Experiences and Challenges of building up an Open Source based Livestreaming System with Back Channel to implement a Hybrid Classroom Scenario

Herwig Rehatschek

Executive department for teaching with media, Medical University Graz, Auenbruggerplatz 2, 8036 Graz, Austria

Herwig.Rehatschek@medunigraz.at

Abstract. The set up of a hybrid scenario, where part of the students resides in the classroom and a part of the students resides at home, is a big challenge in terms of technical implementation but also in terms of skills required by the teachers. On the other hand, a hybrid scenario has many advantages. Advantages include flexibility for the students in terms of location independence, increase of the number of students attending lectures, and a possibility to increase student numbers without having the need to build new bigger and very expensive lecture rooms. In this paper will list the main key parameters having to be considered during planning and implementing such a scenario. How to select appropriate software and what requirements shall be considered. We will give our experiences with the open source software chosen for lecture recording and streaming and provide insight into the by us developed open source software components. Next to this, organizational measurements needed in order to successfully introduce a hybrid teaching scenario at a large university are given. This includes skills required by teachers, teachers training and technical support.

Keywords: Lecture Live streaming, hybrid teaching, virtual synchronous teaching, open source.

1 Introduction

During COVID pandemic many universities could not use their full lecture room capacity and were forced to switch either to a virtual synchronous format (students and teacher share the same time window but not the same location) or to set up at least a hybrid scenario (students and teachers share the same time window but only partially the same location). There are various ways for setting up virtual synchronous formats, by set up either infrastructure by yourself or by licencing one of the many existing video conferencing systems such as WebEx [11], Zoom [15], Teams [17]. The set up of a hybrid scenario, where part of the students reside in the classroom and a part of the students resides at home, however is a big challenge in terms of technical implementation but also in terms of skills required by the teachers.

In this paper, we will describe the set-up of a hybrid teaching scenario for teaching large groups of students. At our university large student groups are around 500 people.

We will describe the technical workflow, and the most important steps for set-up of a live streaming solution based on open source software. More specifically, we will describe the extension of an existing open source based lecture recording system 3, 4, 5 by live streaming hardware and software components. We will also state what has to be taken into consideration in order to integrate a chat backchannel for students. We will give the key parameters to be defined, before setting up a streaming solution, and we will state challenges teachers have to cope with in hybrid scenarios.

2 Design and implementation of a hybrid livestreaming system

As a starting point, we investigated three scenarios. Extending local room capacity by offering bidirectional transmission between local lecture rooms, bidirectional lecture streaming by integration of a standard video conferencing system into classroom teaching and provision of lecture streaming with backchannel to the students by expanding an open source lecture recording system [2]. In this paper, we will discuss the most suitable scenario for us, which is the last one.

First, we will give an exact definition based on national [1] and international best practice, of virtual synchronous, asynchronous and hybrid teaching. This is to have a common understanding since these terms are currently often used with different meanings. This is visualized in a structured graphic.

Second, we define the key design parameters of technically setting up a hybrid teaching scenario for large user groups. We defined the main technical workflow and identified the main technical building blocks. These building blocks are the lecture room control interface, the transcoding server, the data delivery server, the video portal, the central control software and the interfaces between them.

Third, the accompanying measurements have been defined such as legal aspects, announcement to teachers and students, teacher training and technical support.

As a last step, we performed an evaluation amongst our students in order to get data on acceptance of the hybrid approach and on potential improvements.

2.1 Definition of terminology

Recently – especially driven by the Corona pandemic - a great number of different terms was used by the community, including virtual teaching, blended learning, distance learning, eLearning, synchronous and asynchronous teaching and hybrid teaching. In a first step we clearly classified the different scenarios and terminology used and defined a model for virtual teaching scenarios embedded in university teaching in general. The by us elaborated model is depicted in **Fig. 1**.

Generally, we distinguish between virtual teaching, hybrid teaching and classroom teaching. The classical classroom teaching involves all students at the same time at the same location.

Virtual teaching means teacher and students are geographically and/or in time separated. Here we further distinguish between asynchronous virtual teaching and synchronous virtual teaching. Asynchronous virtual teaching means that, neither teachers nor

students are at the same place nor in the same time window. The asynchronous virtual teaching can be further classified by a supervised and unsupervised mode, meaning that students either study completely on their own or get active support during their study phase. Typical examples include lecture recordings, eBooks and MOOCS (massive open online courses).

