Lecture Recording – a Success Story

Lecture Recording – vom Experiment zum Hochschulalltag

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Summary Today, digital recording of live lectures is a common practice at many universities. This article provides an historical overview of this idea, from the first approaches starting 40 years ago to present-day systems and questions still subject of research.

▶▶▶ **Zusammenfassung** Die digitale Aufzeichnung von Vorlesungen ist heute an Hochschulen Alltag. Der Beitrag beschreibt die 40-jährige Entwicklung dieser Idee von den ersten Ansätzen bis zu aktuellen Produkten und heute noch offenen Fragen.

Keywords ACM CCS: Applied Computing → Education, e-learning, distance learning, digital libraries and archives ▶▶▶
Schlagwörter E-learning, Fernstudium, digitale Bibliotheken und Archive

1 Introduction

As early as 1970, first experiments aimed to record university lectures and to transmit them to remote locations. In the 1990s, research on that field focused on tools and methods for the effective and convenient creation of learning material out of a live presentation, including digital slides, handwritten annotations, voice, and video of the lecturer [23; 55]. Since then, many prototypes have found their way into full-fledged products available on the market. The recording of lectures and presentations is part of the daily routine of many universities nowadays so that even entire curricula are based on recorded lectures. Trends like online videos, podcasting, and initiatives like *Massive Open Online Courses* (MOOCs) have increased the interest in presentation recording even more.

With respect to the innovation curve of Rogers [49], we locate lecture recording in the phase of the "early majority" at present. Thus, we still expect some development (in terms of diffusion and technical progress); the research field, however, has reached its main objectives. In this article, we will give an overview of the 40-year history of lecture recording and its state of the art[1]. The overview is organized along the phases of the innovation curve. There is a certain bias towards European and in particular German research projects and their environment. However, in our opinion the main focus of activity and most of the seminal work indeed took place there.

2 Innovators: Visions and Basic Concepts

2.1 First Approaches

On December 9, 1968, long before the introduction of the personal computer and the Internet, Douglas Engelbart transferred his conference talk as online-video – presenting his latest invention, the computer mouse.[2] In the following decade some universities regularly videotaped talks and lectures as (S-)VHS video. For example, Stanford University used to distribute videotapes with lectures

[1] This paper contains ideas and topics which have been presented by Thomas Ottmann at a keynote speech at the conferene DeLFI 2012 in Hagen.
[2] http://sloan.stanford.edu/MouseSite/1968Demo.html

of famous researchers worldwide.[3] Also at Karlsruhe University, a "video lecture" on programming methodology took place in a classroom with a fixed schedule. Since the 1970s analogue lecture recording, media content production and even educational TV programs were commonly practiced.

With the upcoming personal computer in the 1980s, the vision of computer-based learning became popular. Interaction with a computer was intended to substitute the communication of a learner with a human teacher. So called "intelligent tutoring systems" are typical of this period. Because the programming of a particular learning system for a certain subject turned out to be expensive, high hope was put in the development of easy-to-use and universal authoring systems. An early example is the teletext terminal *MUPID* together with its authoring tool *Autool*. The *COSTOC* project (Computer Supported Teaching of Computer Science) [41] produced the content of nearly 50 lectures as instructional learning programs with these tools.[4] Unfortunately, even with authoring tools supposed to be simple, most universities could not afford the expenses to implement lectures as learning programs in a larger scale. Therefore digital learning material was considered more as a supplement to traditional lectures, rather than an equal alternative at that time.

2.2 Lecture Recording and Synchronous Transmission

In the 1980s the Fernuniversität Hagen was using videotelephony and television for industrial trainings. As the Internet evolved as a medium for communication in the beginning of the 1990s, the *MBone*-tools (multicast backbone) showed up at some universities [15]. In the first place, MBone was designed for transmitting audio, video, and whiteboard streams over the Internet. It could also serve as a recorder if the data packets were not only sent and received, but also stored for future re-transmission on demand. The MBone software whiteboard *wb* replaced a blackboard. Together with a large interactive projection board, e. g., by SMART Corporation[5], it provided a convincing computer-based implementation of the blackboard-and-chalk paradigm.

