PHOTODENTRO SAAS: SOWING THE SEEDS FOR AN ECOSYSTEM OF "PHOTODENTRO" OPEN EDUCATIONAL RESOURCE REPOSITORIES*

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Abstract

The "Photodentro SaaS" initiative drives the expansion of the Photodentro ecosystem of Open Educational Resource (OER) repositories. The initiative is based on the "Software as a Service" model (SaaS), allowing for all interested organisations to implement a Photodentro repository to manage, describe, and publish their digital artefacts. The benefits are twofold: (i) the new content provider gains exclusive access to a standards-based digital repository, integrating the best practices and workflows specifically designed to meet the needs of OER for K12 education; (ii) being part of the Photodentro ecosystem, all resources of the new repository are readily available and profit of high visibility through the web portal of the Photodentro Greek National Educational Content Aggregator.

Keywords: Photodentro, repository, open educational resources, Software as a Service, DSpace, SaaS, OER

1 INTRODUCTION

Photodentro [1] is a family of web-based software systems that implement a federation of online repositories of digital resources catalogued for educational purposes, along with a set of open access mechanisms for search, navigation, and web-based interactive playback of resources. Its development started in 2011, as part of the Greek National Strategy for educational content. During the first two years, a couple of Photodentro repositories were launched, holding discrete types of resources ranging from self-contained learning objects that had been developed for the enrichment of Greek textbooks, to educational videos, and standalone educational software. During the next years, the family of Photodentro installations grew to include repositories of user generated learning resources, open educational practices, and cultural resources from external online libraries that have been annotated for educational purposes. While each of these repositories is a standalone and autonomous system, all of them are brought together through the Photodentro Aggregator, an online gateway that effectively implements a single point of reference for OER targeted to the Greek school community.

This Photodentro ecosystem has been experiencing solid adoption by teachers and pupils alike for their daily educational activities. At the same time, an increasing number of content providers, as part of their Open Access policy, have expressed their interest in using Photodentro for managing and publishing their digital resources. However, education presents a complex domain altogether, demanding contextualised approaches and unified concepts, which cannot be served with one-size-fits-all solutions, superficially adapted for learners and educators. Moreover, the investment required for an OER repository is significant and needs to secure resources for setup, configuration, and administration of related software and hardware. These costs can be daunting, which is indeed the main motivation behind the interest in Photodentro: its successful implementation and the adoption by the school community have resulted in a rising demand for setting up additional Photodentro-alike repositories by content providers.

The selected strategy for responding to this profound demand is to offer Photodentro through the Software as a Service (SaaS) model. The design alternatives and the approach for offering the

* *In Proceedings of iCERi 2016, the 9th annual International Conference of Education, Research and Innovation, Seville, Spain, 14 – 16 November, 2016. ISBN: 978-84-617-5895-1 / ISSN: 2340-1095, doi: 10.21125/iceri.2016, Publisher: IATED, https://library.iated.org/view/KOUTOUMANOS2016PHO*

"Photodentro SaaS" solution are thoroughly discussed in this work. Section 2 holds an overview of the Photodentro ecosystem and a description of the main requirements of new content providers, followed by an analysis of available design options for the provision of self-contained, semi-autonomous digital repositories using alternative service models in Section 3. Section 4 presents the Photodentro SaaS implementation approach, and Section 5 concludes the paper with some initial findings and indication of future steps towards the uptake, support, and evolution of the Photodentro SaaS model.

2 ABOUT PHOTODENTRO - THE NATIONAL DIGITAL REPOSITORY OF OPEN EDUCATIONAL RESOURCES FOR GREEK SCHOOLS

Digital educational content is a key priority of the Greek national digital educational policy for primary and secondary education, which is reflected in the design of the national programs for the exploitation of Information and Communication Technologies (ICT) in school education. In-service teacher training and development along with operation of computational and networking infrastructure and services for schools, including a national-level schools wide access network, computer school labs, e-classrooms and interactive whiteboards, are the other two pillars of the national policy, strongly linked with the provision and exploitation of digital educational content.

