Multi-component Infrastructure for e-Lectures

A Viable Solution for Small and Medium-Sized Organizations

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Abstract. e-Lectures dominate course material in many e-learning environments. Even small and medium-sized organizations need a way to make their e-lectures systematically and easily accessible. The paper presents a viable multi-component infrastructure for e-lectures as an incremental prototypical development. The selection and customization of the components is derived and discussed from the state of the art and the specific organizational requirements. In order to measure the performance of the resulting system, computer experiments were carried out according to scientifically sound procedures. As small and medium-sized organizations have significant budget constraints, the affordability of the multi-component system was finally examined applying an argumentative-deductive analysis.

Keywords: e-Lecture, Video Management System, Semantic Content Management, Dual Video Cast, Video Deployment.

1 Introduction

Due to significantly lowered barriers for the production and delivery of videos and not least due to the didactic proximity to classical lecture formats, e-lectures dominate course material in many e-learning environments, particularly in nearly all MOOCs (Massive Open Online Courses) [1, p. 3]. While in MOOCs as well as in administrated university courses the e-lectures are integrated in learning management systems (e. g. Moodle, to name a widely distributed open source tool) the problem of giving open and course-independent access to e-lectures remain not well addressed. There are several reasons why such prominent streaming platforms like YouTube or Vimeo should not be used directly: cluttering by advertisement, limited opportunities for structuring, lack of support for certain production and delivery styles.

The market offers a wide range of video management systems for businesses, but they are not viable for small and medium sized organizations [2]. In addition, these systems cannot solve all the above problems, particularly in terms of structuring and delivery styles. On the other hand, there is a great variety of open source components and technologies as well as high-performance services at affordable prices which can be combined to an accordingly customized system.

The paper presents the experiences and insights from several years of developing a multi-component system for e-lectures at a small university. The system is openly accessible and is not only used at the home university but also at cooperating institutions. A schema.org-based business knowledge schema serves as a central structuring artifact. All in all, the infrastructure encompasses a wide range of different components: (i) the hardware for video production in a style flexibly combining talking head with screencasts, (ii) a Vimeo[1] account for storing videos and providing streaming services, (iii) OntoWiki[2] as back end of the e-lecture management system, (iv) a web-based user interface[3] based on OntoWiki's site extension feature providing structured access to e-lectures, (v) the OpenHPI[4] dual player software for customizable and synchronous delivery of talking head and screencast videos, (vi) a streaming app providing metadata and control features for consuming e-lectures[5], and (vii) a business process for populating the relevant databases with new e-lecture data and files implemented in Camunda BPM[6].

Research methods applied in this paper are prototyping for the system development, computer experiments for performance measurements, and argumentative-deductive analysis for proving the overall affordability in small and medium-sized organizations. Quantitative and/or qualitative research on the didactic value of e-lectures and on the general use of semantic technologies in e-learning environments (see e. g. [1, 3-5]) are outside the focus of this work. The rest of the paper is structured as follows. Section 2 discusses the main concepts and definitions, mainly e-lecture, video management system, and knowledge schema. Section 3 provides a deeper insight into the state of the art of e-lecture platforms. The research questions and methods applied are stated and explained in Section 4. Section 5 addresses in detail the system design and implementation. Section 6 is concerned with the evaluation of the system. The paper closes with a summary and an outlook on future work in Section 7.

2 Main Concepts and Definitions

The main concepts to be defined in this section are e-lecture, video management system and knowledge schema. Since these concepts are subject to different interpretations, the following definitions are intended to ensure a uniform understanding within the framework of this work.

Following [6] we call *e-lecture* any digital learning resource in lecture format which is recorded in a studio in the absence of the intended audience. In differentiation to this, [6] names a lecture recorded in a real context as life digitized lecture.

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1 https://vimeo.com/de/upgrade
2 http://ontowiki.net/
3 https://fbwtube.th-brandenburg.de/
4 https://github.com/openHPI/video-player
5 See e. g. http://univera.de/FHB/fbwTube/?id=DFW_EN&chapter=0
6 https://camunda.com/products/bpmn-engine/

[1] provides a comprehensive typology of 18 video production styles, including eight types of e-lectures. Nevertheless, the type used in the given case is differs from all of them. The closest type is picture-in-picture, where the screencast integrates a smaller video of the speaker. The e-lectures at hand combine flexibly a so-called talking head video and a screencast video, which is genuinely supported by the recording technology used. It is flexible because the user of the streaming app can resize the presentation canvas between talking head and screencast according to his or her needs. Applying the classification criteria stated in [3, p. 73] the e-lectures considered in this paper are characterized as follows:

Table 1. Characteristics of e-lectures in the context of the paper

Criterion	Characteristic
Recording method	Combination of camera and screencast
Content mediation	Classical lecture
Recording location	Studio setting
Duration	5 – 20 minutes, collected in series
Integration of the lecturer image	Flexibly sizable separate video

A *video management system* (VMS) is a specific type of content management system (CMS) where video is the main content provided. According to [7], a CMS assures the division of content, layout, and structure. The video content is stored at ideally powerful video (streaming) servers. The layout ensures a consistent and concise appearance, and the structure comes from the implemented data models. Another characteristic of CMS are the roles and corresponding rights provided to user agents. Three of them are of relevance in the given context: consumer, editor, and service. Consumer and editor are humans, whereas a service is a technical agent. It "uses" the CMS via application programming interfaces (API).