Lecturers prepared their slides with a special editor and presented them with the *wb* on a SMART-Board[6] using a digital pen for annotations. All those data streams were transmitted over the MBone network to a group of receivers. Furthermore, the presenting computer or one of the receivers had the possibility to store the transmitted data packages as a recorded presentation. Among others, the universities of Freiburg, Karlsruhe, and Mannheim improved the software tools and established a regular exchange of lectures among their partners [2; 4].

Organizational and coordination issues of common lectures between multiple universities prevented the establishment of synchronous lecture transmissions to become really popular, in spite of continuously improved hard- and software, limitations of network capacity reduced to a minimum, and several successful events proving the concept. By transmitting lectures, students had the benefit of the flexibility to watch the lecture distantly or later. At that time, there was no didactical advantage over a lecture in the classroom (which was actually never intended).

In spite of never becoming mainstream for regular courses, the paradigm of synchronous lecture transmission has found its place for special events and in form of *webinars* using web-conference systems where lecturer and auditory participate over their PC.

2.3 Lecture Recording and Time-Independent Distribution

During the 1990s research focused less on the broadcast but more and more on optimizing the recording quality as well as on formats appropriate for distribution to the students. In this way, lectures should not be only independent of the location, but also of time. Moreover, the aim was not only to transfer the blackboard-and-chalk paradigm from the lecture room into the digital world, but also to produce a clear user benefit over a simple videotape and, if possible, even over the participation in the live-event.

Another innovation driver was the spread of a new presentation style: more and more *PowerPoint*- or *PDF*-slides replaced blackboard and overhead projector. Hence, avoiding any media discontinuity, it was easier to include other digital material like video, animations, simulations, and web pages in the presentation. With the introduction of digital whiteboards, pen-sensitive displays, and tablet-PCs, dynamic annotations became more and more important. This raised the challenge to merge all those data streams in the recording as well. It turned out that audio, slides, and annotations transport the most important information. At least in computer-science teaching the video of the lecturer – the "talking head" – seems not to contribute much to the understanding of the content [18; 20].

Obviously, lecture recording depends on the expertise of lecturers, often gained over many years. High-quality multimedia documents preserve the personal style of the lecturer without an intermitting media production process.

Among the first projects of the 1990s were *Authoring-on-the-Fly* (short AOF) [e. g. 3; 36; 45], *Classroom 2000* or *eClass* [1], and *Liveboard*, developed at Xerox PARC [13]. Later, several others emerged like: *e-chalk* at FU

[3] One can find e. g. lectures of D. E. Knuth from the early 1980s, now digitized, under http://scpd.stanford.edu/knuth/index.jsp.

[4] There are still relics on the web: http://www.db.informatik.uni-kassel.de/Lehre/prev/unix/costoc.de.html comprises besides the original programs an HTML-Version of a COSTOC-course on Unix, http://much.iicm.tugraz.at/projects/costoc_2/index.htm/ gives general information on the project.

[5] http://smarttech.com/

[6] http://smarttech.com/smartboard

Berlin [26], *tele-TASK* (Teleteaching Anywhere Solution Kit) at Trier University and today at Hasso-Plattner-Institut [52], the *TeleTeachingTool* at Trier University and TU München [57] and the *virtPresenter* at Oldenburg University [43].

2.4 Basic Principles of Lecture Recording

These projects developed different methods which can be classified in three main approaches: screen-grabbing systems, VCR-recording, and object-oriented recording. To some extent, the borders between the classes are blurred and there are hybrid systems combining several methods.

Systems based on *screen grabbing* (or *screencasting*) regularly store snapshots during the presentation of the whole screen or a defined area on it. At the same time the audio is recorded. Both streams are merged and transformed into one synchronized digital video. One of the first products of this kind was Lotus/IBM *ScreenCam*[7] released in the beginning of the 1990s. Contemporary products are *Adobe Captivate* and *Presenter*[8], *CamStudio*[9] or *Camtasia*[10] by TechSmith.

