Opencast Matterhorn:
A community-driven Open Source Software project for producing, managing, and distributing academic video

Markus Ketterl*, Olaf. A. Schulte and Adam Hochman*****

***Virtual Teaching Support Center, University of Osnabrück, Heger-Tor-Wall 12,**
49074 Osnabrück, Germany
Email: mketterl@uni-osnabrueck.de

****IT Services, ETH Zürich, Rämistrasse 101, 8092 Zürich**
Switzerland
Email: schulte@id.ethz.ch

***** Educational Technology Services, University of Berkeley, 9 Dwinelle Hall,**
Berkeley, CA 94720
USA
Email: adam@media.berkeley.edu

ABSTRACT

Since its formation in 2007, Opencast has become a truly global community around academic video and its related areas. One of Opencast's major projects to emerge from the community, Opencast Matterhorn, will be presented here. Matterhorn is a community-driven collaboration to develop an end-to-end, open source solution that supports the scheduling, capture, managing, encoding, and delivery of educational audio and video content and the engagement of users with that content.

Keywords: Lecture Recording, eLectures, Web Lectures, Podcast, Webcast, Media Management

1. INTRODUCTION

On November 14, 2008, the U.S. President-elect Barak Obama made history by recording the Democratic Party weekly address on YouTube. "We're living," said Ellen Miller of the Sunlight Foundation, "after all, in the Internet era. This is an individualized version of the 'fireside chats.' It's not delivered between 7 p.m. to 8 p.m. but whenever anyone wants to see it." The 2008 U.S. presidential election was the tipping point for internet video, demonstrating its indisputable power to communicate powerful ideas and transmit culture. The Obama campaign understood the need to go where the people were.

Universities also want to go where the learners are to share their rich scientific and intellectual knowledge beyond the walls of the academy and to expand the boundaries of the classroom. This desire

has become a critical need, as the worldwide economy calls for advanced education and training through unconfined access to learning resources.

For more than a decade, a small group of international universities has pioneered the promise of accessible knowledge and has strived to realize this promise through the capture and distribution of lectures. However, it is only in the last five years that quantity, quality and use of the recordings has reached a level that makes lecture recording and video management a topic of strategic importance for universities.

On the one hand, eLectures, otherwise known as web lectures, lecture capture, and podcasting, have emerged as a key element of universities' learning portfolios. From an institutional perspective, they are a core element of teaching content, documenting the full range of academic knowledge as well as highlighting first-rate teaching and research efforts through the recording of conferences and workshops. Due to technological developments, they are easy to produce and distribute, making them omnipresent in the full variety of online channels utilized by students. They extend the outreach of the university to remote learners in different regions, countries, and time zones (Lauer and Ottmann, 2002, Hermann et al., 2006, Krüger, 2005). From a student's perspective, they enable learning anytime from anywhere on any device available, thus meeting the demands of their busy schedules.

On the other hand, the increased importance of this domain for academic institutions has lead to a more critical analysis with respect to the way the content is being produced, managed, and distributed. Through many years of experience, some institutions have realized that their home grown solutions cannot keep up with the constant innovation within the lecture capture domain, and their dwindling budgets limit their ability to aquire expensive commercial products .

2. FROM PODCAST TO OPENCAST

Applications and research in the field of lecture recording have grown exponentially across the world. Particularly in German-speaking countries, applications have existed for quite some time now. The E-Chalk project (Friedland et al., 2004) is a system to transform the lecturer`s input on a large touch-sensitive screen into an intelligent electronic chalkboard (e.g. process handwriting input of the user). The lecturer's audio and board strokes are combined and recorded automatically. Another approach presented in (Hürst and Deutschmann, 2006) focuses on the development of a lecture recording search engine for academic content. Also, a number of universities discovered podcasting as an easy distribution method for lecture recordings (Hürst et al., 2006, Michael-Brian, 2009).