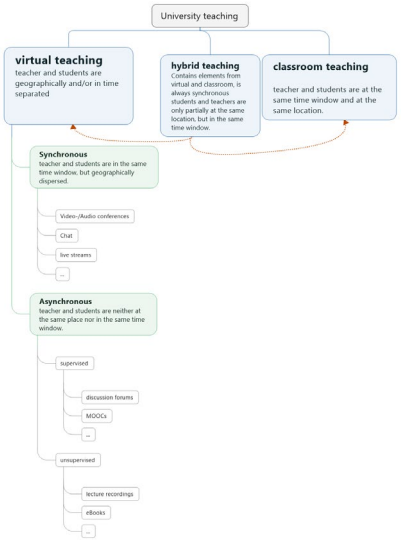

Fig. 1. Model for virtual teaching scenarios

Synchronous virtual teaching means that teacher and students are in the same time window, but geographically dispersed. Typical examples include video conferences, feedback tools and chats.

With hybrid teaching, we refer to a synchronous teaching mode, where part of the students are in the classroom, and another part resides at different locations. This is not only technically but also from a teacher's point of view the most challenging scenario. This is because you have to look after two groups of students, which are separated from each other: one directly in front of you in the classroom and one following you per live video stream from home.

2.2 Key parameters of a livestreaming scenario

When set up a livestreaming scenario a number of key parameters have to be defined in advance. These key parameters have essential influence on the technical implementation. So, you should take a considerable amount of planning time fixing these parameters with the decisions makers of your institutions, because changing them later may result in a significant increase of costs and personnel efforts.

The key design parameters of a livestreaming system are:

- Maximal number of parallel watching users

- Maximal number of parallel streaming lecture rooms
- Definition of offered resolutions and number of streams for the users
- Maximal acceptable delay of live stream

Maximal number of parallel watching users.

This number influences together with the offered number of streams and resolutions and the maximal number of parallel lecture rooms streaming directly the maximal necessary bandwidth you must provide in order to supply the users with the streams.

For our university we calculated it as follows. First, we defined the realistic maximum number of parallel streaming lecture rooms, which is 9. Then we summed up the person capacities for these rooms, assuming that in worst case all students stay home, which is in our case 2.310 students.

Maximal number of parallel streaming lecture rooms.

As already mentioned above the number of parallel lecture streaming rooms heavily influences the required bandwidth but also the capacity of your transcoding server (which will be explained later in this chapter). So, you should define this number carefully and realistically by looking at your curricula and decide, what is the maximal number of lecture rooms used in parallel, and maybe add a reserve.

We will have by end of 2022 10 rooms equipped with livestreaming, and since we had to extend the hardware resources anyway, we decided to go for maximal 9 rooms in parallel.

Definition of offered resolutions and number of streams for the users.

The number of offered streams and their resolution directly influences the required bandwidth and the necessary capacity of your transcoding server. So depending which maximal bandwidth you will be capable to provide (depends on the data delivery server, to explained later in this chapter) you shall chose the resolutions offered. Of course the choice of the resolutions is heavily dependent on the content you plan to deliver. In case you want to stream images with a lot of fine structures (eg x-ray), you should provide a resolution which is still feasible. Anyway, we recommend to test it before hand with different types of content! From our experience we recommend to offer at least 720p and 480p – because there are still many students who have bandwidth issues and with 480p they can still participate. In case you want to be future proof, 1080p is a good choice.

For our university we have chosen two streams (stream#1: teacher, stream#2: slides) and three resolutions:

- 1080p, 1920x1080, 3.5 Mbit/s
- 720p, 1280x720, 2.5 Mbit/s
- 480p, 853x480, 1 Mbit/s

This results in six streams per lecture room (3 resolutions á 2 streams) which have to be handled by the transcoding server.

Maximal acceptable delay of live stream.

