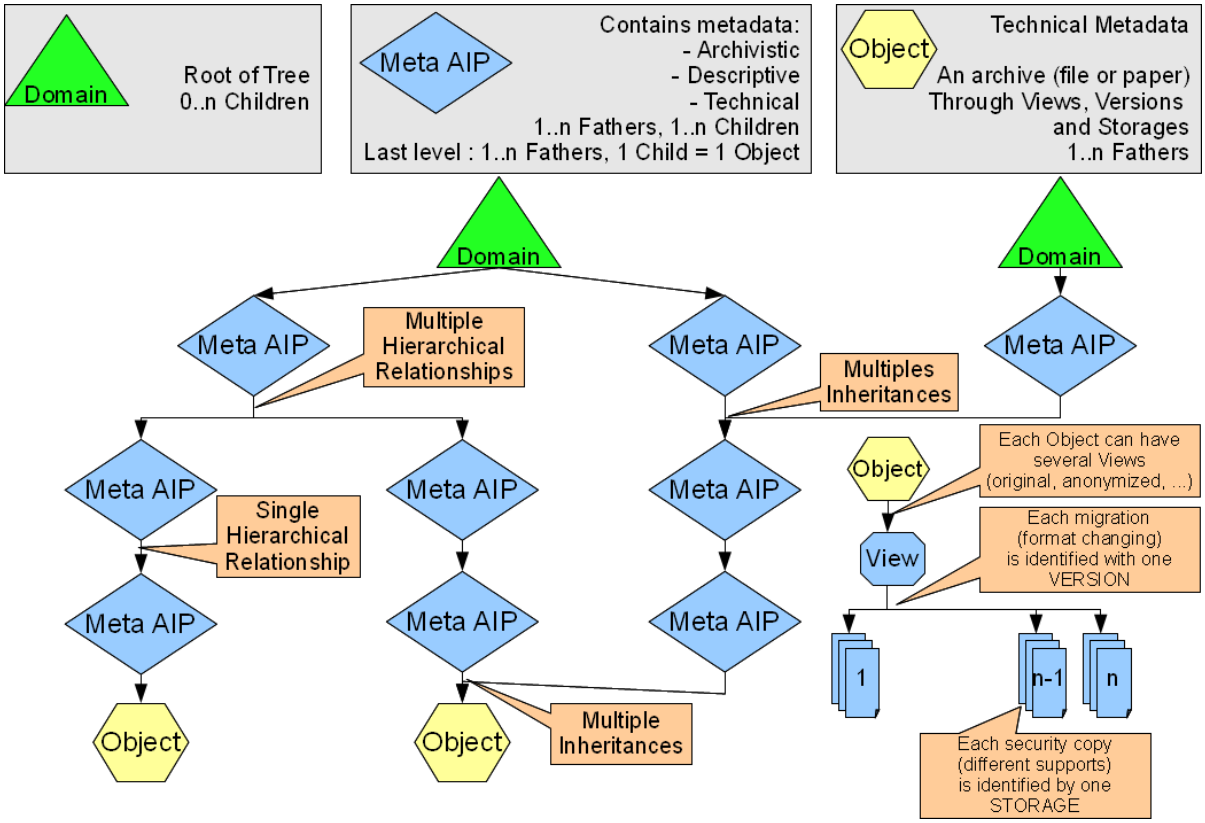

Figure 1. VITAM Data model inspired by MoReq2010. France, Prime Ministry, DISIC/POC, part 1, April 2013.

It is important to underline that this is an implementation experiment of the interesting data model of MoReq2010 in the French Archives administration (for records and digital archives).

In addition to the standard model, the ability to have multiple inheritance for each node in the graph, while not allowing cycle, leads to a directed acyclic graph (DAG as defined in mathematical theory, for instance in [8]).

The impact of multiple inheritances (multiple parents) is that inherited properties can have multiple values, due to multiple parents. While processing the search, the property resolution follows the access path to an object, since access to an object (or a meta-AIP or AIP or a node in the graph) is always from a root and following a path down to it.

The DAG approach is already used for medical ontology [9] and with RDF (Semantic Web) [10], but its application to archive classification scheme is quite new.