The last concept to define in this section is *knowledge schema*. One of the basic sets of concepts in the field of Information Systems comprises data, information and knowledge (comp. e. g. [8]). The content provided in an CMS can be characterized as information. The structure of content representation depends on the implemented data model which may range from lightweight metadata structures to formal schemata. A knowledge schema is a domain-specific, semantically rich and standards-based conceptualization which may constitute the structure of an information system. In the case at hand we use an RDF-based knowledge schema for shaping the VMS back end.

3 State of the Art

In order to assess the adequacy of the prototype described in Section 5, the state of the art for VMS shall be summarized in this section. Therefore, three categories of VMS will be scrutinized: (i) major VMS platforms like YouTube or Vimeo, (ii) non-semantic VMS, and (iii) semantic VMS, where the term semantic refers to Semantic Web technologies. Since the paper deals with systems for small and medium-sized organizations, high-priced systems from categories (ii) and (iii) are not considered. Instead, the focus is on open source solutions.

Major VMS platform Vimeo. In general, Vimeo can be used as an organizational VMS with customizable roles and domains where videos may be embedded. Videos can be proactively grouped in albums and/or channels. This grouping doesn't provide ordered list features. Further, videos can be tagged with a title and a description. Each video is provided with a URL for streaming. Creation and modification dates as well as duration and some other streaming features are captured automatically. Finally, several pictures including their metadata are created, e. g. for thumbnails (comp. [9]). More complex didactic relations, e. g. between lectures and lecturers or study programs, are not implementable. The main exclusion criterion in the given context, however, is that Vimeo does not support the synchronous display of two videos.

Non-semantic VMS. A low-threshold architecture for a non-semantic VMS combines an easy to implement open source CMS (e. g. WordPress) with an appropriate video player. This is how the problem of dual synchronous video display can be solved. Content can be arranged in predefined categories, enriched by human-readable metadata and probably tagged. Basic search functions are limited to string matching in textual data. With the help of plugins, a facetted searching or filtering can be implemented. However, specific relations between the categories are not feasible and therefore no complex queries are possible (comp. e. g. [10]).

Semantic VMS. Since 2014, the TIB AV Portal [11] has been a very powerful, open VMS for quality-checked scientific e-lectures from six scientific disciplines. The portal relies genuinely on semantic technologies and services such as automatic video analysis and semantic tagging. Basic lecture metadata is entered along the schema for non-textual materials (NTM). Further structured data is created by automatic annotation of video content. The NTM schema is based on the collection interests of libraries and less on didactic issues. Relationships between e-lectures and courses or degree programs are not offered, but relations to subject areas and subjects can be established along controlled vocabularies. The VMS is equipped with rich filtering and search functions. Content delivery by a dual video player is not supported.

Another approach to providing video content via semantic platforms is offered by freely configurable semantic wiki systems such as Semantic MediaWiki (SMW) [12] and OntoWiki. Both are available as open source. OntoWiki not only allows but requires the use of individual knowledge schemata to build semantic content structures, whereas SMW as an extension to MediaWiki – the software that powers Wikipedia – inherits from it all wiki-typical classes and functions but allows the import of additional RDF data. OntoWiki's benefits are genuinely structured, nested views and rich browsing functions. Equipping OntoWiki with a VMS interface nevertheless requires the implementation of a sophisticated site extension. Both systems are mainly programmed in PHP. It should be noted that SMW has a vibrant development community issuing regularly new software releases, while the development of OntoWiki has been frozen on stable version 1.0 in 2017 in favor of newer technologies.

If one weighs up all the advantages and limitations presented against each other and at the same time considers the following two requirements to be indispensable: (i) implementation of the semantic structure of the educational domain in the back end and (ii) support of the dual delivery format in the user interface, the implementation of OntoWiki as back end for the VMS appears to be the means of choice.

4 Research Questions and Methodology

The engagement with e-lectures and a related infrastructure began 2014 as an individual initiative of the author - a professor at Brandenburg University of Applied Sciences (BUAS). As a small university, it has tight budgets and reduced support structures for didactic innovation. Therefore, from the very beginning, the project had a research character. Main research questions where stated as follows:

1. Which components are required for a viable infrastructure for e-lectures that is driven by semantic technology and allows dual display of talking head and screencast videos?
2. Which level of performance can achieve this multi-component infrastructure for e-lectures in comparison to other production processes and VMS?
3. What types of resources does the implementation of the system in question require and what does it look like compared to large VMSs?