This number defines the maximal acceptable delay between the livestream and the classroom event. It has to be stated, that there will be always a (constant!) delay, which is caused by the initiation of the transcoding and the delivery of the streams to the users. The delay cannot be perceived by the livestream users at home, but it has an influence on the backchannel and the teacher. If the delay is too big, questions via the back channel arrive much later and the teacher might get confused by receiving questions to things stated quite a while ago. From our experience, a good and also realistic value for a delay is below 10 seconds. We have currently a delay of approx. 7 seconds.

2.3 Technical workflow and technical implementation

Based on the definition of the key parameters we defined the main technical workflow showing the main components and started the technical implementation. The main technical workflow is depicted in **Fig. 2**.

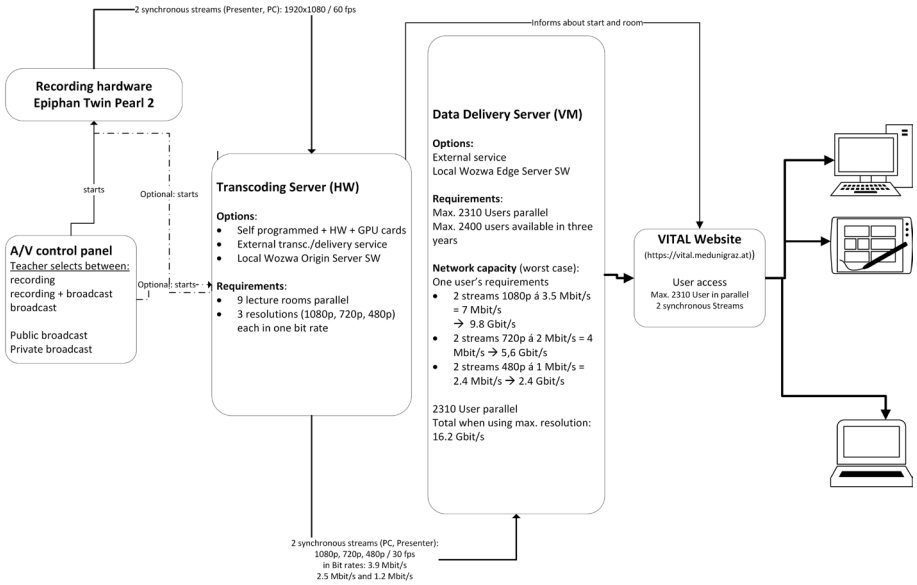

Fig. 2. Technical workflow of our open source based live streaming system

Technically, the live streaming system is an extension of our existing lecture recording system [4], which is based on the open source software OpenCast [6] and Epiphan Pearl II recording hardware [7]. It is a highly customized system with a, for our university individually tailored technical workflow [5]. Our lecture recording system is capable of recording two synchronized Full HD streams, the teacher video (including blackboard if required) and the PC output. It features a capture management interface programmed by ourselves and available as open source [18] utilizing the Epiphan application programming interfaces, a quality oriented manual editing of recordings and the publishing on a video portal and within our learning management system Moodle using

the by IMS standardized LTI [8] interface. The system is fixed installed in 10 large lecture rooms and includes a fixed installed camera filming the presenter and the blackboard / whiteboard. Our video portal VITAL [9] is also open source based, and will be soon public available for the OpenCast community base. The main building components of the livestreaming system and hence the extensions we made to our existing system are the classroom control panel, the transcoding, the data delivery and the streaming portal.

Classroom control panel.

The first important component of livestreaming system is the seamless integration into the classroom audio visual control controls. Since this is the main interface for teachers, it shall be as easy as possible to use in order to reduce technical support to a minimum. On the other hand, it shall provide all functionalities which you plan to offer.

We have in all lecture rooms Crestron touch panels installed, which we extended by live streaming features. In order to keep it as simple as possible we provided for starting and stopping the live stream only a play and stop button. Furthermore the teacher has to select the camera setting and if the stream shall be internal (only accessible by students and affiliates of our university) or public (accessible by everyone).

Transcoding server.