VCR-recording captures the video signal, taking place between PC and the monitor or projector. In contrast to screen grabbing the recording computer is usually not the same as the presentation computer; hence there is no need for any installation of special software on the presentation computer. A popular example of such a product is *tele-TASK* [52].

In contrast to the methods described so far, the *object-oriented* approach (e. g. found in the AOF system and later in *Lecturnity* by imc[11]) preserves the symbolic representation of the source data. During the presentation all data-streams are *separately* recorded and stored, transformed into different output formats if necessary, and then adapted to the replay device. In the final step, the separated streams are synchronized and rendered for replay. The object-oriented method provides for the following features:

- A media-stream, e. g. the audio or slides, may be separately edited *after* the recording.
- Structural information, like slide changes, are obtained automatically.
- Full-text search within slides can be implemented straightforwardly.
- Symbolic information, like vector graphics, may be rendered for different display sizes without loss of quality.

However, as a disadvantage, special software must be installed on both, the recording and the replay computer.

Besides the main research on lecture recording, additional features have been explored, e. g. the automatic evaluation of math formulae in *e-Chalk* [26] and the quick browsing of video files [25]. For students or teachers such features yield an added value compared to a traditional lecture.

3 Early Adopters: Lecture Recording for Large-Scale Content Production

In the second half of the 1990s, politics became interested in the "new media". According to Tsichritzis [56], a university should not rely on live-performances alone like a renaissance quartet. Rather, it should learn the lesson from the music industry and build an institutional memory of all the knowledge produced by lectures day by day. Due to shrinking state budgets, the focus was primarily on better efficiency [14], but hopes were high that this trend would open new ways to improve the quality of recording techniques too.

As an early example – and the first among the German-speaking countries – the German state of Baden-Württemberg funded a major project in order to speed up the technological development and to motivate necessary organizational changes at universities,[12] followed by many other states [27].

Around the year 2000, many universities recorded and archived lectures as a routine. An interesting initiative aimed at the synergy of cooperating universities: 12 universities joined the project "Universitärer Lehrverbund Informatik – ULI", giving their students virtual access to all lectures on computer science. Lecture recordings played a leading role, complemented by local tutorials in a classroom, if applicable. Again, the sustaining success of this initiative failed not because of technical issues but through problems in coordinating the curricula and formally accrediting student performances [28].

Nevertheless, based on the broad experience gained in the funded projects, the technology for lecture recording has since permanently improved. Consequently, people became aware of the added value of digital educational content related to the usage of lecture recordings, among others, group discussions, group learning, and graphical user annotations made during replay [37; 54].

We do not want to conceal the sometimes vehement criticism on lecture recording from a didactical point of view: instead of using the potential of didactically well-made learning software, the lecture recording projects would perpetuate once again the questionable scenario of a lecture in the digital world. However, especially in the systematic sciences such as physics, computer-science, mathematics, and engineering, the lecture has always been an indispensable part of university teaching. The success of lecture recording clearly has shown that this approach can essentially contribute to more flexible studies and that entire curricula can be followed independently from time and place, if sufficient support by (online) tutors

[7] http://www.smartguyz.com/

[8] http://www.adobe.com/de/products/captivate/ and http://www.adobe.com/de/products/presenter/, resp.

[9] http://camstudio.org/

[10] http://www.techsmith.de/camtasia.asp

[11] http://www.lecturnity.com

[12] "Virtuelle Hochschule Baden-Württemberg – VHBW", 1998–2003, ca. 25 Mio. EUR

is provided. After all, one of the fundamental ideas of lecture recording is to organize the instructional part of teaching cost efficiently, in order to move the focus and the resources on supporting the students whilst actively constructing knowledge.