Main research method applied in this work is prototyping. The state-of-the-art analysis in the previous section showed the absence of easy-to-implement solutions that meet the stated requirements. Therefore, the development process was characterized by intensive literature and source studies, experimental developments and well-founded reflections. At the same time, the implemented parts of the system were continuously used in teaching and thus subjected to regular practical tests. The knowledge gained in this way influenced further developments. The results of prototyping are demonstrated and critically reflected in Section 5 and thus give an answer to research question 1. In order to solve research questions 2, computer experiments were carried out according to scientifically sound procedures. Finally, research question 3 was subjected to an argumentative-deductive analysis. The results of these experiments and analyses are described in Section 6.

5 System Implementation

In this main section of the paper the overall multi-component solution for e-lectures in a small and medium-sized organization will be scrutinized in detail. The main design and development steps will be explained, and the direct results reflected. The successively growing system is in productive use since 2015. As already explained in Section 1, the system consists of seven components. They will be discussed in a system-oriented logic in the sections 5.2 - 5.6. The following section provides an introductory description of the system's core architecture.

5.1 System Design

As first asset of the overall system the university acquired the so-called TeleTask Recording System[7] together with lightening equipment and a streaming server. After

[7] https://www.tele-task.de/about/

a series of discouraging tests, the server was replaced by an external streaming service. Another disappointing experience was the built-in delivery format of the e-lectures. An acceptable adaptation to our corporate design was not possible with the preconfigured settings. A direct manipulation of the built-in software was also prohibited. We agreed with the manufacturer – a subsidiary of Hasso Plattner Institute (HPI) by University of Potsdam – to reconfigure the software for direct export of the two e-lecture videos (talking head and screencast). Then we were able to build our own customized interface reusing the HPI open source dual player software. This historical part of the system is visualized in the upper right part of Fig. 1. The e-lectures now could be used via URLs provided in Moodle, i. e. in the context of specific courses. Fig. 7 shows the appearance of e-lectures in that environment. At that point, the first of two crucial requirements were met.

Over time, the collection has grown to almost 200 e-lectures with a total duration of approx. 40 hours. The individual e-lectures are arranged in series, which correspond to a class. They are currently used in eight courses and in all four major study programs of the Department of Economics at BUAS and in addition, at four foreign partner universities. Therefore, a need for a VMS arose that would not only enable efficient management of e-lectures but would also provide easy access to that material beyond specific courses and study programs.

Right from the start, the goal was to base the VMS on a domain-specific knowledge schema. First, the possibilities of the CMS Drupal were tested, which had a semantic plugin in its version 8. Since earlier good experience had been gained with a semantic catalog application, another prototype was then built from scratch. Both prototypes could not meet the requirements. Finally, an OntoWiki project was set up and successfully implemented. Fig. 1 shows the implemented IT architecture of the e-lecture system in an abstract graphic. OntoWiki acts as back end with Virtuoso as data storage. Data on new e-lectures are imported as RDF files and edited in the back end as required. The VMS business logic and user interface were implemented on the base of a so-called site extension. By browsing, searching and filtering, users pull data from OntoWiki via its SPARQL API. On click on an e-lecture link, the dual player application starts in a new tab and loads the video streams from Vimeo.

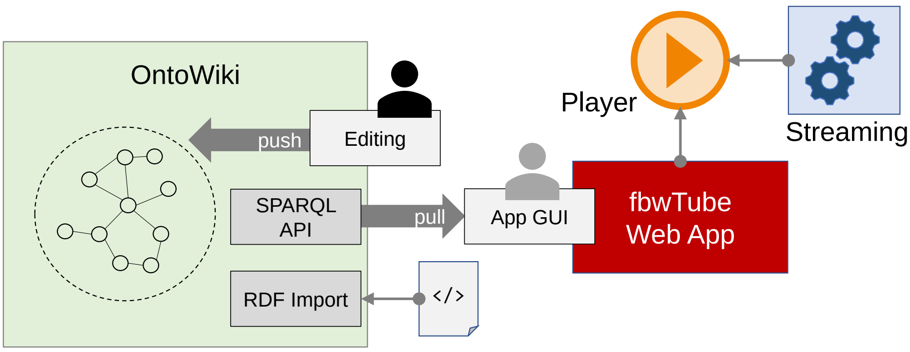

Fig. 1. Abstract architecture of the e-lecture system

5.2 Production Studio

Budget bottlenecks in smaller organizations affect not only money and human resources, but also premises and other equipment. Therefore, the video recordings were first carried out in a seminar room (comp. [13]). The recording equipment had to be set up and dismantled each time. In addition, it was not possible to illuminate the speaker as desired. Fortunately, a small basement room could be occupied after one year. With the help of a photo expert, the headlights could be installed as intended.

The equipment of the studio is completed by a desk for the recording assistant, a sideboard for the lecturer as well as a touch screen presentation computer for the handling of learning material or resources. Camera and computer are cable connected with the recording box via device interfaces. The lecturer uses a wireless microphone which is pre-tuned to be recorded by the box. All components are visible on Fig. 2.