A prominent outcome is the emergence of a number of systems to easily capture, distribute, and engage with lecture recordings (Hürst et al., 2006). The virtPresenter lecture recording framework (Mertens et al., 2007) focuses on the automation of lecture recording production and the presentation of the recordings through highly adaptable Web 2.0 user interfaces accessible in social environments and other distribution channels. ETH Zurich's REPLAY (Schulte et al., 2008) automates lecture recording and content indexation resulting in user interfaces that accesses isochronic metadata. Another interesting example for an automated lecture capture system can be found in the work done by Peter Ziewer (Ziewer, 2006).

For the most part, these systems and technologies were originally introduced as research projects and evolved to meet local institutional or academic needs; none of them, however, achieved the critical mass of users and/or developers to become a focal point for collaborative work in this domain, thus lagging behind the status quo in research around audio and video (rich media analysis, user interaction research etc.). In the commercial domain, proprietary technologies provided academic institutions with an interesting alternative, especially with iTunes U[1] and YouTube EDU[2] providing distribution platforms to

1 1 http://www.apple.com/education/itunes-u/.

exploit the increasing abundance of this content. Although these platforms furthered the visibility and increased the usage of eLectures, academic institutions became dependent on these commercial offerings at the expense of integrating innovative concepts – based on technologies developed at the very same academic institutions. To counter this trend, an alternative concept, Opencast, was introduced by UC Berkeley to explore an open source alternative to the production, distribution, managment of and engagement with audiovisual content. Opencast recognized the numerous academic efforts emerging from isolation, and created a landscape on which institutions can combine efforts and increase innovation around one project – Opencast Matterhorn.

3. OPENCAST PROJECT AND OPENCAST COMMUNITY

The Opencast Community is open to all interested institutions and individuals including commercial stakeholders. The Opencast mailing list[3] and infrastructure has fostered the exchange among institutions over various issues around academic video, such as codecs formats and licensing. Notable initiatives, such as the drive for a common metadata standard (cf. paragraph "Metadata") and Open U[4], a free non-commercial alternative to iTunes U, have thrived with the support of Opencast. But, at the moment, the most impactful Opencast effort is the Opencast Matterhorn Build Project (descibed in the next section).

Since its onset, approximately 600 institutions have officially expressed interest in Opencast and more than 500 persons have joined its mailing list. The Opencast Matterhorn project has maintained strong interest in the US, Canada and Europe from its inception. FIGURE 1 depicts data based on a Matterhorn pre-release survey launched in December 2009 via the Opencast mailing list and other related communication channels.

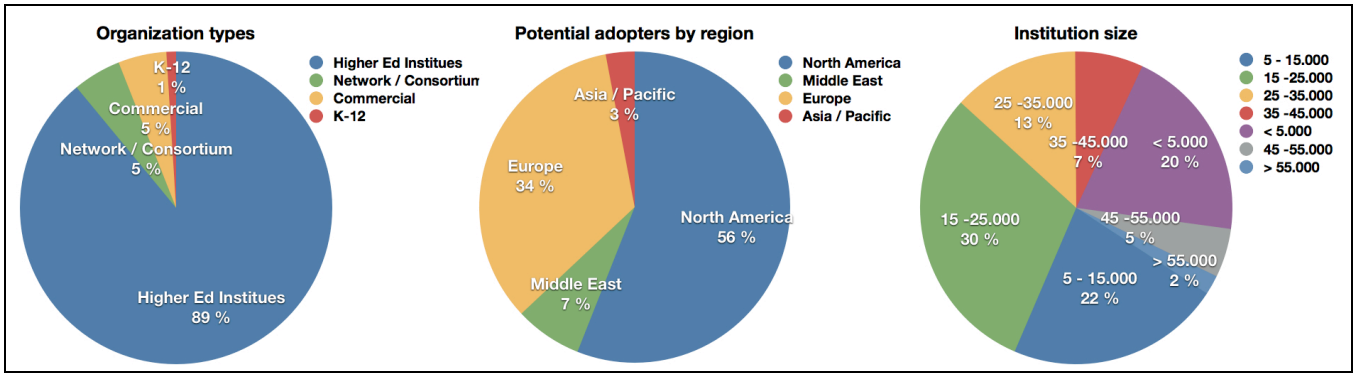

Figure 1: Opencast Community – Organization types, adopters by region and institution size

Organization types: The distribution reflected in FIGURE 1 left hand side emphasizes the strong participation from higher education institutions. While not being exclusive to other types of organizations, it is fair to say that the basis of Matterhorn stems from academic institutions' needs. Nevertheless, the growing interests of commercial entities and consortiums play an important role in the ongoing development and sustainability of the project.