Figure 1: The homepage of Photodentro LOR (http://photodentro.edu.gr/lor)

The key action lines of the Greek national policy for digital educational content are the following: a) Focus on the creation of reusable units of learning; b) Promotion of Open Educational Resources (OERs); c) Promotion of re-use, adaption, and re-purpose of existing digital learning resources; d) Improvement of digital infrastructure to facilitate search, retrieval, access and utilisation of digital learning resources for all (teachers, pupils, parents, everyone); and e) Promotion of the active role of teachers and pupils in the creation, documentation, and evaluation of digital learning resources. These key action lines were defined in line with the directions of the Digital Agenda presented by the European Commission as part of the Europe 2020 Strategy, international trends, as well as the experiences and lessons learned from recent national initiatives. A core component of these action lines is thus digital learning resources in the form of "OERs", which, according to UNESCO [2], are any type of educational materials that are in the public domain or introduced with an open license. The nature of these open materials allows anyone to legally and freely copy, use, adapt, and re-share them.

In response to these action lines, the Greek Ministry of Education launched in 2010 a national initiative for the modernisation of school education in Greece. It included a series of actions organised into five key areas: Infrastructure, Digital Educational Content, Teachers Training, Electronic Management of

Education, and Support actions. The “Digital School Platform, Interactive Books, and Learning Object Repository” has been a flagship project within the Digital School initiative. A key outcome of this project has been “Photodentro”, the national digital repository infrastructure for learning resources for Greek schools. The implementation of Photodentro has been structured in three core action lines:

- Design, development and operation of the Greek National Digital Learning Repositories for hosting, organizing, and distributing learning resources for schools: Photodentro LOR is the cornerstone of the infrastructure, hosting learning objects (http://photodentro.edu.gr/lor, Fig. 1). The Photodentro Repository ecosystem also includes Photodentro EduVideo (http://photodentro.edu.gr/video), hosting short length educational videos suitable for in-class use, and Photodentro UGC (http://photodentro.edu.gr/ugc), hosting learning resources developed by teachers, thus representing the user-generated branch of the ecosystem, as well as the Photodentro OEP (http://photodentro.eud.gr/oep), hosting Open Educational Practices [3], i.e. teaching techniques that draw upon OERs in order to facilitate collaborative and flexible learning [4].
- Design, development and operation of the Greek National Educational Content Aggregator Photodentro, a national service for harvesting and accumulating educational metadata from various repositories and collections (museums, libraries, audiovisual archives, etc.), thus serving as the central access point to learning resources for schools in Greece (http://photodentro.edu.gr).
- Content population that includes selection, uploading, metadata authoring, validation, and publishing of digital learning resources to the national repositories, as well as harvesting, selection, and metadata enrichment of resources hosted in external repositories.

Photodentro thus implements the Greek national strategy for educational content, with a strong emphasis on open access: all learning resources are freely available to everyone under the Creative Commons’ Attribution-NonCommercial-ShareAlike license. Photodentro supports browsing, free text search, and faceted search, allowing users to narrow search results by applying multiple filters, such as learning resources type, educational context, etc. Its implementation is based on DSpace [5], an open source platform for building digital repositories. It provides an Open Archives Initiative Protocol for Metadata Harvesting (OAI-PMH) target [6] and it fully supports the IEEE LOM [7] specification for standards-based description and exchange of metadata of the managed educational resources.

The growing adoption of the Photodentro family of OER repositories from the Greek K12 community during the last years has led to growing demand of external organisations to openly publish relevant resources through Photodentro to the very large audience of the Greek K12 community. Furthermore, an increasing number of content providers have expressed their interest in setting up Photodentro alike repositories for the management of their digital resources, looking forward to the benefits of an applied and well tested approach as well as to the intrinsic ability to selectively publish collections of their repositories through the Photodentro Aggregator.

3 PHOTODENTRO SAAS – DESIGN

The rising demand for making use of the Photodentro services from external content provides is a clear indicator of the problem-solution fit and the domain traction that has been achieved. The obvious route for responding to this high demand, is to offer the Photodentro repository through the SaaS model. However, this approach poses its own challenges: Photodentro is a complex system, based on DSpace, which has been heavily customised to address the specific needs of the Greek K12 community. The next paragraphs in this section provide an insight of the selected approach and the main parts of the system design for offering the “Photodentro as as Service” solution.