This component is responsible to create the different resolutions per stream, which you want to provide for the students, hence needs a lot of calculation power which is best performed with graphic cards (GPU server). As mentioned above, it is important to define how many lecture rooms you want to serve in parallel, since this directly affects the transcoding hardware. In our case we want to serve 9 rooms. For our specific case we will need for each room 6 streams (3 resolutions * 2 streams). A reasonable priced graphics card (such as nvidia A10 tensor – approx. 3.100 €) can transcode up to 8 streams in the resolutions and qualities defined above. Hence we need 9 graphic cards to serve 9 rooms in parallel. We decided for a local solution for the transcoding server and a self developed open source software based on ffmpeg [18] and Nvidia specific drivers, in order to save the costs of a commercial transcoding server such as Wowza [10]. In order to minimize failures we decided to buy two transcoding servers and distributed the graphic cards amongst them. In case one of the servers has a hardware failure, the second can still handle 4 or 5 rooms in parallel. Furthermore, we have deployed a load balancing strategy which works as follows: all 9 available graphic cards on the two servers reside in a pool. Each time a new stream starts, one of the available graphic cards is randomly selected. This distributes the load on both servers and guarantees availability and reliability. In case one graphic card or server fails, it is simply removed from the pool. In case you consider a cloud service for transcoding, we can recommend Amazon AWS media [12], which offers transcoding for reasonable prices.

Next to the transcoding software the server also hosts the by us developed central control software, providing REST interfaces [19] to the control panel in the lecture room, the data delivery server and the video portal. The software is also provided as open source [18] and controls the entire workflow of the livestreaming, initiated by the

control panel in the lecture room, starting the transcoding, data delivery and providing the streams to the video portal. The software offers also an administration interface where experienced technicians can manually start and stop streams or manipulate the resolutions, which is important in case of failure of the control panel in the lecture room.

Data delivery server.

This component is responsible for delivering the streams in the desired resolution in parallel and real-time to the connected users. The choice whether you want to host this server locally or externally is heavily dependent on the maximum number of parallel users resulting in the maximum bandwidth you need to provide locally. Based on our definitions of these key parameters we would have to provide a maximum bandwidth of 16.2 Gbit/s, which is more than the entire university currently has. Hence, the decision to outsource this server was clear. Here we went for the provider – Hetzner [13] – where we rent two servers (EPYC™ 7502P 32-Core CPU, 128 GB DDR4 ECC RAM, 2x 960 GB NVMe SSD) with each 10 GiB/s dedicated bandwidth and 20 TB data volume / month for 2.200 €/year. Each TB more is 1 €. As a software solution we again use a self developed software based on low cost Varnish [14] components provided as open source [18] instead of a quite expensive commercial solution such as Wozwa [10].

Streaming portal.

The last component in the workflow needed is a portal, where users can access the live streams. For this purpose we have extended our already existing open source video portal VITAL [9] by livestreaming features.

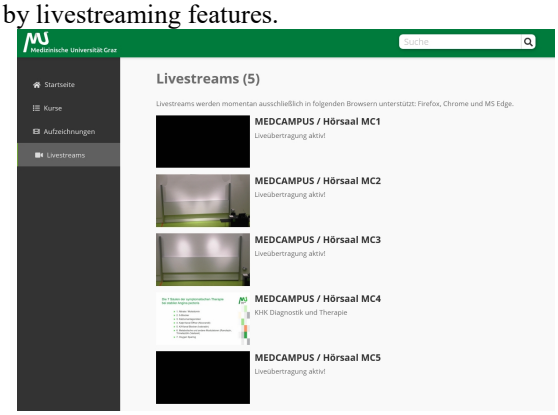

Fig. 3. Overview of rooms with livestreaming on our video portal VITAL

Since we have a vast amount of different lectures, but only 10 rooms capable of streaming we decided to implement a streaming channel per room. Hence students know from their electronic schedule in which room the lecture takes place, and according to this they can select the appropriate stream on the portal. In the list of rooms it is clearly indicated in which rooms there is currently a stream active as it can be seen in **Fig. 3**.

By selecting one room, students can view the two streams with our special video player. We use the by the Universitat Politècnica de València developed open source paella player [16]. This player offers a vast amount of features including enlarge one of the streams, zoom in/out, concentrate on one specific stream and the selection of desired resolution. Especially the last feature is important for students who have a low bandwidth Internet connection.