On wish list remain an additional sound system with multiple microphones to record group teaching or discussions and a camera with better resolution for brighter talking head videos. To improve the resolution of screencasts, a new recording box with HDMI interfaces must be acquired. According to the manufacturer, an upgrade of the box in use is not possible. That would be a large investment, which actually cannot be made solely from the university's own resources. Another useful add-on would be a teleprompter to allow the lecturers to look directly into the camera more often. Such an additional screen could be implemented without much effort.

Fig. 2. e-Lecture production studio with dual cast equipment

5.3 Knowledge Schema

As stated at the beginning and repeatedly confirmed, a domain-specific knowledge schema should form the structure-giving backbone for the VMS. In this role, it allows flexible traversing of the entire graph and thus valuable queries and views in the user interface as well as at the back end. In addition, it is planned to publish metadata about the e-lectures in the system openly on the web by using semantic annotation based on schema.org. That's why the classes, relations and attributes were taken from the schema.org vocabulary as completely as possible. Basic structuring relations and attributes were taken from RDFS, namely `subClassOf`, `label`, and `comment`. Apart from that, all domain-specific predicates come from schema.org.

The situation with the relevant classes is more problematic. Videos and e-lectures can be interpreted as subclasses of the schema.org top-level class `CreativeWork`. There is an explicit subclass `VideoObject` which initially was part of the domain schema. It is defined as a class of video files, in the situation at hand MP4 files for the talking head or the screencast of a single e-lecture. In the course of the development it becomes clear, that this level of granularity will yield no benefits. Therefore, the class was omitted from the schema. Strictly speaking, an e-lecture (in Fig. 3 depicted as `DoubleClip`) is a series of two corresponding video objects and therefore they form a subclass of `CreativeWorkSeries`. The same applies to the other granularity levels, namely series of e-lectures for a single class (modeled as `VideoLecture`) and series of these series represented as `LectureSeries`. The schema.org class `MovieSeries` does not fit properly for any of these classes, therefore the mentioned proprietary classes are introduced.

Similar problems arose at modeling courses and study programs. Both appear as subclasses of schema.org's `Course` and are modeled for distinction purposes as `Module` and `StudyProgram`. Lastly, subclasses for `Person` were introduced: `Lecturer` and `Accountable`. Fig. 3 shows the schema at a conceptual level.

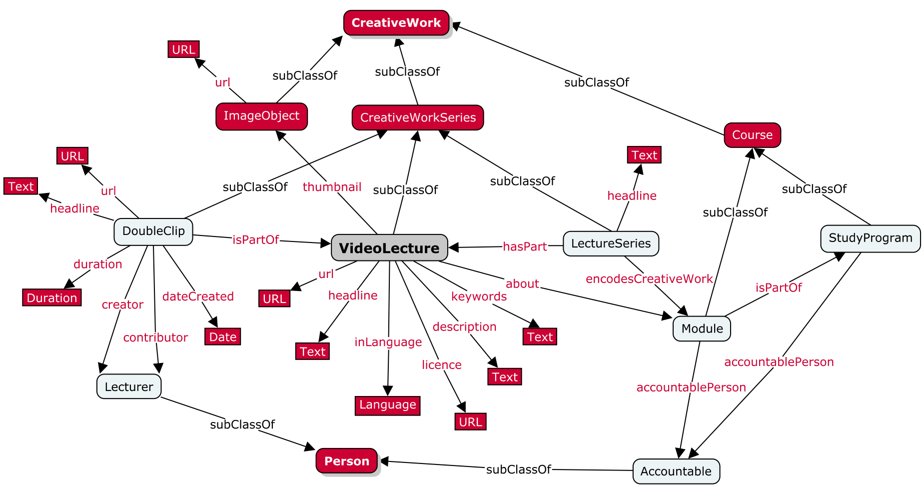

Fig. 3. Knowledge schema for the e-lecture system

5.4 Back End

The knowledge schema discussed in the last section provides the navigation structure for the OntoWiki system which finally was chosen as back end resource. At the left side in Fig. 4 a snippet of that schema is visualized, namely the subclasses of Creative Work Series: Double Clip, Video Lecture and Lecture Series. OntoWiki depicts on the surface `rdfs:labels` wherever they are available. The schema itself as well as the bulk data on e-lectures can be imported directly in OntoWiki as soon as they are available in RDF. All data – schema data as well as productive data – are stored in the associated Virtuoso Triple Store. The populated knowledge base allows editors to browse, to edit and to request structured data from the graph via user interface functions and widgets [14]. In the center of Fig. 4 the data for a specific video lecture are depicted. On the right side a window element labelled as “Instances linking here” lists the corresponding e-lectures (Double Clips) as well as the lecture series this video lecture is part of. All resources are clickable and therefore further explorable.