3.1 Current systems’ architecture

A multitier architecture has been used for the Photodentro infrastructure, which includes four tiers (Fig. 2): (a) the Photodentro web portal at the first tier provides a uniform gateway for the access to all learning resources, combined with social-networking features for interacting with resources and associated persons (rating, commenting, following, etc.); (b) the Aggregation tier manages harvesting of metadata from the host repositories, along with metadata validation and metadata indexing; (c) the Collection Management tier, includes a set of Photodentro repositories for the management of collections of OERs that host the associated digital files along with their detailed descriptions in the form of metadata; and (d) the Ingestion tier, which processes metadata from various external sources

(museums, libraries, audiovisual archives, etc.), based on the MINT (Metadata Interoperability Services) [6] for gathering metadata from external repositories as well as for facilitating the metadata and homogenisation and mapping process.

This architecture already provides most of the affordances needed to offer the Photodentro SaaS solution to interested parties. What is missing is an alignment of the SaaS best practices and methodological approaches to systems' design.

3.2 The SaaS approach to software design

Software as a Service (SaaS) is a software delivery model that provides access to software and its functions remotely, usually as a Web service. The software itself is centrally hosted and managed by the SaaS provider. In other terms, the SaaS approach to software delivery provides a 'multi-tenant' model in which subscribers access the same code base, with their data and any customisation kept separate [8]. In fact, SaaS redefines the software deployment model from packaged applications to a dynamic Internet based service relationship, which affects the relationship and value proposition between software vendors and both service users and providers. Delivering software's functionality as a set of distributed services that can be configured and bound at delivery time can overcome many current limitations constraining software use, deployment, and evolution [9].

How does this compare to "hosted" deployment, another renowned approach that has gained track the last decade, mainly after the emergence of cloud-computing? SaaS's multi-tenant system architecture is designed to provision the application's operation across the entire user base and all clients. On the other hand, in a typical hosted solution an individual copy of the application is deployed as a single installation per client.

