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Towards an Integration of 360-degree Video in Higher Education

Workflow, challenges and scenarios

Michael S. Feurstein[1]

Abstract: Today video is being used in different facets supporting the e-learning experience. With a resurging interest and reduced barriers of entry to experience virtual and augmented reality applications, 360-degree video technology is becoming relevant as an option to produce and consume content for VR/AR applications. 360-degree video offers new features, which can prove useful in teaching & learning scenarios with a need for self directed control of view direction, immersion and a feeling of presence. Current adoptions of 360-degree videos are integrated manually for specialized activity-oriented learning scenarios. However, in order to adopt 360-degree video on a larger scale, a sufficient technical integration is required and knowledge of application scenarios needs to be communicated. To approach this challenge, workflow steps are analyzed, challenges are identified and scenarios are described in the context of creating 360-degree video content for higher education. We identify open gaps, which need to be addressed in order to integrate 360-degree video technology in an automated video processing tool chain.

Abstract: Das Medium Video wird in der Hochschullehre in zahlreichen Ausprägungen erfolgreich im e-learning eingesetzt. Wiederaufstrebendes Interesse und reduzierte Eintrittsbarrieren zur Nutzung von virtueller und augmentierter Realität tragen dazu bei, dass 360-Grad Video Technologie als Option zur Umsetzung und Anwendung von VR/AR Applikationen verwendet wird. 360-Grad Videos eröffnen neue Möglichkeiten für didaktische Szenarien bei denen die selbstbestimmte Auswahl des Blickfelds und Immersion sowie das Gefühl von Präsenz eine zentrale Rolle spielen. Die Integration von 360-Grad Videos findet momentan jedoch nur für spezielle aktivitäts-orientierte Lernszenarien statt. Um eine breitere Adoption von 360-Grad Videos in der Lehre voranzutreiben, muss in einem ersten Schritt, die technische Integration ausreichend gegeben sein und mögliche Einsatzszenarien aufgezeigt werden. Der Beitrag beleuchtet aktuelle Herausforderungen für die Integration, analysiert die Arbeitsschritte zur Erstellung und erweitert das Portfolio an Einsatzszenarien von 360-Grad Video in der Hochschullehre.

Keywords: Video, 360-degree Video, Higher Education, Integration, Scenarios

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1 Introduction

Video is present in higher education and being used by lecturers to provide learners with additional content. Lecturers use video in different formats to integrate concepts such as the "flipped classroom" [Lo13] or "learning by teaching" [Fe17]. Universities have integrated recording and streaming solutions in order to support an easy production workflow for video content [Lo11]. Video management and production systems for e-learning environments are available on the market such as Opencast [Ke10] or self maintained solutions by universities [Lo11]. Video has become a substantial part in higher education.

New developments in the area of video constantly push the boundaries of its application. The resurgence of virtual reality (VR) and augmented reality (AR) products are driving factors behind these developments. Web technologies such as WebXR[2] enable the integration of VR and AR experiences in the web. 360-degree cameras simplify the creation of VR content [He17]. Consumer products such as the head mounted display (HMD) Google Cardboard reduce barriers to explore new applications of VR [BG16]. This motivates the question how these new developments will influence video use in higher education and what is needed to support these new developments from a technical point of view.

360-degree video technology is one part of this new development. With 360-degree cameras, content creation for VR can be accelerated. 360-degree video technology offers new features to communicate and view content, such as self directed control of view direction and immersion, which both influence the feeling of presence [He17]. Also, one does not necessarily need a HMD to view a 360-degree video; a web based video player may suffice, supporting drag and drop in order to pan and zoom around in the video. Scenarios have already been evaluated and successfully supported with 360-degree video in educational settings [He17, Gä17]. However, these scenarios were integrated for a dedicated environment and were developed to support e.g. sports education classes. For a broader adoption of 360-degree video, the content creation process and delivery environment needs to be streamlined. Additionally further scenarios need to be identified with more generic areas of application in order to raise awareness for applying 360-degree video in education.

This paper highlights and analyzes the production and delivery workflow of 360-degree content based on a prototype implementation addressing challenges, which need to be solved in order to assure a technical integration with e-learning environments. Finally an attempt is made to identify further scenarios in the context of the Vienna University of Economics and Business (WU).

[2] https://immersive-web.github.io/webxr/spec/latest/

2 Terminology and Related Work

2.1 Virtual, Mixed and Augmented Reality

The terminology of virtual reality and augmented reality is not consistently defined [Mi94, Zo18]. In order to place 360-degree video in the realm of VR and AR, this paper builds on the dimensional taxonomic framework by Milgram et al. [Mi94] and the classification of VR and AR by Zobel et al. [Zo18].