Potential adopters by region: The Opencast Matterhorn project has maintained strong interest in the US, Canada and Europe from its inception (FIGURE 1 mid). The original 13 partners that came together for the grant-funded effort (more information in next section) were almost equally divided between North America and Europe. So while we knew that these regions would hold the most adopters, we were a little surprised to find the scales tipped more towards Canada and the US.

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2 2 http://www.youtube.com/edu.

3 http://lists.opencastproject.org/mailman/listinfo/community.

4 http://www.participatoryculture.org/.

Institution size: The data in the above chart (FIGURE 1 right hand side) was obtained through Carnegie Classification[5] for Institutions of Higher Education data for US institutions and from wikipedia for other international institutions. Student enrollment ranges from a small campus in Pennsylvania (US) with 680 students to a very large distance education university in Spain with 180,000 students. The vast majority of interested institutions enroll under 35,000 students (72%), with a fairly equal representation within the categories of <5,000 students, 5,000-15,000 students and 15,000-25,000 students. This data suggests a higher contigent of large universities than what we expected, especially as our initial surveys identified smaller institutions as our prime target group with a small podcasting program in place and limited resources. With the project approaching the 1.0 release and beyond (see section 5. Project: Milestones and Roadmap), we expect to find a growing base of adopters representing smaller schools. These are the institutions that would benefit the most from an open source lecture capture solution.

OPENCAST MATTERHORN – THE COMMUNITY SOURCE BUILD PROJECT

In 2008, the active core of the Opencast Community consisted mainly of universities who had already developed their own solutions for the management of lecture recordings and/or other audiovisual objects.

VirtPresenter[6] of the University of Osnabrück, REPLAY[7] of ETH Zurich, PuMuKIT[8] developed at the University of Vigo, and the Recollect system from the University of Saskatchewan existed as standalone software solutions, whereas UC Berkeley's "Webcast Next Generation" incorporated Podcast Producer like many universities do these days. However, the evaluation of these programs and the discussions conducted within the framework of the Opencast Community had shown that none of the systems offered the range of functionality universities desired. In addition, analysis of commercial systems showed smaller institutions especially were not able to afford the technology offered by systems like Echo360 or MediaSite[9], in light of the growth anticipated and the additional fees most licencing models imply.

To fill this gap, Opencast Matterhorn was launched as Opencast's first community source project. Matterhorn is a collaboration between North American and European institutions, funded by the Mellon and Hewlett foundations. This collaboration strives to meet the needs of the Opencast Community and ensure Matterhorn's continuity after financial support has ended.

To this effect, the following 13 partners operate under the name of "Matterhorn Partners": UC Berkeley, ETH Zurich, University of Nebraska-Lincoln, University of Osnabrück, Northwestern University, Cambridge University, Indiana University, University of Vigo, University of Catalonia, University of Saskatchewan, University of Copenhagen, University of Toronto, and Jozef Stefan Institute. As a matter of principle, the Matterhorn Project is open for collaboration with any interested persons and institutions. The project's governance model of "meritocracy" means that the role and influence of the participating institutions are predicated exclusively on their contributions. Key access points are the project's mailing list, wiki, issue tracker, code repository, and public virtual meetings that are recorded and documented.

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5 http://classifications.carnegiefoundation.org./

6 http://www.virtpresenter.org.

7 http:// www.replay.ethz.ch.

8 http://www.pumukit.uvigo.es.

9 http://www.echo360.com/, http://www.panopto.com/, http://www.sonicfoundry.com/.