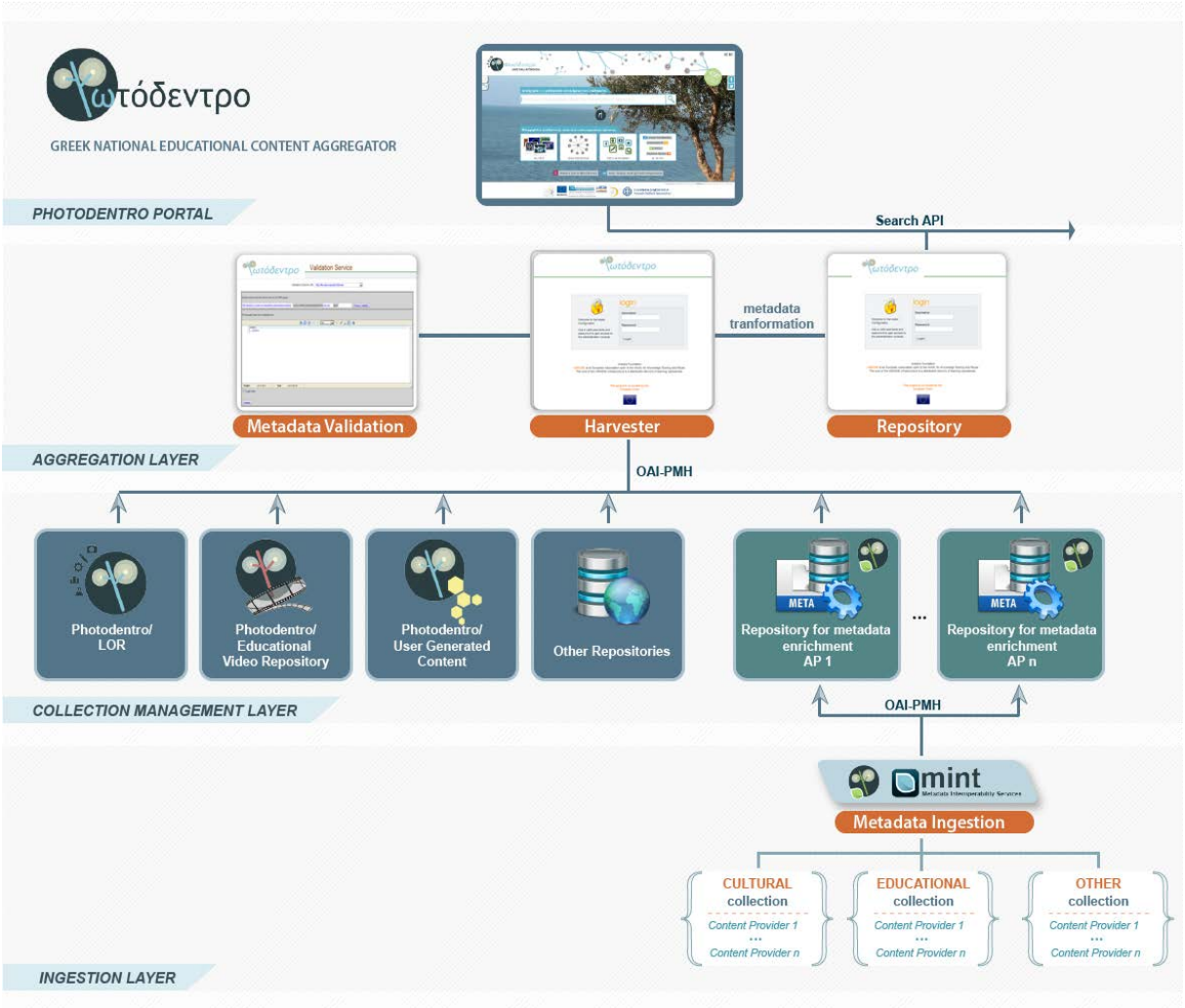

Figure 2: The multi-tiered architecture of Photodentro

3.3 Design alternatives for Photodentro SaaS

When it comes to education, educational institutions and related organisations are in need of repository systems that allow them to manage and publish digital educational content. However, they don't always have the resources to support such software projects in-house, and any available resources could be better targeted for the parts of the content creation and curation, metadata annotation, advertisement and support of end-users, making digital resources openly available, worldwide. Outsourcing parts of these projects, allows them to focus on their core activities. When considering the different approaches for responding to this need through the Photodentro ecosystem, we quickly reached to four alternatives:

1. *Collection-based approach:* Use an existing Photodentro repository where prospective new content providers would be able to have their own "collections", i.e. self-contained and managed workplaces where they can upload, manage, and properly describe their content with educational metadata. The frontend of the repository is common for all content providers, with minimal support for customisation of textual elements per collection.
2. *Hosted deployment approach:* Create a new Photodentro instance for every new content provider, hosted on cloud computing infrastructures that provide shared processing resources and data on demand. While this approach allows for maximum configurability, the associated costs for managing the setup and operation of one repository for every content provider makes this not a viable option.
3. *Microsites approach:* Allow for the use of a Photodentro repository as a data backend, where interested parties can manage the digital files and associated metadata descriptions of their resources, while providing the ability to integrate these resources in their organisational web sites and frontend services. In effect, through digital media syndication, resources that lie in the Photodentro-based repository can be combined with local level information and pushed through to multiple channels. In effect microsites provide a site-within-a-site capability, using a plugin-based architecture and exploiting Photodentro's standard-based protocols and Application Programming Interfaces (APIs). While they are an interesting and viable alternative, microsites can only meet the requirements of specific cases and, furthermore, require significant investment from both sides.
4. *SaaS approach*: Implement a SaaS layer for Photodentro, allowing for a single Photodentro instance to be customised in various ways by each content provider, by configuring and theming the user interface, graphical and textual details, as well as the layout of specific page elements.

After analysing the alternatives, the selected approach has been the SaaS one, which apparently combines most of the benefits of the others, while at the same time significantly lowering the adoption barriers for any interested content providers. In fact, creating and testing a new repository through the Photodentro SaaS solution is only a few clicks away by any typical web user. There's no need for special system infrastructure, specific operating system, software compilation, installation and configuration, nor there's a need for an interaction with the support team of Photodentro for setting up new collections, user accounts, etc.