In order to provide a back channel we extended our portal by a live chat feature, where students can actively chat with each other or ask questions to the teacher. Furthermore it is also displayed how man students are online, which is an important indicator for teachers. A typical livestream setting is depicted in **Fig. 4**.

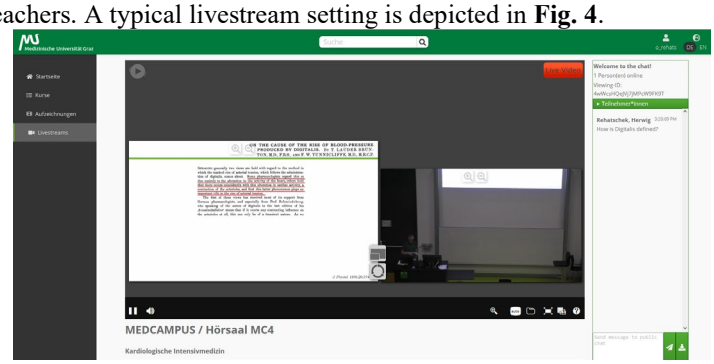

Fig. 4. Livestream on video portal VITAL including chat.

3 Accompanying measures and experiences

3.1 Accompanying measures

Next to the technical set up of a hybrid / livestreaming system a number of accompanying measures have to be planned and performed, in order get accepted by teachers and students and hence to make the introduction of this new format a success.

First, legal issues shall be considered. At our university we signed prior to introduction of lecture recording and live streaming an agreement with the works council. In this agreement we formulated the legal framework for lecture recording. Important issues include that lecture recording and live streaming is voluntary for teachers, the university has a right to publish the live streams and recordings to students, teachers may request to delete them, and streams and recordings may only be started by authorized persons. This is implemented by a key card system.

Second, a successful introduction always needs a proper announcement and training offers for teachers, but also to provide technical support. We provided two meetings shortly before semester start, where we introduced the system to interested teachers. Furthermore we affiliated two students who we trained on the system. These two students provided then active support during lessons to the teachers. So at least at the first hybrid lesson each teacher has active support by one of our students, who help also with the chat.

Third, during the pilot phase we actively watched the streams remote in our office so that we could immediately react in case of technical failures.

3.2 Do's and don'ts in hybrid scenarios

In this section, we summarize our experiences from one year hybrid teaching. We list clear recommendations what teachers shall pay attention to when teaching in a hybrid scenario and how they could be supported.

For teachers it is essential to know and to train, to repeat questions from people in the classroom and in the chat so that both student groups are synchronized.

For teachers it is important to know not to use laser pointers, because they cannot be seen in the livestream. Here the mouse pointer or devices such Spotlight from Logitec have to be used.

For the technical success of a livestream, audio is the most important issue. So the usage of a microphone is essential, and it should be checked in advance if the batteries are still good.

For the livestream it is important to stay in the area of the camera. At our university, we have marked this area by orange lines in the lecture rooms, so that teachers keep within the area of the camera.

Last but not least we highly recommend to support teachers by so called eTutors. At our university eTutors are student workers, who we technically trained on the system and who support teachers technically. Even equally important is also the support during the lesson by keeping an eye on the chat backchannel and to raise questions arisen from the chat to the teacher. Because it is quite challenging for teachers to hold a presentation and in parallel to service students in the classroom and having an eye on the chat.

Furthermore we highly recommend to offer proper trainings for teachers, where they learn to use the system and where they can try out hybrid teaching in a controlled environment.

4 Evaluation results

We started with our first livestreams in October 2021. The first semester was defined as a pilot trial and we performed a user evaluation. Some of the results we want to present here briefly. For the evaluation 456 students were asked, 148 answered them, which results in a response rate of 32.46 %. We asked 5 closed questions (Q1 – Q5), which could be answered on a lickert scale with 6 options. The range was from totally agree (1) to totally disagree (6).

Q1: The flexible participation either from home or by coming to the classroom is important for the study success in this lecture.

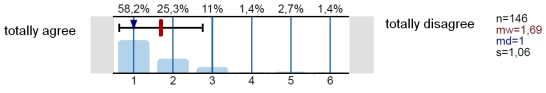

Fig. 5. Evaluation results of question 1

As it can be seen in **Fig. 5**, 58.2% totally agreed and 25.3% strongly agreed. Hence the offered hybrid format was seen to positively influence the study success.