4. OPENCAST MATTERHORN

Matterhorn 1.0 offers a simple open source reference implementation of an end-to-end enterprise lecture capture suite and a comprehensive set of flexible rich media services. This release will consist of a primary package that includes the scheduling, capture, encoding, and delivery of recordings to multiple distribution channels. The release package will include installation documentation, virtualized images, and/or operating-system specific installation scripts to ensure that Matterhorn installation is a straight-forward procedure for a moderately technical system administrator. The Matterhorn 1.0 capture infrastructure includes no hardware but will include a set of specifications for institutions with no existing infrastructure. Scheduling services, capture scripts, and inbox monitoring will allow institutions with capture systems already in-place to easily integrate with Matterhorn's infrastructure. The project's Service-oriented Architecture (SOA) approach will enable institutions to flexibly deploy the services to help them meet their needs now and into the future, regardless of the size and scope of their resources - from the large research university to the small liberal arts college.

UNDERLYING TECHNOLOGIES

The members of the Opencast Community have selected Java as Matterhorn's primary programming language to develop most of the necessary applications and SOA (Barry, 2003) infrastructure. The overall application design is highly modularized and relies on the OSGI (dynamic module system for Java) technology. The OSGI service platform provides a standardized, component-oriented computing environment for cooperating network services. Matterhorn is architected to be as flexible and open as possible and further extensions should not increase the overall complexity of building, maintaining and deploying the final product.

To minimize the coupling of the components and 3rd party products in the Matterhorn system, the OSGI technology provides a service-oriented architecture that enables the system to dynamically discover services for collaboration. Matterhorn uses the Apache Felix[10] implementation of the OSGI R4 Service Platform[11] to create the modular and extensible application. Matterhorn provides getting started guides and additional information for developers on the public project wiki-page[12].

The tools and frameworks available for enterprise Java development have evolved rapidly in recent years. Traditional J2EE containers have become more modular, leveraging the POJO-style development pioneered by the Spring framework. The Matterhorn developer team is aware of the emerging trends in the J2EE ecosystem to make pragmatic tool and framework choices. Some of the open source products and tools that are being used in the reference implementation are: OSGI Containers (Felix), JCR Implementations (Jackrabbit), Web services frameworks (Axis2, CXF), Persistence (JPA), UI development (HTML, JavaScript, FLEX, XSLT), Unit acceptance testing (JUnit, EasyMock, QUnit, FlexUnit, Selenium), Logging (JCL, Log4J), Media transcoding (ffmpeg), Streaming server (Red5), Build systems (Maven).

THE MATTERHORN WORKFLOW

FIGURE 2 exemplifies four typical Matterhorn workflow phases. The following subsections explain the phases and related services in this workflow in more detail.

10 http://felix.apache.org/site/index.html.

11 http://www.osgi.org/Main/HomePage.