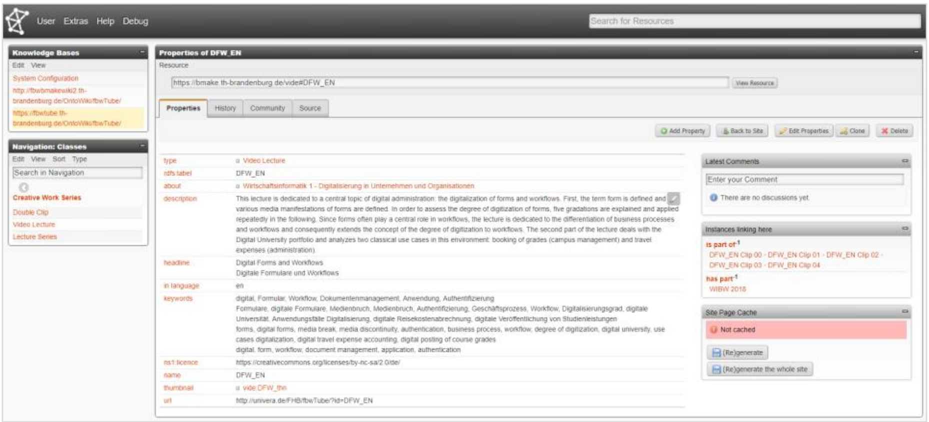

Fig. 4. OntoWiki back end with exposure of e-lecture data

After extending OntoWiki with the help of the site extension for creating a VMS user interface, new items are automatically added to the OntoWiki Navigation Classes: `Navigation` for the specification of the Web app navigation and `WebPages` for the definition of all pages (templates) used in the app. Static pages like Imprint or Privacy can be edited directly in the back end. The following listing shows an excerpt of RDF data in Turtle format for the video lecture exposed in Fig. 4.

```
vide:DFW_EN   a        vidp:VideoLecture ;
  rdfs:label           "DFW_EN" ;
  schema:headline      "Digital Forms and Workflows"@en ,
  schema:inLanguage    "en" ;
  schema:thumbnail     vide:DFW_EN ;
  schema:about         vide:WIBW ;
  schema:url  "http://univera.de/FHB/fbwTube/?id=DFW_EN".
```

5.5 User Interfaces

In this section two technically independent user interfaces will be discussed. The first represents the front end of the VMS, the second acts as the dual player interface. Tele-Task runs an inhouse-developed VMS with multiple filtering functionalities and a powerful search embedding the dual player directly in the application[8]. We opted for this easier to implement lightweight variant of connecting two separate applications.

Another decision which differentiates the presented here VMS user interface from others is the omission of the common, often unaesthetic thumbnails and the use of clear, expressive, and theme-related logos instead. Thematically close video lectures can be tagged with the same logo and therefore show their proximity at one glance. For every video lecture, concise metadata are provided: language, number of associated e-lectures, total duration, lecturer(s), and description teaser (Fig. 5). Several surface elements link to a details page with a comprehensive description, the creation date, courses where the video lecture can be used as learning material, and links to the e-lectures itself which open in the dual player (Fig. 6-7).

Filter functions are provided for languages, lecturers, courses and study programs. In addition, a search function is implemented which executes string matching in all textual data. To booster this function, the keywords are enriched with prominent terms and phrases extracted by text mining from the PDF scripts of the video. This seems to be cheaper and less error prone than applying sophisticated NLP technologies to the screencast or the audio track.