Virtual reality can be defined as an environment in which the participant is fully immersed into a synthetic world simulating the concept of presence, which is the natural perception of "being in an environment" [St92, Mi94]. More recent definitions describe virtual reality as a simulated reality or as a stereoscopic perspective [Zo18]. Augmented reality can be defined as an environment in which the participant receives simulated cues as an extension to the real worldview [Mi94, He17]. Zobel et al. [Zo18] describe augmented reality by adding a dimension of assisted reality in order to differentiate between displaying information versus integrating information into the reality.

In the context of VR/AR the term Mixed Reality (MR) has been defined by Milgram et al. [Mi94], which in its concept represents a *Reality-Virtuality (RV) continuum* between a real environment and a virtual environment. Within this spectrum Milgram et al. [Mi94] define levels of augmented reality and augmented virtuality depending on the environment which may consist of real or virtual objects, presented together on a single display. They define seven classes of mixed reality displays, ranging from monitor-based to HMD-based video with computer generated overlays and optical see-through systems [Mi94]. Milgram et al. [Mi94] propose a taxonomic framework to classify MR displays by defining three dimensions:

1. Extent of World Knowledge (EWK): differentiating between unmodeled, partially modeled and completely modeled worlds.
2. Reproduction Fidelity (RF): referring to the relative quality of displaying images or video. Ranging from conventional video to stereoscopic video to 3D HDTV.
3. Extent of Presence Metaphor (EPM): focusing on the level of immersion within a displayed scene. Ranging from monitor-based to HMD.

Zobel et al. [Zo18] present a classification of VR and AR by mapping the projection medium to a certain level of reality ranging from full-featured VR HMDs to AR glasses. Conventional media in education such as a beamer or laptop provide no level of virtuality or augmentation according to Zobel et al. [Zo18].

2.2 360-degree Video and VR/AR in Education

360-degree video, if used with a projection device such as a HMD, adds to the extent of presence metaphor dimension and can be classified as a VR application according to Milgram et al. [Mi94] and Zobel et al. [Zo18]. Depending on the projection device and the extent of world knowledge 360-degree video technology can therefore support the integration of VR.

VR for use in education is not a new topic. Early origins of VR concepts date back to first attempts of creating the illusion of flying at high altitude for digital flight simulators in the 1950s [Pa00]. Bricken [Br91] discusses potentials and challenges of VR for learning environments, highlighting costs, usability and fear of new technology. Winn and Bricken [WB92] designed virtual worlds for learning Algebra. Allison and Hodges [AH00] developed a VR Gorilla Exhibit for students to observe gorilla behavior. Creating these VR applications involved knowledge in modeling and programming of virtual environments.

With 360-degree video, the process of creating virtual environments has been reduced in complexity, hence enabling a broader mass to adopt the technology in education. Kavanagh et al. [Ka16] present a case study highlighting the process of creating 360-degree video for HMDs in an educational setting. They identify challenges including the “giant hands” effect, which is produced by handheld shooting as well as video quality and directing attention. Gänsluckner et al. [Gä17] present a blended learning course for sport climbing, utilizing 360-degree videos in order to communicate climbing techniques, knots & rope techniques or security concepts. Specifically 360-degree videos on climbing techniques were evaluated as being the most beneficial for the learning experience. Hebbel-Seeger [He17] focuses on usage and utility of 360-degree video for training and learning processes in sports. The study identifies 360-degree video to have high potential for adaptation in athletic training processes also highlighting challenges such as the need to adapt contemporary storytelling in order to direct user attention.

360-degree video is being used in education, mainly sports education. However, a more generic and technical approach of integrating 360-degree video in higher education is missing. This paper attempts to make a step towards filling this gap by analyzing the production workflow and identifying steps needed in order to technically integrate 360-degree video in an e-learning environment.

3 360-degree Video in Higher Education

In order to integrate 360-degree video in an e-learning environment, the production workflow is analyzed with a prototype implementation of the complete workflow. Based on this analysis missing technical implementations are identified and next steps recommended for further integration. Finally scenarios are extended in the context of an economics and business university, adding to the current scenarios in education, hence contributing to a more generic pool of scenarios.