12 Opencast documentation: http://wiki.opencastproject.org.

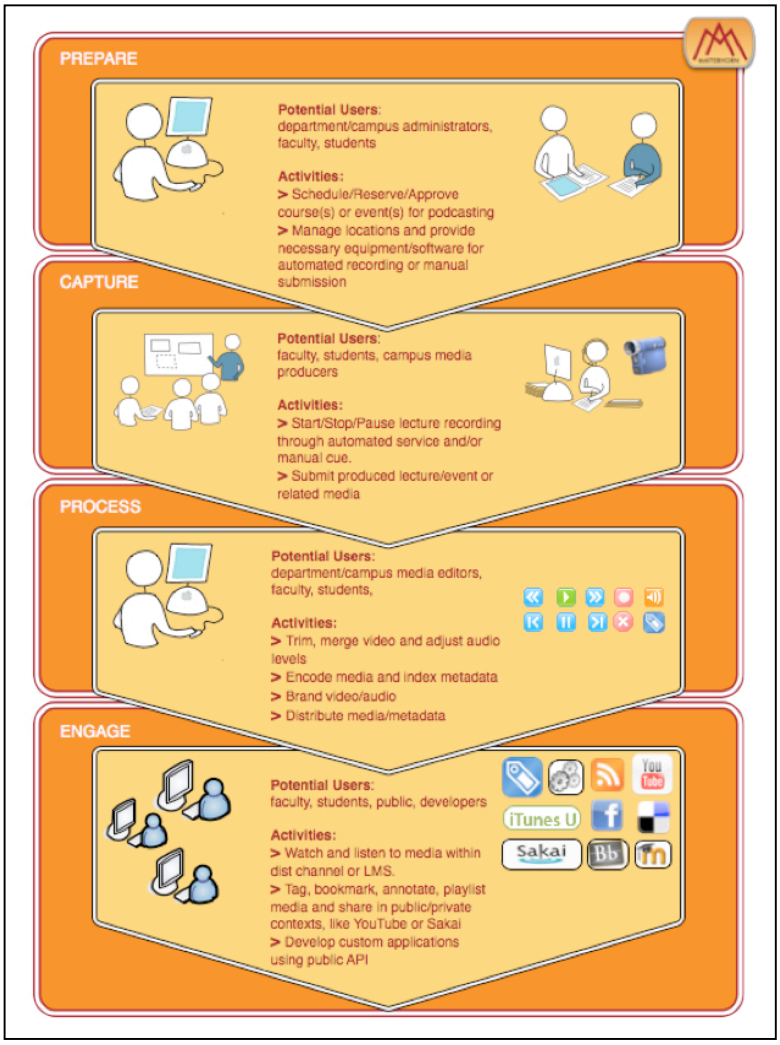

Figure 2: 4 Phases of the Matterhorn Workflow

Prepare/Schedule and Capture

The recording process begins by determining what is to be recorded, where and in what form, including metadata and parameters for distribution and the associated formats. Campus data will be integrated by the universities' IT departments. For this purpose, Matterhorn will be open to both the learning management systems and administrative databases. Syllabi, lecture, and room timetables will allow for the access to information necessary for scheduling (room, time etc.) as well as most of the metadata related to the recording (title, summary, language etc.). Recording devices are then scheduled to automatically record in lecture hall X.26, every Tuesday from 10:00 c.t. to 12:00, the lecture on "XYZ" by Prof. ABC.

Process

At the end of the recording the capture agents send tracks to an "inbox" for them to be processed. The different recording tracks (audio, content, video presenter, video presentation) are bundled to a media package, content-indexed (at first through optical character recognition of the slide, later through audio recognition also). They are encoded according to the specified distribution parameters.

The inbox also serves as "ingest" for video objects not coming from a capture agent to be integrated in subsequent workflows of Matterhorn. At most institutions, user-generated content, image films, or digitalized historic recordings would constitute only a small percentage of the overall repository (in

contrast to the rapidly increasing number of lecture recordings), but Matterhorn nonetheless offers a uniform solution for all audiovisual materials, in order to serve as a "video management system" to academic institutions.

Media Analysis

Afterwards, the media is bundled into a media package. A media package is considered the business document within the Matterhorn system. Besides the media objects, it includes further information from media analysis as well as metadata. Every media package therefore consists of a manifest and a list of package elements that are referred to in the manifest. Package elements are media tracks (audiovisual material; movie container), metadata catalogues and further attachments (slides, pdf, text, annotations). Services are planned to modify media packages (update metadata, change attributes). A media package manifest as well as service description can be found online in the project wiki documentation[13]. Media analysis helps to implement not only basic navigation features for engage applications (e.g. slide change, chapters) (Ketterl et al., 2007), but by indexing slides as well as (English) audio, media analysis provides a rich source of isochronic metadata to be utilized by other applications and technologies. Stored in MPEG-7, this metadata is the basis for the searchability of the video and its subsequent accessibility. REPLAY from ETH Zurich as well as different research projects have demonstrated the successful use of this technology (Breuel, 2003, Breuel, 2008). For its further development, Opencast Matterhorn is looking forward to benefit from work of the OCRopus[14] group for document analysis and OCR, Sphinx-4-related research[15] for speech recognition (Walker et al., 2004).

Distribution

The distribution demands of the universities are extremely heterogeneous: they go from simple integration of the videos to local blogs, to posting in password-protected LMS (Learning Management System), to distribution via iTunes U or YouTube. Here, the distribution module must be able to cope not only with the heterogeneous distribution formats (RSS, Atom, Web service interfaces), but also with the recording formats specified at the beginning (cf. “Schedule/Prepare & Capture”) which must be transmitted in homogeneous form to external services and platforms. In addition, the distribution channels will re-transmit the information necessary for statistical analysis and user data (e.g. most popular video).