The structure of our DAG is as follow:

- A *Domain* is the root of a tree. There may be multiple roots, and one node may be accessed from multiple roots.
- A *Meta-AIP* is a node in the tree corresponding to a level in the classification scheme. It must contain enough information to be a good candidate.
- An *Object* is a node denoting an archive object. It is the smallest unit in a classification scheme (*Item*). It contains mainly technical information. In the case of a joint solution for paper and electronic, it is the lowest node for a paper archive, containing the location and packaging information.
- A *View* is a node to distinguish between different types of object representation from:
  - *Original* archive: the authentic piece, according to the original;
  - *Anonymized* view: similar to the original but with all the data relevant to privacy protection legislation withdrawn (i.e. ready for broadcasting);
  - *Raw* view in plain text format, useful for full text search or mixed presentation mode, for picture (scanned papers) and plain text formats for instance.
- A *Version* is a node to distinguish different versions of a View, following file preservation process (file format changing over time).
- A *Storage* is a copy of a version. It contains information about physical access to the actual archive. This is the lowest node in the hierarchy.

4. THE PROOF OF CONCEPT FOR THE IT DIRECTION OF THE PRIME MINISTER: NOSQL TECHNOLOGIES FOR DIGITAL ARCHIVING PLATFORM, A NEW APPROACH

To ensure the adequacy of this approach, we achieved a proof of concept based on an experiment from medium to large scale (a few hundred of GB to tens of TB) for metadata only. This article presents a subset of the results.

The objectives of this NoSQL study applied to archive metadata are as follows:

1. Ensuring that data model for representing metadata records is feasible and queryable;
2. Ensuring usage of flexible patterns is effective and practice;
3. Ensuring the performances in writing, but especially in reading are valid (ingest, access and preservation functions);
4. Ensuring these performances are met for a multiple concurrent clients ("front-office");
5. Ensuring the high availability of the solution and its robustness.

Firstly, the IT department of the Ministry of Culture made a study of NoSQL databases. Then, the experiment was done with real XML format of digital archive metadata on virtual machines (VM) at the IT Centre of the Ministry of Culture.

Each VM has 2 vCPU, 16 GB of RAM and 1 TB of disk. Up to 8 VM (x2 for reliability test) were created. The used softwares were MongoDB (version 2.4.3 http://www.mongodb.org/) for the NoSQL document database and ElasticSearch (version 0.90 http://www.elasticsearch.org/) for the indexation engine.

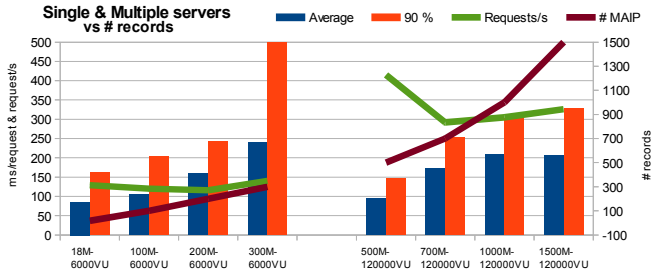

Figure 2. Single and multiple servers requests vs nb of records

The highest ingest performance was 7000 items/s with 8 VM, which leads to great DRP capability (less than 3 days for 1.5 billions of items), while this result is 4 time faster than with a single VM.

The graph 2 shows the metadata request performances on a single server (left side, 6 000 simulated users) and on multiple servers (right side, 120 000 simulated users), with up to 1.5 billion items with less than 500ms per request (90% of all times).

This graph shows that performances are still correct up to 300 millions on a single VM, even if the memory limit is reached. It shows also the good horizontal scalability, as previously observed during ingest (insert operations x4) but during access (request operations). We were able to grow 5 times bigger than with a single VM with 8 time servers.

During the tests, we used concurrently 10 different data structures (JSON schema) put in the same DAG without any issue, thanks to the schema-less capability of the NoSQL databases.

Finally, our reliability tests were also conclusive with no service interruption while disasters were simulated.

To conclude, the use of NoSQL technologies to cope with our needs of irregular description and variety of digital archives appears to be a perfect choice in term of performance, requests capabilities and adaptation to the digital administration and to the future digital information governance.

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