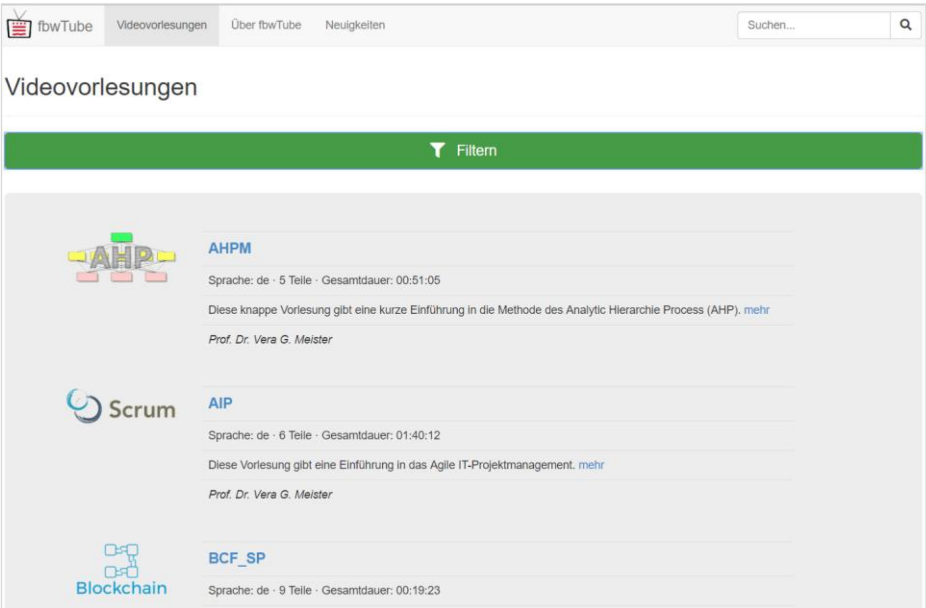

Fig. 5. Main page of the OntoWiki-based VMS user interface

8 https://www.tele-task.de/series/

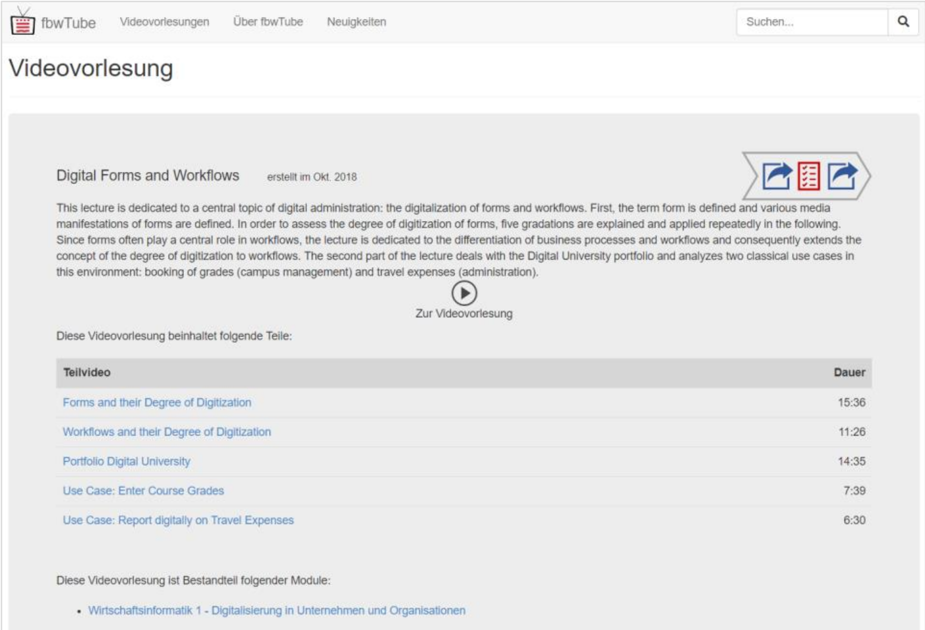

Fig. 6. Details page of the VMS interface with links to e-lectures

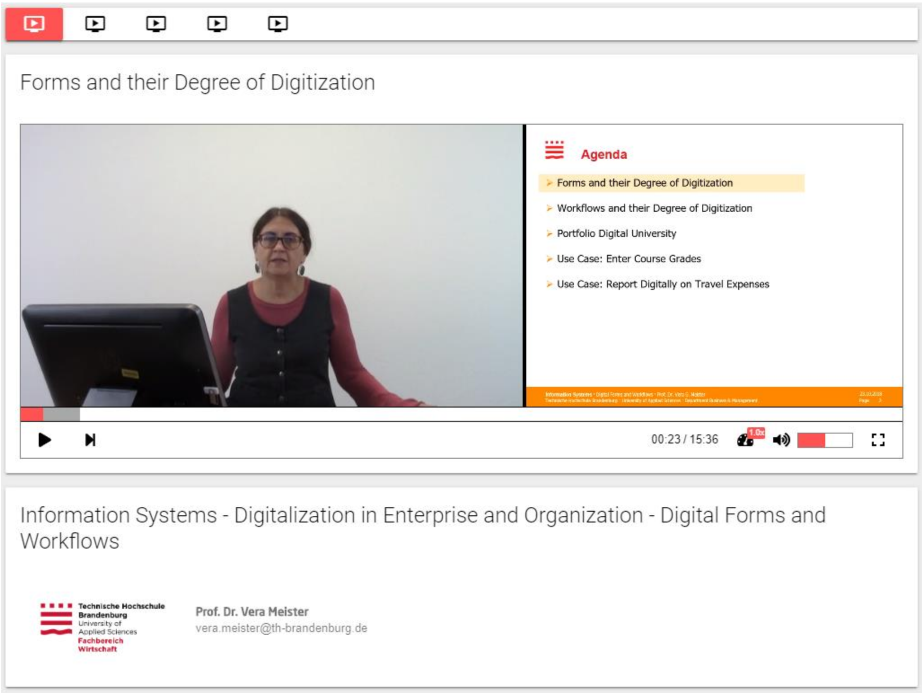

Fig. 7. Dual player interface with sizable videos, metadata and control elements

5.6 Population Process

The last infrastructure component for e-lectures, the business process for the e-lecture production and VMS population is partly a management and partly a technical asset. At the moment, the management part is fully implemented and runs with the help of routines and templates. Fig. 8 shows the to-be version of the process, implementing a lot of automated tasks. For the evaluation of these pre-planned automations a series of tests with the APIs of related systems (Vimeo and OntoWiki) was performed. Since the number of newly produced e-lectures is easily manageable up to now, the mostly not-automated execution is fair enough. The efforts for automation would far exceed the expected time savings.