4 Early Majority: Lecture Recording as Routine Service Today

4.1 Lecture Recording as a Service

Lecture recording is an everyday practice at many universities nowadays. The entire workflow, starting from the recording during the live-event up to the distribution in different formats, has largely been automated. A lecturer or an institution finds convenient products on the market. Besides the ones mentioned in Sect. 2.4 further examples are *Cisco Lecture Vision*[13], *Echo360*[14], *Tegrity*[15] by McGraw-Hill, *mediasite*[16] by Sonic Foundry and several VGA frame grabbers by Epiphan systems[17]. Their functionality and features have converged, irrespective of their basic technology. Interactive digital whiteboards and tablet computers enable handwritten annotations at an affordable price.

Service institutions of a university like computer centers or media centers have integrated lecture recording in their support portfolio and assist teachers with preparing, producing, and editing recorded lectures. Students intensively demand and work with recordings of a lecture, for instance, in order to prepare for exams [5; 8; 18; 50]. Advanced education programs based on recorded lectures find their customers [21].

4.2 Distribution: eLecture Portals, YouTube and Co.

The growing number of lecture recordings is managed by so-called *eLecture*[18] servers, enriching the media documents with metadata and convenient search-functions. Examples in Germany are Freiburg University[19] [19], tele-TASK portal[20], Hamburg University[21], Stuttgart University[22], Frankfurt University[23], TU Clausthal[24], the Multimedia Kontor Hamburg[25], openHPI[26], and many others. Examples in the United States are Harvard University[27], Massachusetts Institute of Technology[28], Georgia Tech[29], Trinity University[30], and Sonoma State University[31]. Other professional servers are *Mediasite* by Sonic Foundry[32], *Kaltura Mediaspace*[33], *Explore*[34], and *Mediacore*[35]. A more complete list can be found online.[36] While there is a market for recording systems, portals are most often proprietary developments.

The growing success of podcasts and videos on the Internet has opened very popular distribution channels for lecture recordings.[37] While during the phase of early innovators recorded lectures sometimes did not even count as "real" e-learning, they are now one of the most prospering areas using platforms like *YouTube*[38], *YouTube EDU*[39] by Google or *iTunesU*[40] by Apple. Popular examples are the YouTube-lessons by Loviscach on Mathematics and Informatics, which are frequently consulted by pupils and students [40]. Lecture videos on a popular platform serve also as a promotion activity to attract new students [50].

5 Still to Be Done: Ongoing Research on Lecture Recording

As we have already mentioned, the pure technological aspect of recording and distributing lectures has shifted from an IT research area towards the state of production. This means that profitable and non-profitable organizations develop and offer commercial solutions for any purpose.

More recently, other areas inspired by or associated with lecture recording have become the focus of researchers all over the world. In this section, we describe two domains of research on eLectures, namely the didactical application scenarios and the retrieval of multimedia content.

5.1 Didactical Scenarios for Lecture Recording

Today there exist a substantial amount of studies on the effects of working with lecture recordings [e. g. 10; 50; 53]. Even though the evaluation scenarios are in general not comparable, they all show a demand for recorded lectures from the students. Besides the obvious facilitation of organization for learners, there is some evidence that eLectures can increase learning efficiency, i. e. same level of performance with less work [38]. Using e-Learning in general or eLectures in particular does not necessarily

[13] http://www.cisco.com/web/strategy/education/enhanced_edu_capture.html
[14] http://echo360.com/
[15] http://www.tegrity.com/
[16] http://www.sonicfoundry.com/mediasite
[17] http://www.epiphan.com
[18] We will also use the term eLecture in the following.
[19] http://electures.informatik.uni-freiburg.de
[20] http://www.tele-task.de/
[21] http://lecture2go.uni-hamburg.de/
[22] http://www.uni-stuttgart.de/online/dienste/aufzeich/
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[36] http://www.refseek.com/directory/educational_videos.html
[37] The Khan Academy http://www.khanacademy.org is a well-known educational website with more than 3.300 videos online.
[38] http://www.youtube.com/
[39] http://www.youtube.com/edu
[40] http://www.apple.com/de/education/itunes-u/

imply that the students get better results in a test, but suggests that other qualities and competencies of students are fostered, e. g. motivation, differentiated learning rhythm, and creativity [e. g. 9; 22; 46]. The fear that classrooms will remain empty if learners may learn from elsewhere has been proven wrong. There is only a limited decrease of attendance in the classroom, since most students still highly value the traditional lecture. The remaining part of this section should be read as a non-exhaustive list of ideas, principles, and best practices of eLectures as a didactical tool.