3.4 A methodological adoption path for SaaS in Education

According to the "Vital Analysis" report [10] there is a fairly consistent SaaS adoption path (the *4E* path) across different organisations, including the following phases:

1. Experiment – A small part of the organisation undertakes a SaaS implementation, for a specific application with an identified SaaS provider. The main goal of the experiment is to provide confidence about SaaS technology that permits the further adoption of SaaS.
2. Expansion – SaaS solution legitimacy is growing among the organisation.
3. Extension – In the third phase of SaaS adoption, the organisation uses a number of product extensions, platform services, plug-ins and other capabilities related to the SaaS product.
4. Enterprise – In the fourth phase of the adoption, the company, as a whole, welcomes the solution for much of its business.

However, the adoption of technology in education cannot follow a one-size-fits-all approach. Each educational setting presents different challenges and requirements that have to be taken into account

when offering the respective solution. In the case of learning repositories of content, such differences can present themselves as described below.

A Non-Governmental Organisation (NGO) that works with children of immigrants is one case. This institution needs the learning resources used in teaching to be readily available on site, through mobile devices. This institution has no technical people to support this, but it does have a capable team of content creators. The same people that create the resources are metadata literate, so they can provide something more than merely a title and a description for each resource. Without these resources available on site, the NGO cannot fulfil its mission.

Another case is that of a public school, which generates hundreds of digital resources per year from student projects. The school has no technical staff, while the content creators and annotators are inexperienced pupils. The school is not really dependent on storing this content, but it's a nice-to-have service that would help build a nice repository of interesting resources for the next school years to come.

Finally, there's the case of a Ministry of Education of a European country. Although the ministry spent a lot on digital services for schools, just a decade ago, today their systems are outdated & obsolete. There is no interoperability with current platforms, limited metadata, high-quality content but with low-quality search mechanisms. The MoE has a strong technical team, no content authors and only one metadata expert that provides horizontal support.

In all the aforementioned cases, there are significant differences in the aspects of the technological know-how (Technology), the types of content hosted (Content) and the quality of existing metadata (Metadata). Therefore, prior to deploying Photodentro SaaS an assessment takes place that measures the status of each institution on these aspects using the TCM Maturity Meter (TCM^3). Fig. 3 shows the respective outcomes from the assessment of the three cases that were described, in a visual way. It is evident from the figure, that each candidate institution will be procured with specialised support, even if the systems that will be deployed on the technical end, may be identical.

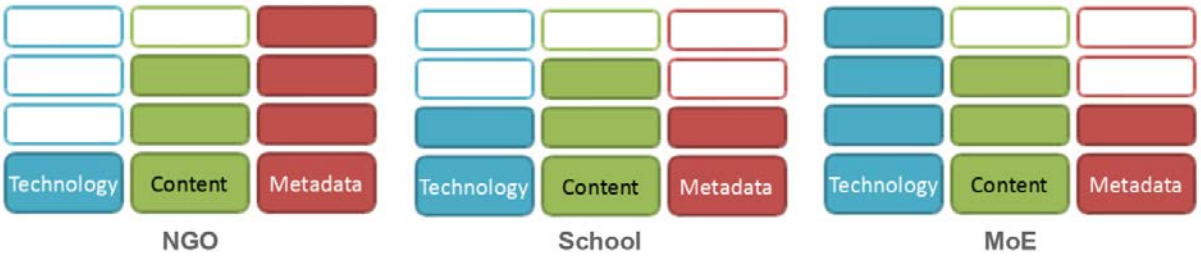

Figure 3: TCM^3 matrices for three different organisations

3.5 Photodentro SaaS Vision

The objective of implementing and offering the Photodentro SaaS solution is expressed in its vision:

> *Photodentro SaaS is expected to act as a catalyst for the expansion of the Photodentro ecosystem of digital repositories, sowing the seeds of Photodentro to all interested content providers in the educational domain and further related domains. This expansion shall determinately lead to a significant increase in the offering of OERs to the Greek K12 community as well as the general public.*

3.6 Fundamental design principles

The fundamental design principles for the Photodentro SaaS solution are related to the ease of its adoption by all interested parties and the sustainability of its support and offering.