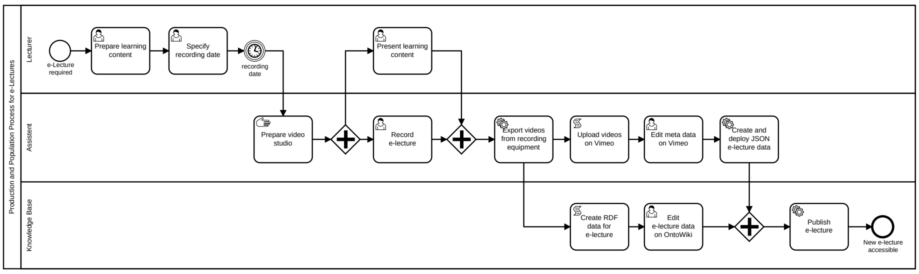

Fig. 8. To-Be production and population process for e-lectures

The most suitable candidate for automation is the activity "Create and deploy JSON e-lecture data". This file delivers structured metadata and necessary links for a video lecture consisting of several e-lectures to be displayed in the dual player. The necessary data can be captured partly from the Vimeo API and partly from the recording equipment. The following listing presents an excerpt of such a file (see also Fig. 7).


```
{
  "courses":[
  {
    "title": "Information Systems - Digitalization in
              Enterprise and Organization",
    "lectureTitle": "Digital Forms and Workflows",
    "lecturer": "Prof. Dr. Vera Meister",
    "lecturerMail": "vera.meister@th-brandenburg.de",
    "chapters": [
    {
      "title": "Forms and their Degree of Digitization",
      "videos":
      {
        "url_teacher": "https://vimeo.com/296600095",
        "url_presentation": "https://vimeo.com/296600051"
      }
    }, …
```

6 Evaluation

In the last section, the components of an infrastructure for e-lectures built on semantic technologies and supporting the synchronous recording and dual display of talking head and screencast videos was presented and discussed in detail. Therefore, research question 1 is answered. The remaining research questions 2 and 3 are partially addressed in the last section and will be consolidated in this section. Performance measures of the implemented infrastructure for e-lectures are presented in Subsection 6.1 whereas the affordability of the overall system for small and medium sized organizations is proved in Subsection 6.2.

6.1 Performance Measures

The performance of the overall system (comp. Fig. 1) depends on the performance of its four presentation-related parts: (i) the video streaming service by Vimeo, (ii) the SPARQL queries in OntoWiki, (iii) the VMS pages (main and details), and (iv) the dual player software. Since the system is in use mainly at a small university, issues of scaling to a huge number of parallel requests is not in the focus. The performance of the services offered by Vimeo can be considered as verified (comp. e. g. [15]). The performance of the other three components is mainly represented by the response and loading times respectively. According to [16], a loading time of 3 seconds is considered a benchmark.

The response time for the SPARQL queries is measured directly in OntoWiki. Table 2 shows the results of a test series for all queries used in the VMS pages. Even the aggregation of all queries takes less than 1 second.

Table 2. Response times for SPARQL queries in OntoWiki (measured in ms)

Test number	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**∅**
aboutQuery	2	2	2	2	2	2	2	2	2	2	2
clipInfo	35	49	45	61	48	45	52	45	44	45	46,9
filterLecturer	3	3	2	2	2	2	3	2	3	3	2,5
filterModule	3	4	2	3	3	2	3	3	3	3	2,9
filterStudyProgram	4	3	3	2	2	3	3	2	2	2	2,6
moduleInfo	2	2	2	2	2	2	2	2	2	2	2
videoDurationContributor	21	21	22	20	20	21	21	22	21	21	21
videoInfo	10	9	9	10	9	10	10	9	11	9	9,6
videoLectureSearchFilter	752	638	726	594	649	702	616	663	670	556	656,6
Aggregated times	**832**	**731**	**813**	**696**	**737**	**789**	**712**	**750**	**758**	**643**	**746,1**

As in [16], dotcom-tools[9] were selected to measure in random computer experiments the loading times of the VMS pages and the dual player software. Two different browsers and two different mobile operating systems were chosen for testing. The tests have been conducted using six different server locations in Europe: London, Paris, Amsterdam, Frankfurt, Warsaw, and Madrid. The results are listed in Table 3.

9 https://www.dotcom-tools.com/website-speed-test.aspx

Table 3. Loading times for VMS pages and dual player software (in seconds)

Tested site/software	Mozilla Firefox	Google Chrome	iOS	Android	∅
VMS main page	4,3	4,5	3,8	4,7	4,3
VMS main page with filter	3,4	3,8	2,6	3,4	3,3
VMS exemplary details page	2,1	2,0	2,0	2,1	2,1
Dual player software	2,8	3,2	2,8	2,1	2,7

The measurements show that the main page of the VMS exceeds the benchmark of 3 seconds, while the other features remain below it. For comparison, two other VMSs were examined: TeleTask operated by the University of Potsdam and TIB AV operated by the University of Hanover. Their main pages loaded on average 2 seconds.

6.2 Affordability

In order to demonstrate the affordability of the presented multi-component infrastructure for e-lectures for a small or medium-sized organization (here a small university), all necessary cost items are listed by category and quantified where possible or necessary. Direct comparability with other solution alternatives is difficult because there are too many influencing factors. Nevertheless, a cost comparison is made for one case. In the present case, a large part of the investment costs was covered by public grants. This is also broken down and presented.

