A Multimedia Help System for a Medical Scenario in a Rehabilitation Clinic

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ABSTRACT

In this paper we outline instructional, legal, and software requirements as well as a prototypical software implementation for a multimedia help system in a rehabilitation scenario. The help system will be used by patients in a rehabilitation clinic to support their pelvic floor exercises. After describing the use case we will outline the requirements for the scenario and show how our software was extended to meet the requirements. We present the key features of each component of the SIVA Suite: the authoring tool, the redesigned HTML5 player, and the server application. Thereby, important new features are described and illustrated. Design decisions are presented and explained.

Categories and Subject Descriptors

H.5.2 [**Information Interfaces and Presentation**]: User Interfaces—*Interaction styles*; H.5.4 [**Information Interfaces and Presentation**]: Hypertext/Hypermedia—*Navigation, User issues*

General Terms

Human Factors

Keywords

Multimedia; Help System; HTML5 Player; Hypervideo; Authoring Tool; Server Application

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1. INTRODUCTION

Today's means of information and communication in companies aim at fast and effective provisioning of interconnected data. Especially for knowledge conservation and electronically supported learning [44, p. 60], the usage of hyperlinked texts and pictures (hypertexts) have become widely spread. Despite the benefits of accessibility and individualization of information transfer, hypertext has weaknesses in presenting dynamic processes. Videos can fill this blank. But until quite recently, videos still had been regarded as passive, with minor applicability of logic that enables the needed interactivity, non-linearity and enrichment abilities [41]. Hypervideos, also known as hyperlinked videos and video based hypermedia [13], can be described as video streams with defined clickable anchors that enable the user to navigate and also to call up further information [32]. The author beforehand structures the video and provides the material in his branching tree of video sequences and annotated texts, pictures, animations, more videos, and audio files [13, 32]. Therefore, hypervideo combines the benefits of audiovisual presentations with a high level of interactivity [47, pp. 11-12].

In this paper, we show how the SIVA Suite, consisting of an authoring tool, a player, and an application server is used to produce a hypervideo in cooperation with a rehab clinic. It helps patients to perform their daily rehabilitation exercises correctly. The exercises were broken down into small steps of action and analyzed regarding necessary knowledge to perform the movement correctly. Furthermore, the requirements for the development of the content and the adaptation of the existing software are described.

2. SCENARIO

Among other services, the Prof. Schedel Clinic provides rehabilitation measures for patients whose cancerous prostate had been surgically removed. The clinic treats approximately 150 prostate patients simultaneously. The patients are male and are aged between 50 and 85 years. They don't

necessarily have previous experience in using a computer but are assumed to be highly motivated to participate in the therapy.

The patients start their three week stationary rehabilitation approximately two weeks after surgery. The surgical removal of the prostate leads to incontinence. During the rehab the patients have daily exercise to strengthen the pelvic floor and regain continence. For a successful therapy the patients have to keep on doing the pelvic floor exercises for 6 to 24 month after returning home.

To support the home training, the clinic hands out a flyer with descriptions of the most relevant exercises to the released patient. But for several reasons this method is ill-suited for the support. First, the correct execution of the exercises is hard to explain using still images and text. Dynamic presentation like video and animation are much better suited for procedural motor skills. In the long term the clinic wishes to establish the hypervideo application as primary source of information for the rehabilitants' individual and home exercises. Due to the German rehabilitation system, after the three weeks of stationary rehabilitation the clinic and their rehabilitants lack any direct interaction channel. Therefore, the clinic doesn't receive feedback whether the patients actually use the flyer and do their exercises. The patients lack the needed guidance for the proper execution of the training. In order to solve this problem of disconnection, we develop a hypervideo for the patients to use after they have been released from the clinic. During the project phase all participating patients ought to use the hypervideo for at least one year after being released from the clinic. The clinic's hypervideo application contains a theoretical introduction into the anatomy and functioning of the pelvic floor and practical workouts. It is mandatory for the patients to first watch the theoretical introduction before starting the practical training. The practical training has three parts: the beginner and the advanced workout each consist of a predefined sequence of exercises. The individual training allows the user to freely select exercises for a training session.