Smooth transition to the Photodentro ecosystem is the core principle, allowing for each content provider to release its material on its own pace, methodology and policy, with a bare minimum requirement for open access licences. Proper attribution of content providers, combined with analytical reporting of the use of resources are key components of the Photodentro SaaS offering.

The sustainability, as well as the growth and extension of the solution is carefully planned and embedded in the system's design: software systems and applications become obsolete very quickly; therefore, when developing infrastructure with public funds, efforts should focus on the development of

the underlying “framework” which can communicate and exchange data with other systems and services through established protocols and specifications. Sensitive data reside in regulated and publicly controlled infrastructures, while the sustainability model encourages the software market and the educational community to contribute with services that extend the core functionality.

3.7 Non-functional requirements

An important aspect of any digital content repository is that of digital preservation, i.e. the formal endeavour to ensure that digital information of continuing value remains accessible and usable [10]. Furthermore the use of the SaaS model necessitates new relationships between the service provider and the content provider with respect to service availability, service performance and response times. The Service Level Agreement (SLA) has evolved to become a useful tool which governs both service expectations and the consequences of failure to meet these agreed upon metrics. More specifically, it suggests a set of non-functional requirements including:

1. Security – the data is protected against malicious access, while any data can be restored to its previous state through a carefully planned and managed backup strategy;
2. Availability – the system is available for use for a specified minimum as a percentage of time or period;
3. Scalability – system performance can adopt to varying user demand;
4. Performance – system response time does not exceed a specified maximum;
5. Configurability – specific elements of the system’s user interface and operation are configurable by the content provider;
6. Flexibility – the content provider can opt to allow or disallow the use of specific system functionality;
7. Interoperability – the system makes use of standards, specifications and APIs that make all data (and metadata) readily available to other systems and services;
8. Usability – all aspects of the system can be used without any training and through an intuitive and user-friendly web based interface;
9. Accessibility – the system makes best effort to remove barriers that prevent interaction with its functionality and access to its content by people with disabilities, ensuring a minimum level of the Web Content Accessibility Guidelines;
10. Localisation / Internationalisation – the system provides functionality for adapting to different languages, regional differences and technical requirements of specific target countries;
11. Supportability and Serviceability – the system integrates mechanisms for resource monitoring, alerting for exceptional events, and capturing user feedback. All events are properly recorded and escalated through a help-desk and associated workflow.
12. Graceful degradation – the system is designed to allow recovery from exceptional events with minimum intervention by technical support staff.

3.8 Functional requirements

The core functional requirements for Photodentro SaaS are layered in four increasing levels of service:

- *Layer 1* includes the ability to change the logo and key labels, to choose one of the existing themes for the graphical user interface, in order to match the institutional identity of each content provider; any existing metadata is migrated and mapped to the Photodentro SaaS IEEE LOM Application Profile; support and guidance is provided for importing content and metadata into the new Photodentro SaaS repository.
- *Layer 2* further includes extra support with metadata, in terms of designing custom input forms and creating specialised control vocabularies; additional support is provided for enhancing the content’s quality and matching the criteria of the Photodentro ecosystem, in order for resources of the new Photodentro SaaS member to be harvested by the National Photodentro Aggregator and be readily available through the Photodentro portal.

- *Layer 3* builds ontop of the previous level, allowing additional customisation of the frontend and creation of custom search facets to allow for special cases as well as the ability to adopt a custom template for the unique identifiers of the resources; the frontend can be optionally replaced with a microsite alternative approach, thus including the content of the new Photodentro SaaS instance into an existing institutional web site.
- *Layer 4* is targeted for very large repositories and adds to the previous levels the ability to move the Photodentro SaaS instance to non-shared infrastructure, the ability to fully customise the frontend as well as the backend. Additionally, the analytics services can be configured to match any requirement, with support for custom analyses and regular reports.