Since e-lectures are a didactic offer – i.e. part of the genuine business of a university – the costs of core and support services, which are provided anyway, are not counted separately. In addition to the preparation of materials by the lecturer, this includes the maintenance of servers and software applications. The process of recording itself is designed to take 2 hours of studio time for a 90-minute lecture. The teacher is supported by a student assistant. This assistant then handles the post-processing and publication of the recorded e-lectures, which takes another 2 hours. This will result in additional costs of approx. 50 € for such a recording.

The external service costs for the Vimeo subscription amount to € 180 per year. The largest cost block includes the investment costs, which consist of the following items: the acquisition costs for the recording system and the additional studio equipment (approx. 16.000 €) as well as the costs for the customization of the back-end software and the development of the front-end applications by student assistants (approx. 10.000 €). Internal costs for the room and usual equipment, such as chairs, tables and PCs, are not considered.

If the lifetime of the entire system is calculated at 7 years, the annual depreciation is approx. 3,700 €. In the present case, 80 % of the acquisition costs and 100 % of the labor costs for customization and development were covered by public grants. Thus, the actual imputed costs per year amount to € 460. Together with the Vimeo service costs this amounts to 640 €. Both values are significantly lower compared to the license fee of € 16,000, which must be paid, for example, for the MOOC House service platform offered by HPI[10].

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[10] https://mooc.house/

7 Conclusion and Future Work

The paper examined the viability of an infrastructure for e-lectures in small and medium-sized organizations. This is an issue of relevance as e-lectures are an important instrument of digital teaching. Via a VMS, the offer can be made accessible across departments and courses. A prototype consisting of seven different components was developed and evaluated in terms of performance and affordability. The latter could be proven. The system has been in operation since the beginning of 2019. Work must continue improving performance, the loading times of the main pages must be shortened. Improvement of the search function and of the publication process are also planned. Finally, the VMS pages shall be enriched with automatically published semantic annotations to improve the retrievability of e-lectures in the web.

References

1. Hansch, A. e. a.: Video and Online Learning: Critical Reflections and Findings from the Field. HIIG Discussion Paper Series No. 2015(02), pp. 1–34. HIIG, Berlin (2015).
2. Gartner Inc.: Reviews for Enterprise Video Content Management, https://www.gartner.com/reviews/market/enterprise-video-content-management, last accessed 2019/05/19.
3. Handke, J.: Handbuch Hochschullehre Digital – Leitfaden für eine moderne und mediengerechte Lehre. Tectum Verlag, Marburg (2015).
4. Mouromtsev, M., d'Aquin, M.: Open Data for Education – Linked, Shared, and Reusable Data for Teaching and Learning. Springer International, Switzerland (2016).
5. Wang, Y., Wang, Y.: A Survey of Semantic Technology and Ontology for e-Learning. In: Semantic Web – Interoperability, Usability, Applicability. IOS Press Journal (2019).
6. Demetriadis, S., Pombortsis, A.: e-Lectures for Flexible Learning: A Study on their Learning Efficiency. In: Educational Technology and Society, 10(2), 147-157 (2007).
7. Lehner, F.: Wissensmanagement. 3rd edn. Hanser, München (2009).
8. Davenport, T., Prusak, L.: Working Knowledge – How Organizations Manage What They Know. Harvard Business School Press, Boston (2000).
9. Vimeo API, https://developer.vimeo.com/api/reference, last accessed 2019/05/19.
10. WordPress Online Manual, https://codex.wordpress.org/, last accessed 2019/05/19.
11. Arnold, P. e. a.: Handbuch E-Learning. 5th edn. Bertelsmann, Bielefeld (2018).
12. Semantic Media Wiki, https://www.semantic-mediawiki.org/, last accessed 2019/05/19.
13. Meister, V., Hu, W.: Videovorlesungen in der Wirtschaftsinformatik – Systemanalyse und Reflexionen. In: Barton, T. e. a. (eds.) Angewandte Forschung in der Wirtschaftsinformatik 2016, pp. 304-317. Mana-Buch, Heide (2016).
14. Frischmuth, P., Martin, M., Arndt, N.: OntoWiki 1.0: 10 Years of Development – What's New in OntoWiki. In: SEMPDS 2016 Posters & Demos at SEMANTiCS 2016 and SuCCESS'16 Workshop, http://ceur-ws.org/Vol-1695/paper11.pdf, (2016).
15. Bulkan U., Dagiuklas, T.: Predicting quality of experience for online video service provisioning. In: Multimedia Tools and Applications, Springer (2019).
16. Kissmetrics, https://blog.kissmetrics.com/wp-content/uploads/2011/04/loading-time.pdf, last accessed 2019/05/20.
17. Bartuskova, A., Krejcara O., Sabbahb, T., Selama, A.: Website Speed Testing Analysis Using Speedtesting Model. In: Jurnal Teknologi, 78:12–3, 121-134 (2016).