The clinic wants the patients to use the hypervideo each time they do their exercise. A notebook or tablet PC can be used to watch the videos while lying on a gymnastics mat or sitting on a gymnastics ball. The application also logs user data to give the patients an overview over their training. Furthermore the data can be used as an automatic feedback for the clinic. Additionally, the rehabilitants will be given the opportunity to make use of the hypervideo application for their individual training outside group training.

3. REQUIREMENTS

We now present the demands for a hypervideo application supporting users learning and executing procedural motor skills. In cooperation with the rehab clinic the SIVA Suite is used to produce a hypervideo that helps patients to perform their pelvic floor exercises correctly. For the analysis of the demand and requirements of the hypervideo application several interviews with the company management and with the responsible therapists were conducted. According to [34] interviews are suitable for "identifying relevant requirement sources, eliciting existing requirements, and developing new and innovative requirements." Furthermore the exercises were broken down into small steps of action and analyzed regarding necessary knowledge to perform the movement correctly. The therapists participated in all stages of the development process. In the remainder of this paper we will first present resulting requirements for:

- the development of the content,
- the adaptation of the existing software and
- the compliance with legal regulation.

We furthermore present the current state of our software and how it meets the described requirements.

3.1 Meeting the Instructional Requirements for Motor Skills

It is the goal of the hypervideo tool to support patients learning and executing pelvic floor exercises. Research on multimedia learning provides evidence, that dynamic presentations like video and animation are well suited for procedural skills [19]. Especially motor skills like assembly tasks or body movements can be explained using animation or a model that performs the action in a video [6, 25, 46]. In accordance with these research findings, we will produce videos of the therapists performing the pelvic floor workout to illustrate the correct execution of the exercises.

Unfortunately, in several exercises the relevant movement is inside the body and not visible in a video. If the movement in the visual presentation doesn't match the relevant motions of the process to be taught, this seriously impedes the comprehension [24, 45]. For that reason, the recordings of the pelvic floor exercise will be enhanced with anatomic overlay animations of the muscle contraction. The design principles of multimedia learning theories like CTML [26] and CLT [43] will be applied to reduce extraneous cognitive processing and foster the comprehension. In accordance with the Coherence Principle irrelevant details and background music will be excluded. Furthermore, spoken narration will be used for the verbal explanations (Modality Principle). It is important to guide the user's attention to the relevant aspects of the video presentation (Signaling). Therefore, color changes will be used to emphasize crucial elements and movements [10, 15].

The dynamic and transitivity of information in animation impose strong demands on the work memory ([2, p. 335], [7, p. 697], [11, p. 113]). If the information rate is too high, learners can't process a content element before they have to focus on the next one. They miss parts of the content or process them only in a superficial way. The negative effects of dynamic and transitivity can be overcome by segmenting ([18], [26, p. 175]) and adding user-control to animations [19, 20]. The pacing of the video can be controlled using standard VCR buttons, which allow users to adapt the presentation to their individual cognitive capacity.

Taking these findings into account, in the designed pelvic floor application the content is segmented into manageable units. Each exercise consists of two video clips: The first one contains an explanation of correct execution of the exercise. The patients will be instructed to watch the first video clip while sitting on a gymnastics mat. The second clip shows ten repetitions of the exercise. The patients perform the exercise while the narration of the second clip guides them.

When working with the pelvic floor application, users need to access individual workouts and exercises without having to watch the whole video form the beginning. Hypervideo structures allow patients to select which videos they want to access and let them determine the presentation order [17, p.

256]. The self-regulated cognitive processing allows an elaborative knowledge acquisition [13]. But hypermedia can also overwhelm the users and lead to disorientation ([13], [37, p. 290]). To avoid these negative effects, the hypervideo structure must be communicated using a table of contents, timelines, etc. [47]. In most cases hierarchic structures are best suited for learning and support applications because learners understand them quickly without being overwhelmed [1, 16].

In the pelvic floor application we will apply these findings and arrange the video clips in a hierarchical hypervideo structure. Predefined video sequences like the beginner and the advanced workouts help the patients to use the tool. A table of contents allows patients instant access to all videos.