4 PHOTODENTRO SAAS - IMPLEMENTATION

In order to meet the requirements of the Photodentro SaaS design, we face an interesting technical endeavour, as it addresses a very large scale of users, i.e. the whole Greek K-12 community that includes more than 1,100,000 pupils and 120,000 teachers. Implementing and centrally supporting a software system for such a large scale is a challenge itself. Allowing for this system to be used by multiple content providers, raises the challenge to yet a higher level. The frontend design should be based on principles that guarantee broad acceptance and exploitation of the system's functionality and associated learning resources. Moreover, it should take into account the digital literacy skills and the e-maturity level of teachers and students and their dynamics, the existing computer infrastructure in schools and the penetration of PC and tablet equipment to pupils' homes, as well as the digital culture in general. Furthermore, other conditions should be considered, such as the viability of such an investment, the maturity of the local market to take part in the venture, and the digital strategy of the education authorities.

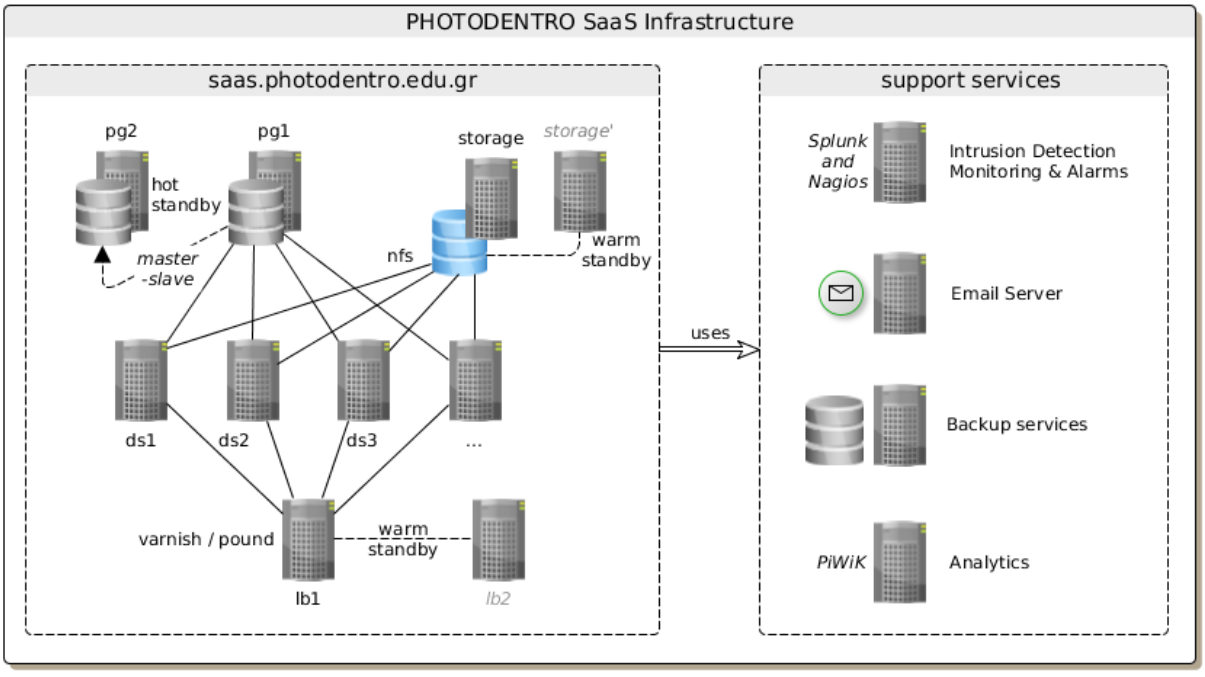

Figure 4: Photodentro SaaS Cloud Computing Deployment

In terms of the implementation approach, the intrinsic choice for the development team has been to adopt an agile process [12]. The essential characteristic of the agile approach is its explicit focus on creating business value for the intended users. The development process itself becomes a value creation process that relies on active participation of all key stakeholders. The value creation is ensured both through the final product as well as through the process itself [13]. Moreover, agile methods seem to be most effective in respect to keeping the development times low, as well as in respect to the harmonisation of project goals with the project deliverables. The user-centered design of the Photodentro SaaS solution is emphasised even from the design stage through the requirements elicitation process that has been largely driven by early adopters. The development team benefited from the agile approach, both in terms of the valuable motivation as a result of immediate visibility of

their work and the direct insight concerning the intended usage and the expected functional characteristics of the end product.