Q2: the implemented hybrid format at our university is attractive.

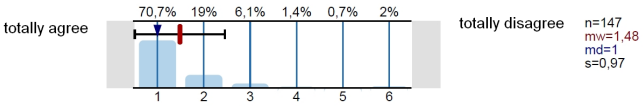

Fig. 6. Evaluation results of question 2

As it can be seen in **Fig. 6**, 70.7% totally agreed and 19% strongly agreed that the implemented hybrid scenario was highly attractive and hence accepted by the students.

Q3: teachers answered questions raised via the chat back channel in a thorough way.

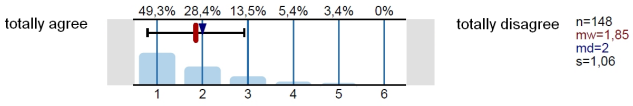

Fig. 7. Evaluation results of question 3

As given in **Fig. 7**, 49.3% totally agreed and 28.4% strongly agreed, that teachers answered questions raised in the chat backchannel in a satisfactory way.

Q4: the participation in the live stream worked satisfactory for students.

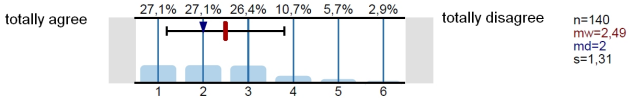

Fig. 8. Evaluation results of question 4

As depicted in **Fig. 8**, 27.1% totally agreed, 27.1% strongly agreed and 26.4% agreed, that the live streaming worked technically in an acceptable way. Of the technical problems raised, the most often raised were problems with their browsers and bandwidth issues. We tried to support them as good as we could.

Q5: this lecture shall be given in the future only in a virtual synchronous or asynchronous format (instead of hybrid).

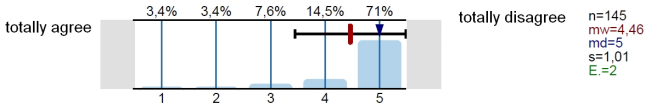

Fig. 9. Evaluation results of question 5

From the results visualized in **Fig. 9** it can be clearly derived, that students do not prefer a pure virtual asynchronous (eg lecture recordings) or synchronous format. 71% totally disagreed, which – together with the results of Q1 and Q2 - clearly indicates, that a hybrid scenario is highly attractive for students.

5 Conclusions and outlook

The implementation of a hybrid scenario for teaching at a university is a highly customized and therefore no out-of-the-box installation. Someone cannot simply buy an existing product and install it. It requires on the one hand special teacher skills and on the other hand on site technical personnel to plan and implement it.

A hybrid scenario is the most complicated scenario in terms of technical set-up and requirements on teaching skills. Even though the students not residing in the local classroom will always have a disadvantage, the goal of our scenario was to make their learning experience as good as it would have been when being present in the classroom. The success of this goal was underlined by the first evaluation results.

A hybrid scenario has also many advantages. Advantages include flexibility for the students by giving them location independency. They have the chance to decide on their own if they want to participate in the classroom or from home. The number of students attending lectures can be increased, because students attend who would maybe have not attended when offering only a classroom lecture, students may still have direct contact to teachers. Last but not least, a hybrid scenario offers a possibility to increase student numbers for universities, without having the need to build new bigger and very expensive lecture rooms.

From the students feedback we can clearly state, that students want next to a pure livestream also the slides as PDF and a recording of the lesson so they can make notes during the lesson and repeat difficult parts again later on when they prepare for the exam.

The by us chosen solution is the extension of our already existing open source lecture recording system by means of a streaming feature including a text based backchannel. This is because it is scalable by means of number of remotely participating students, and can be easily streamed to each room of the university if needed. The software is open source and hence no license fees have to be paid, and it seamlessly integrates with our existing platform. We described the solution at at a level of detail, that it can be easily adapted also to other universities.

From the first evaluation results it can be clearly derived, that students like hybrid scenarios. They highly appreciate the flexibility to decide whether to come to the classroom or to stay home. But they also clearly stated, that they do not like a pure virtual asynchronous or synchronous format. The possibility coming to the classroom is important.