It is a general truth that some persons are more "visual learners", some need to read, and others prefer to touch something in order to assimilate new knowledge. Mostly, content that is presented in multiple forms, called "multimodal learning", is not only easier to understand for a broad majority of people, but also more attractive. However, it is still an open question whether there are learner types (based on psychological characteristics) who particularly profit from knowledge presented via lecture recordings.

A main goal of didactical scenarios for eLectures is to activate the students to construct knowledge. In particular, the discussion about the inverted classroom[41] argues strongly for a shift from the traditional lecture to a self-learning period and for saving the valuable time in the classroom for more discursive activities such as discussions or (collaborative) exercises [33]. Indeed, this has been the main motivation for the work on lecture recording years ago; move from a teacher centered knowledge transmission paradigm to a learner focused, explorative, and constructive learning paradigm. However, the concept of the inverted classroom generalizes the idea and supports it with didactical details.

Dyckhoff, Herding, and Schroeder [12] and Krüger [32] propose the use of recorded lectures within cooperative learning scenarios. A similar idea is realized outstandingly in *Massive Open Online Courses* (MOOC), which characteristically have thousands of participants (there are MOOC with over 100 000 learners).[42] Lecture recordings in a MOOC act as common ground for the learners but are not the main issue. Following a connectivistic approach, the courses are built upon exercises, the students' participation, discussion and construction of information [7].

Other possibilities are structured group discussions [54] and the compilation of printable lecture notes out of recordings, for example into a Wiki [17]. Furthermore, the partitioning of a recording into smaller units and the integration of interactive elements such as self-assessments can help to make the actual content more "attractive" and better understandable. Reinmann and Jocher-Wiltschka describe the didactical concept of an entire course using podcasts [47].

Integrating eLectures in social networks facilitates the usage outside the limits of a scheduled course. Learners can find similar lectures, which have been elected or are watched just now by "friends" [16; 29; 42].

After its success at the university, video (comprising lecture recordings) has found its way into secondary education as well [31]. As an example, Linckels, Dording, and Meinel report how 7th grade school students worked autonomously during 6 weeks in mathematics [38]. The kids asked questions in natural language to an *E-Librarian Service* on fractions. The system delivered one, the best, video in which they could find the answer to their question. In this experiment pupils played the role of an explorer.

5.2 Search and Metadata for eLectures

One of the major problems triggered by the success of lecture recording is to manage the huge amount of data and the search in large archives. For example, over 10 000 hours of lectures on computer-science are available at the tele-TASK online archive with some 30 hours of new material added weekly. This enormous amount of data makes the finding of requested information more and more difficult.

Since a recorded lecture is essentially a video (at least, if not rendered in an object-oriented format), search engines cannot process the actual content. Therefore, archives need to process meta-information such as title, keywords, or categories. These additional data can be generated manually by the author of the recording or automatically. For the latter, there is still no reliable solution.

Different techniques can be used for the recognition of semantic information within recordings. If applicable, characteristics from the transcripts of the lecture are used (e. g. PowerPoint slides). In this way, headings can be processed to automatically generate a table of contents. Another technique is the automatic detection of slide transitions. Finally, analyzing the audio data, i. e. the spoken information by the lecturer, has proven to be very useful [24; 48].