To address the challenge of the large-scale targeted user community, the implementation approach makes use of the capabilities offered by of the cloud-computing paradigm. The system's deployment relies on sharing of resources to achieve coherence and economies of scale. Furthermore, the chosen approach makes use of concepts from the Service-Oriented Architecture (SOA) architectural pattern, to decompose the system's operation into semi-autonomous services that can be weaved together to provide the complete functionality of the software platform. The core components of the system is the DSpace open-source repository management system, running within an Apache Tomcat Java 2 open-source Java Enterprise Edition container, and supported by the open-source PostgreSQL database management system. Usage tracking and analytics are collected and managed using the PiWiK open-source analytics server. Additionally, the Photodentro SaaS implementation adopts the container architectural paradigm, and the inversion of control software engineering design pattern, allowing external systems and services to receive the flow of control from the main user interface and safely interact with data of the platform. This is achieved through a well-documented REST API (Representational State Transfer Application Programming Interface), which can be used by external apps.

A thoughtfully designed and automated continuous integration mechanism drives the deployment of the Photodentro SaaS software components to a dynamically arranged set of Virtual Machines (VMs). The VMs themselves are managed through the ViMa (Virtual Machines) service of [14] the Greek Research Network (GRNET), which makes use of physical server computers and networking infrastructure operating at a set of Network Operation Centers distributed around Greece [15]. The suitable arrangement of VMs, operated by Debian GNU/Linux, form a dynamic cluster that is configured for high availability, both in terms of hardware and software failures, as well as for handling excess usage and peaks of demand for service delivery. In the case of a VM's or a process's failure, the overall system stability is not affected and all services remain operational, by dynamically re-routing the network traffic to the operational VMs.

The current system architecture used for the pilot launch of Photodentro SaaS (Fig. 4) includes four sets of VMs: the first handles the dynamic routing of incoming traffic and the caching of the repository's static content; the second provides the core functionality of the repository, based on the DSpace [5], the Apache Web Server [16] and the Apache Tomcat container [17]; the third hosts the system's PostgreSQL open source relational database system [18]; and the fourth provides a network-attached filesystem, based on the NFS protocol, shared by all VMs in the cluster. The shared filesystem allows for the immediate access to shared resources (configuration settings, static pages and associated data), as well as for the efficient deployment of new code by the development team using an efficient continuous integration approach based on git. Finally, a set of other VMs supports the operation of various tools and services that are used for analytics, monitoring and administrative purposes.

5 FUTURE WORK

After the successful launch of Photodentro SaaS and the feedback from its pilot usage, the next steps towards large-scale adoption involve: (i) sizing and employment of load balancing techniques to increase the scalability of the platform; (ii) alignment of the identified workflows and processes to the needs of different types of content providers; (iii) enhancement of the services for online support and feedback of the content creators, the metadata authors, as well as the end-users of the Photodentro SaaS instances; and (iv) continuous deployment on an infrastructure with the capacity to host an increasing number of members from the targeted community of users.

ACKNOWLEDGEMENTS

The authors wish to express their special appreciation and thanks to the development team who have implemented all parts and pieces of the Photodentro ecosystem: Kostis Alexandris, Katerina Antonopoulou, Pantelis Karamolegkos, Panagiotis Drakoulogkonas, and George Kyrgiazos. Part of the work described in the paper has been funded by the "Digital School Platform, Interactive Books, and Learning Object Repository" National Greek Program (Contract No 296441/2010-2015), co-financed by the European Union (ESF) and National funds in the context of the Operational Programme "Education and Lifelong Learning" of the Greek National Strategic Reference Framework

(NSRF), coordinated and implemented by “Computer Technology Institute and Press - CTI Diophantus”, Strategy and Digital Educational Content Directorate (http://dschool.edu.gr/p61cti/).

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