3.1 Workflow & Challenges

We analyzed the production workflow with the goal in mind to integrate 360-degree video in an e-learning environment such as *Learn@WU* [Al03]. As a reference for the production workflow, the *Ricoh Theta V 360-degree* dual-lens camera was used. The camera was chosen based on previous work by Kavanagh et al. [Ka16]. Its ease of use in the sense of a click-and-record functionality and its low price make it a good choice for users with little or no experience with 360-degree cameras. One could also use a rig of multiple cameras, however this remains to be a complex task involving multiple processing steps with a high effort in post processing [He17]. A prototype video processing tool chain and a proof of concept integration was developed in an OpenACS[3] module, resembling a generic e-learning environment which delivered the 360-degree video content via a web based player with *video.js*[4] and *video-vr.js*[4].

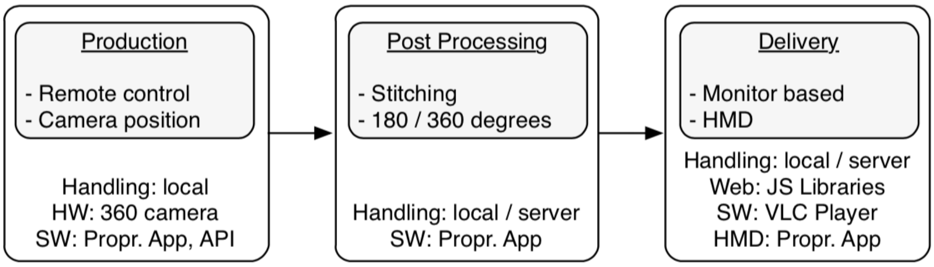

Fig. 1 Workflow Content Creation 360-degree Video

Fig. 1 illustrates the production workflow for a 360-degree video. The first step involves the production of the 360-degree video. With the *Ricoh Theta V* two main options exist to control the production phase: (1) starting and stopping the recording manually by pressing a button on the camera and (2) remote controlling the camera via a proprietary application on a mobile device (*iOS*, *Android*). Feedback is provided via small LED lamps signaling an ongoing recording.

Two challenges are identified for the production phase: (1) Controlling the camera and (2) positioning the camera. Having to start and stop the recording directly at the camera can lead to overhead activity needed in order to access the camera resulting in the “giant hands” effect, which needs to be cut in post processing [Ka16]. This is the case if the camera is placed at a different spot than the lecturer. In order to avoid additional work, a camera which can be remote controlled via an integrated interface is essential. Options

[3] https://openacs.org/
[4] https://videojs.com/; https://github.com/videojs/videojs-vr

exist, such as proprietary applications from manufacturers, which need to be installed on mobile devices. Lecturers might disapprove of this, as it may interfere with their personal devices. The *Ricoh Theta V* is controllable via an API over USB through *libptp2*[5], a library to control camera functions. For this purpose a prototype has been developed enabling a mobile ad hoc remote control via a web interface in order to explore this challenge. It incorporates a Raspberry Pi, a Wireless LAN USB adapter and a USB cable connected to the Ricoh Theta V. Simple remote control actions such as starting and stopping a recording were tested and confirmed functional via terminal commands. This web interface could replace proprietary applications and offer a flexible way to control and preview the camera via any browser interface.

Fig. 2 Camera position at the side, with no readability of slides.

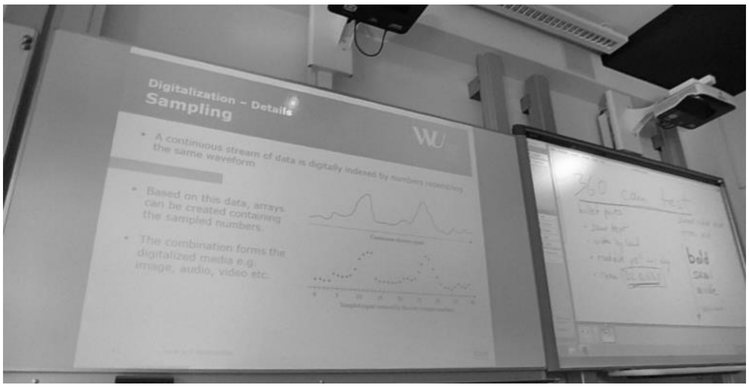

Fig. 3 Camera position at the front (zoomed in), with readable slides.