New approaches in the management of digital archives are based on semantic technologies. There are currently two different approaches. The first is about "social" Web 2.0 techniques that offer users the possibility to provide their own view and opinion on the lecture. This can be done for example by tagging the content with keywords (*tags*), grouping the content into categories given by the users (*folksonomies*), or adding general comments (*blog*). Search engines can take advantage of such information and calculate the statistical probability that the found lecture is an actual hit and satisfies the search request. For example, if 90% of the viewers were of the opinion that a particular video is about "IP addresses", then this information can be classified as reliable information for

[41] http://www.flipteaching.com presents a lot of material on the inverted classroom.

[42] Examples for MOOCs are Udacity http://www.udacity.com, Coursera https://www.coursera.org, edx https://www.edx.org, and openHPI https://openhpi.de/.

search engines. There are several online archives that rely on this form of user feedback, like *YouTube EDU*[43] or *TechNet Video*[44].

The second approach is based on techniques emerging from the *Semantic Web*. Here, metadata are represented in a structured form, such as RDF or OWL. This metadata are not provided by visitors but by experts in that field. The principle is that any application should be able to trust the metadata and to semantically reason over it, for example by using it in the context of an ontology. More precisely, search engines can infer the semantic distance between a user query and objects in the archive in order to compute which object should be yielded as best hit [39]. A pertinent vocabulary (i. e., set of elements) for the structuring of metadata is important so that search engines can "understand" the meaning of this information. The *Linked Data* [6] initiative heads exactly towards that direction and aims to provide bridges between existing vocabularies. The *Linked Open Data*[45] community project has hundreds of millions of RDF-links between resources. More and more search engines rely on this approach of representing knowledge and processing queries, for example *Yovisto academic video search*[46] [51] or *Linked Education Cloud*[47] [11].

5.3 Further Research Topics

Even though lecture recording has been largely automated, the subsequent steps from the recording up to the publication in a digital archive still require manual intervention. Ongoing projects such as *Opencast* have the goal to completely automate the entire process, using a flexible system [30]. Such promising projects try to figure out automatic solutions for different steps.

Another research topic is the "automatic cameraperson". Often lecture recording solutions work with one fixed camera. Either only the head of the teacher is visible all the time in the center or the video is shot in a total view. In both cases, long videos can become boring because of the static camera position. Otherwise, a person is required to keep the presenter in the focus of the camera. The automatisation of this task involves moving the camera in a way to always have the speaker in focus. A more challenging problem is to control multiple cameras, for example one focusing the speaker and a second one focusing on a student in the audience who makes a comment or asks a question [34].

Last, a topic should be mentioned which since the early MBone seems to be annoyingly persistent: the representation of handwritten information. The drawing produced by a digital pen often appears "shaky" as if written by a child and does not reflect the personal writing style. Also, digital handwriting cannot be resized or reduced without loss of quality. But it is already possible to smoothen and flatten the drawing by replacing it by a symbolic approximating curve. In this way, the personal touch of the lecturer is maintained during resizing without loss of information. There is still ongoing research yielding interesting improvements [44].

6 Conclusion

Today, the recording of lectures is a common service at many universities. Concerns of lecturers that classrooms remain empty if students can participate from home – live or later – were proven wrong. Some students prefer a rare or no participation in the lecture and instead rely on the recordings. Evaluation results provide sufficient evidence that it is a realistic option to prepare for a test and to assimilate new material only with the help of recorded lectures. Lecture recording has provided students as well as lecturers with greater flexibility and is often the only way to avoid scheduling conflicts.

Today, lecture recordings often replace course scripts and contain far more information than those presented on slides. Production, storage, and distribution of recorded material are not an issue anymore. The open question is how the digital content is used in an optimal way.

Finally, a large collection of recorded lectures also adds some kind of prestige for a university and provides new possibilities for advertising as well as for institutional knowledge management. In this way, universities can preserve particularly successful courses and make them public and accessible for all learners. Of course, the maintenance of such an archive requires efforts, as well as academic and legal expertise. These are the new great challenges for universities in the digital age.

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Received: April 18, 2013

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