Likewise, support of learning LMS or Virtual Learning Environments (VLE) is an important issue for the acceptance of the project. To make sure that the produced material will be used in a variety of environments, Matterhorn video and audioplayer components may be easily integrated into existing course websites, wikis, and blog systems. Just as in the distribution module, collection of user statistics must be supported and the virtPresenter project will be leveraged as the baseline for the engage and statistic applications (Ketterl et al., 2009).

Engage

Although Distribution and Engage modules are closely linked together since both must manage presentation and use of the objects, applications in the Engage module make it possible to use comprehensive information (metadata, video and audio analysis, annotations, use analysis) for intelligent user interfaces.

Social annotations (Waitelonis and Sack, 2008) which can be used to improve search or navigation and feedback possibilities will also flow back to the system like the user statistics already mentioned.

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13 https://opencast.jira.com/wiki/display/MH/MediaPackage+Manifest.

14 http://code.google.com/p/ocropus.

15 http://cmusphinx.sourceforge.net/sphinx-4.

A major requirement in the Matterhorn specifications is (multimedia) accessibility. Matterhorn applications must support assistive technology to engage with users. In particular, time-based multimedia content needs to be presented and enumerated in a way that does not exclude students with a disability. Components must be designed to support captions, screen readers and keyboard navigation. Not all channels, external systems and platforms will be supported with the release of Matterhorn 1.0, but the open architecture should make it possible to create interfaces to existing systems. Overall, the possibility of integrating existing applications with Matterhorn is one of the main objectives of the planned architecture.

Content distribution and Engage Applications

In order to bring the content to the users, Matterhorn will include web and streaming server solutions for media and content distribution. At the moment, open source applications are being evaluated and tested. In addition to the open source streaming server applications Red5 or Mammoth, the corresponding web server applications such as Lighty or Apache with mod_H264 support are also being evaluated for use. Naturally, apart from the SWF-FLV video format, other formats will also be supported (e.g. MPEG-4, WMV, podcast variations, HTML5 etc.).

In the Distribution and Engage modules, the exchange of information takes places over service interfaces. Data is requested over SOAP or REST and transmitted and processed in form of JSON, XML, ATOM or RSS messages to the relevant components. For the intelligent user interfaces, Flex programming will be used for the most part in conjunction with Ajax technologies. The virtPresenter system from the University of Osnabrück will be the main source for the development in this area (Ketterl et al., 2009).

Metadata

While the indexation of slides and audio provides much of the isochronic metadata to search the video, static metadata is still needed to describe and classify the object – and to facilitate its exchange across institutions. While this domain calls for different areas to be covered (standards like LOM/ IEEE 1484.12.1- 2002, protocols like OAI-PMH or technologies like SRU/SRW14), the Opencast Community has taken the first step to work on a metadata scheme describing academic video and recorded lectures in particular[16].

LICENSE AND MISCELLANEOUS

Matterhorn will be published under the Educational Community License (ECL) 2.0 developed by UC Berkeley, a license based on Apache 2.0 licencing which takes into account certain particular needs of academic institutions. The software will be developed using Agile software development methodologies to be able to cope with the project's relatively short duration and a team dispersed over two continents. For the project management, the Atlassian products[17], Confluence (project management) and Jira (issue tracking) are being used.

5. PROJECT: MILESTONES AND ROADMAP

The project officially was launched on July 1st 2009 and will be funded through January 1st 2011.

Alpha Release 0.5 (February 2010)

The 0.5 alpha release of Opencast Matterhorn offers a preview of Matterhorn's capabilities, primarily the basics to capture, encode, distribute, and play media. The release included an accessible media player, lecture capture automation, an inexpensive media capture appliance, and introduced a flexible workflow service for media transcoding, and content distribution.

16 http://www.opencastproject.org/project/metadata.

17 http://www.atlassian.com/.