The second aspect that has to be considered when recording in an educational setting is the camera position. Seven different positions were evaluated in a small seminar room

[5] http://libptp.sourceforge.net/

with a capacity of 30 seats. As shown in Fig. 2 a position at level with the head of the lecturer is recommended in order to create a direct line of sight. If the camera is placed at this angle, there is no need to tilt the video upwards in order to look at the lecturer or other participants. In this case an extendable tripod is needed. However, as shown in Fig. 3 the slides are only readable if the camera is placed in the front row allowing zooming in on the slides. Kavanagh et al. [Ka16] also found that the image quality produced with 360-degree cameras was very low, leading to unreadable text written on a whiteboard. We can see with the given screenshots from the 360-degree video that readability can be partially achieved if the camera is placed in the front row. However, the camera was not suitable for recordings in large-scale auditoriums, due to video quality issues in combination with the size of the room. Further steps are needed in order to evaluate the possibility of using only 180-degrees of the recording, covering the front presentation area.

The second workflow step involves post processing. Main challenge for this step is the process of creating a 360-degree video. In comparison to regular video an additional step is needed to combine two 180-degree videos into one 360-degree video, which is called *"stitching"*. Currently this is done manually with proprietary software provided by the camera manufacturer. Other proprietary solutions exist, such as dedicated stitching software Autopano Video[6] or VideoStitch Studio[7]. Adobe After Effects[8] also offers VR based editing filters, enabling manual stitching of 360-degree video. Open source projects such as FFmpeg[9] or VideoLAN (VLC)[10] do not support stitching of 360-degree video, however they are already working on solutions. At the moment this step is a black box for the end user. Hence it cannot be integrated into an automated video processing tool chain. An open source module for FFmpeg or VLC is needed in order to solve this challenge.

The third and last workflow step covers the delivery of the video content. For a higher education integration we cannot always count on having direct access to HMDs or cardboard viewers, therefore as a first step, it suffices to deliver video via a web-based player, in a monitor-based environment with drag & drop (desktop) or pan & wipe (mobile) interface control [He17]. This works, and is possible by utilizing web-based libraries such as videojs, threejs or marzipano[11]. Additionally, one can integrate a VRDisplay button through WebXR in order to activate the projection for a HMD on mobile devices. The VLC media player version 3.0.1 offers a simple viewing functionality for 360-degree videos on desktop environments.

Three main technical challenges were identified in the production workflow: (1) Controlling the camera via an ad hoc interface; (2) positioning the camera in a way that

[6] http://www.kolor.com/autopano-video/
[7] https://www.orah.co/software/videostitch-studio/
[8] http://www.adobe.com
[9] https://www.ffmpeg.org/
[10] https://www.videolan.org/
[11] https://videojs.com/; https://threejs.org/; http://www.marzipano.net/;

it will not intrude students and still provide for an optimal viewing angle of the lecturer and (3) stitching the video files into a 360-degree video, which currently only works with proprietary software and thus presents a black box for video editors. Solving these issues can provide a better technical integration into an automated production workflow for 360-degree video in higher education.

3.2 Scenarios

With the workflow and its challenges in mind we now identify scenarios where it makes sense to integrate 360-degree video instead of, or in addition to regular video format. When looking at the application area of 360-degree videos currently more activity-oriented scenarios are explored, such as sports education [Gä17, He17]. In order to extend the application area we focused on scenarios in an environment of an economics and business university namely the *WU* [Al03]. Three scenarios in this context were identified: *(1) Teacher Training Video Analysis*, *(2) Group Work Sessions* and *(3) Mobile Lecture Recording*.

Teacher Training Video Analysis: In the context of business education, future teachers are educated and trained to teach classes. Experience in teaching is crucial and it is beneficial for teachers to reflect on their behavior in class and how students react. At the Institute for Business Education it is a common task to record teacher training sessions in order to analyze the behavior and reactions of both teacher and students afterwards. Currently this is done with an expensive and time consuming video setup consisting of multiple cameras, which include time-costly post processing steps. There is a need to capture the complete environment in a small room with possibly different camera positions based on the teaching setup. 360-degree videos could solve this by offering an easy way to capture the complete surroundings with one camera and reduce post processing time by only utilizing a single camera.

For this scenario the challenge of controlling the camera manifests itself by the fact that multiple users handle the camera. An integrated user interface is needed. The students themselves initialize the recording but one cannot expect students to install a proprietary application on their private smartphone in order to control the camera. On the other hand it would still be possible to start the recording by using the buttons on the camera, leading to video content which would need to be cut afterwards due to excess content including the “giant hands” effect.