As an outlook and next steps to be taken we want to integrate some statistical functions into our system. This includes bandwidth used, participants per event and the medium participation time per event of students.

References

1. I. Fallmann et al.: „Quantifizierung von virtueller Lehre an österreichischen Hochschulen“, Whitepaper CC BY, Forum neue Medien Austria, June 2021. <April 2022 / URL: https://www.fnma.at/medien/fnma-publikationen>.

2. H. Rehatschek: "Outline of Possible Synchronous Solutions and Experiences in Order to Supply Large Groups of Students with Learning Content in Classroom and Mixed Classroom/Distance Scenarios". In proceedings of the 24th International Conference on Interactive Collaborative Learning (ICL2021), Volume 1, LNNS 389, TU and HTW Dresden, ISBN 978-3-030-93904-5, published by Springer on 1 Jan 2022, https://doi.org/10.1007/978-3-030-93904-5_52, pp. 523–534, 22 - 24 September 2021, Dresden, Germany.
3. H. Rehatschek: "Experiences from the Introduction of an Automated Lecture Recording System", in Proceedings of the 21st International Conference on Interactive Collaborative Learning (ICL 2018) – Volume 2 of the series Advances in Intelligent Systems and Computing, book title: The Challenges of the Digital Transformation in Education, ISBN 978-3-030-11934-8, ISSN 2194-5357, https://doi.org/10.1007/978-3-030-11935-5, pp. 151 - 162, 25–28 September 2018, Kos Island, Greece.
4. H. Rehatschek: "Design and Set-up of an Automated Lecture Recording System in Medical Education", in Proceedings of the 20th International Conference on Interactive Collaborative Learning – Volume 715 of the series Advances in Intelligent Systems and Computing, ISBN 978-3-319-73209-1,, pp 15-20, 27– 29 September 2017, Budapest, Hungary.
5. J. Smolle, A. Rössler, H. Rehatschek, F. Hye, S. Vogl: „Lecture recording, microlearning, video conferences and LT-platform – medical education during COVID-19 crisis at the Medical University of Graz“. Open Access Article (CC 4.0 attribution) within GMS Journal for Medical Education 2021, Vol. 38(1), ISSN 2366-5017, https://www.egms.de/en/journals/zma/2021-38/zma001407.shtml, published on 28 Jan 2021.
6. Opencast Matterhorn, open source solution for automated video capture and distribution at scale. <April 2022 / URL: http://www.opencast.org/matterhorn >
7. Epiphan, video recording hardware. <April 2022 / URL: https://www.epiphan.com/>
8. LTI – Learning Tools Interoperability, IMS standard. <April 2022 / https://www.imsglobal.org/activity/learning-tools-interoperability>
9. VITAL – VIdeo porTAL of the Medical University of Graz. <April 2022 / URL: https://vital.medunigraz.at >
10. Wozwa video platform. <April 2022 / URL: https://www.wowza.com/>
11. Cisco WebEx, a comprehensive cloud based video conferencing solution. <April 2022 / URL: https://www.webex.com/ >
12. AWS Elemental media life, broadcast-grade live video processing service. <April 2021 / URL: https://aws.amazon.com/de/medialive/ >
13. Hetzner, professional web hosting provider and experienced data center operator. <April 2021 / URL: https://www.hetzner.com/>
14. Varnish, web cache and http accelerator. <April 2022 / URL: https://www.varnish-software.com/>
15. Zoom, Video Webinars. <April 2022 / URL: https://zoom.us/ >
16. Paella, the multistream player for lectures. <April 2022 / URL: https://paellaplayer.upv.es/>
17. Teams, Video conferencing and collaboration software. <April 2022 / URL: https://www.microsoft.com/en-us/microsoft-teams/group-chat-software >
18. OpenSource components, developed by Medical University of Graz. <April 2022 / URL: https://github.com/medunigraz/ >
19. REST interfaces for opencast and Crestron. <April 2022 / URL: https://raw.githubusercontent.com/medunigraz/outpost.django.video/master/Opencast.rst URL: https://raw.githubusercontent.com/medunigraz/outpost.django.video/master/Crestron.rst>