Services stabilization and advanced functionality (May 2010):

The 0.5 alpha release represents only a minor subset of what is planned for the 1.0 release. From February through May, the project will make major code improvements which include further improvements to capture and administration (capture "confidence" monitoring, media review tools, scheduling of recurring events), media ingest and processing (threaded workflow management, multiple database support), distribution (iTunes and YouTube distribution service), and content usage in the engage applications (list of available recordings, multi-stream player to watch slides and video simultaneously, navigating recorded lectures by slide changes and timeline segmentation).

Release 1.0 (July 2010):

The project's remaining time will focus on optimization of Matterhorn's services/applications as well as documentation for deployment of and development with Matterhorn. The other areas of focus are:

- multi-stream support
- "in video search" capabilities for the media player
- capture agent encoding optimization
- integration of 3rd party captioning tools
- UI optimization and scalability
- Multi-server deployment

Production Ready (July – October 2010)

The project will continue with a smaller funded effort to address any core issues that arise from the community's assessement of 1.0. Matterhorn adopters will determine whether it easily deploys, integrates with existing sytems, and performs and scales well in a variety of contexts. Any requirements stemming from the adopter's efforts will be considered of the highest priority, and will be taken on by the funded effort immediately. There will be partially completed features, such as captioning, distribution to iTunes/Youtube, bookmarking video, media trim tools, media player feedback service, that did not make it into 1.0 due to lack of testing or resources that will also be considered essential near term development.

Transition and Enhancement (October – December 2010)

As Matterhorn moves into production on many campuses, development efforts will continue to enhance Matterhorn and will derive from previously documented requirements as well as emerging requirements from the community. Funded project resources will not only focus on these development efforts, but will establish a wider pool of knowledgeable technical staff who can participate in an ongoing and robust open source support model. Individuals and institutions beyond the original project members will become key contributors and the heart of Matterhorn's long term success.

OPENCAST MATTERHORN WELCOME

FIGURE 3 depicts the Matterhorn welcome page that is beeing loaded after a successful installation of the software. The development team includes all necessary information needed to start to use and understand the system and its architecture by providing links to documentation, service endpoints or release notes. The welcome page and parts of the documentation are being generated after every new successful code commit and build. This implies that interested groups can join and test the software without waiting for the next official release.

Figure 3: Opencast Matterhorn welcomes early climbers

6. INTEGRATING EXISTING APPLICATIONS, RESEARCH, AND DEVELOPMENT

As mentioned before, the Matterhorn consortium brings together a range of partners with different focuses and strengths in the process of recording and distributing lectures. The SOA concept and the fundamental understanding that a monolithic system cannot satisfy the heterogeneous needs of international universities play a key role in attracting other universities and research institutions to participate in the project, especially those who already have their own system or relevant applications with respective strengths. Beyond providing a crucial media bootstrap to academic institutions, Matterhorn hopes to provide an innovative research environment for rich media applications. With academic research initiatives focused on media analysis (e.g. speaker recognition), semantic technologies (from media objects to re-useable learning objects (McGreal, 2004, Chen, 2009)) and adaptive user interfaces, the research community will thrive in the Matterhorn environment. Matterhorn will benefit from these technological advances, as will its users, universities, and students. Matterhorn and the Opencast Community can offer research initiatives a prolific environment with a multitude of partners and a technology developed to be adapted, amended or supplemented by new features, be that voice recognition, face detection, or support for mobile devices. The final objective is to ensure that research initiatives will consider Matterhorn a focal point for their activities.

7. PROJECT PROSPECT AND FUTURE PLANS

After Matterhorn 1.0 is released in July 2010, Matterhorn will transition from a grant funded community source initiative to an open source effort. Several post 1.0 efforts will ensue:

Community: "Scaffolding" (July 2010- July 2011)

A core group of resources will provide ongoing support and continuity to the Matterhorn community as it transitions from a funded to unfunded effort.

Deployment: "In Production" (July - October 2010)

15 core institutions will deploy Matterhorn on their campuses by October 2010 and tackle general integration challenges such as authn/authz, CIS data, and LMS distribution.

Matterhorn 1.5: "Patches Plus" (July - Feb 2011)

A coordinated effort to ensure that Matterhorn is "enterprise ready" in that it will be reliable and secure, as well as easily deployable and performant.

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