Group Work Sessions: Another scenario focuses on group work sessions with an interactive character. This may be the case for debates, discussions or dialogs among group members in a learning scenario. Depending on the learning setup a group work session needs to be recorded in order to capture the whole environment. As an example the language learning courses at the university use tandem group work sessions to simulate an exemplary discussion in a foreign language. Currently the discussions are recorded with mobile cameras and uploaded to the e-learning platform where one can give feedback and discuss issues with the students. This is particularly useful for a direct communication with the teacher. A typical constraint in this scenario is the field of view of the camera. 360-degree video could alleviate this issue by supporting a wider viewing angle.

For this scenario the challenge of stitching the video in order to view it correctly is prevalent. Again, students interact with the camera and after finishing the recording upload the video onto an e-learning platform. In order to view the video correctly, stitching is required as an additional manual step. For the setting of an in class group work session this step could become a common source of error, as it may be overlooked. Integrating this step into an automated production workflow would eliminate the need to manually stitch the video and reduce a possible source for errors.

Mobile Lecture Recording: At the WU selected lecture rooms are equipped with integrated recording equipment in order to record a camera, slide and audio signal in parallel. However, not all lecture rooms include this setup and bookings often rather comply with the size of the class than with the specialized equipment needed. Lectures may have to be recorded at locations lacking the required technical infrastructure. For these cases a mobile recording unit is available, however too heavy and without the facility to record a camera signal. Additional setup costs would be needed to record a camera. These include setting up the camera, connecting it to a power outlet and defining a field of view. A more integrated solution is needed with lower setup costs and better usability. 360-degree video cameras can solve the issue of setup costs by recording the complete viewing angle and selecting the appropriate areas afterwards.

This scenario can be put into relation with the challenge of positioning the 360-degree camera at an optimal point in the room. Depending on the setup slides can be recorded separately or need to be readable in the video. As shown above, readability is an issue with 360-degree video content due to image quality. If slides and camera signals can be recorded in parallel, the multi stream Paella[12] player supports playing two streams including 360-degree video in combination with slides.

The scenarios presented add to the current pool of activity-oriented applications of 360-degree video in a generic way. Even though being only conceptual at this stage, they build on scenarios, which are already being used. In a next step these scenarios need to be evaluated in a realistic environment.

4 Conclusion and Future Work

This paper contributes towards a conceptual 360-degree video integration for higher education environments from a technical point of view. Production and delivery workflow steps were analyzed in order to identify challenges. A prototype was

[12] https://paellaplayer.upv.es/

developed in order to evaluate the feasibility of solving identified challenges. Additional scenarios were identified for use of 360-degree video in higher education. The scenarios were put into relation with the identified challenges.

Three main challenges were identified, building on related work and the evaluation of using a 360-degree camera. (1) Control: when producing video with dual lens cameras there is a need to remote control the camera in order to start and stop the recording. This is accomplished through proprietary mobile applications from the camera vendor allowing to preview the image and control the recording. We suggest an integration through a responsive web interface, enabling a flexible reachability through the browser. A prototype has been developed integrating fundamental preview and remote control features via a web interface. (2) Position: for the production of a 360-degree video an optimal camera position is crucial. In the context of higher education this means balancing a combination of viewing angle of lecturer, not intruding students view and possibly providing for the readability of slides. Especially for low cost 360-degree camera solutions image quality of the resulting video is an issue and can result in limitations of adopting 360-degree video in large-scale rooms. (3) Stitching: at the post processing level the main challenge is the process of stitching two videos into one 360-degree viewable format. Currently, proprietary software is needed, however open source projects such as VLC and FFmpeg are already working on solutions. On the delivery side many challenges have already been solved, still the form of delivery may influence the effect of 360-degree videos. In order to move towards a technical integration of 360-degree video into higher education these three challenges need to be solved as a next step.

360-degree video contributes to very specific educational scenarios. We therefore identified more generic learning scenarios, suitable for an adoption with 360-degree video: (1) Video Analysis, (2) Group Work and (3) Mobile Lecture Recording. The scenarios were identified for an environment of an economics and business university, hence adding to the currently communicated scenarios in a more generic manner.

In order to work towards the integration of 360-degree video technology in higher education, the future research agenda will have to focus on three main areas. First, the development of a system that enables a generic web-based control of 360-degree cameras, in order to preview the camera signal and control the recording. Second, the development of open source stitching modules for FFmpeg or VLC in order to guarantee integration with automated video processing tool chains. Third, further evaluation of identified scenarios in order to adapt the integration of 360-degree video. By focusing on these three main areas as next steps on the agenda, the production workflow can be optimized for the end user, post processing steps can be integrated with automated video tool chains and more experience can be gathered on using 360-degree video technology in higher education.

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