3.2 Software Requirements

The required software suite for the previously described application affords four components: an authoring tool to link all media elements to one overall hypervideo, a data description format into which the hypervideo is exported and which is then read by the player (for a detailed description of these components see [29], [27], and [30]). The fourth component is the web, video, and logging server. The latter one provides the complete videos including the control file and all media files for management and download. Our implementation before we started with this the scenario had all basic features, whereby the back channel from the viewer to the author is rarely used. For the application in the rehab scenario several other requirements need to be fulfilled:

- Logging of user data: Two kinds of user data may be logged while the patient uses the hypervideo. On the one hand, device data with information about the used hardware or screen resolutions can help to improve the quality of experience. On the other hand logged user behavior is of great interest for the clinic to improve their services. The physiotherapist is able to monitor the success of the training and may be able to give further advice. This aspect affords the compliance with data protection regulations because personal data are transmitted and collected.
- Online and offline mode: The player needs to be able to work in online and in offline mode. The end user device has to be online for the initial download of the hypervideo. After that, the user is able to use the player without any Internet connection. When the player gets access to the Internet again, it synchronizes with the server either automatically or after the user confirms the synchronization. This process is especially important for the logging functionality, because the end user devices may be used in environments with low Internet bandwidth. This affords that the volume of the logging data has to be kept as small as possible to avoid long loading times and high bandwidth costs.
- Logical elements in the underlying scene graph: The scenario described in the previous section requires two new fork elements for the scene graph. Up to now, there are two types of transitions: a linear transition where one scene follows the other without user interaction or just a click on a "next"-button. The second type of transition is a selection panel. After a button click, the according scene loads. The extended application has two new types of fork elements:
  - Random selection: The random selection is needed if the user selects the individual training part in the practical section. Then, a random combination of five exercises is selected.
  - Conditional path element: The conditional path element is needed because the viewer should be guided to watch the theory part before he can access the practical section. This order is important because the theoretical part provides information about the correct execution of the exercises. After a patient has watched the theoretical part, he should be able to choose what he wants without being forced to watch the theoretical part over and over again.
- User controlled annotations:
  - Adding another visual layer to the main video: With a button in the menu users can fade in and fade out an additional visual layer of the main video. Annotations of this layer need to be marked as "hidable" by the author.
  - Annotation thumbnails in the side area: By clicking on an annotation thumbnail in the side area they are opened as a pop-up over the main video. Thereby the main video pauses. After closing the annotation, the main video resumes playing.

3.3 Legal Requirements

The use of hypervideo is, from a legal perspective, confronted with two main issues. In the first phase, when the hypervideo is produced, copyright problems need to be addressed. In the second phase, when the patients actually use the system, data protection issues need to be handled.

3.3.1 Copyright

Because of the complex structure of links and annotations, hypervideos are protected works of the copyright after article 2 of the German Copyright Act. But the individual parts, the linked videos and annotated texts, pictures and videos are protected works as well. The publisher - in case he's not the author - therefore needs to obtain a license for making the works available to the public, granted both from the author of the hypervideo and the author of the parts. If the hypervideo ought to be used offline, the users need to obtain a license to reproduce the works. In a medical rehab scenario, this is covered by the statutory right of reproduction for private use in article 53 of the German Copyright Act.

3.3.2 Data Protection

User behavior is logged and later analyzed by the physicians of the rehab clinic to measure and improve the effectiveness of their training. The processing of personal data is forbidden, unless the data subject has unambiguously given his informed consent or there's a statute, which permits or demands it. But these requirements have only to be met, if the specific data relates to a identified or identifiable natural person. Anonymous or pseudonymous data can be processed without further limitations. In the case of a hypervideo platform of a rehab clinic, the data processing is within the scope of different data protection legislations. The logging is regulated by the German Tele-Media Law, the analysis by the

Federal Data Protection Act and the rules of medical confidentiality.

Collecting, logging and transferring personal data of a user is permitted, if it is necessary to operate the hypervideo platform. This depends on the concrete platform features and the technical system used for the service. The legitimacy of a yet to be constructed service therefore can't be judged at this stage. Hence, the goal is to design these determining factors in a privacy-friendly way. This can be done by consequent anonymization or - where the data later needed in a personal form - pseudonymization. Whether data are personal or not, is determined by the knowledge of the controller [14, no. 32]. So the user should sign up with a pseudonym that can be dissolved only by the clinic (because it was generated there) and not by the technical provider of the platform. Data collected under this pseudonym is both personal (for the clinic) and not personal (for the technical provider). Therefore one approach aims for the strict separation of both institutions. If designed this way the logging done by the technical provider is not in the scope of data protection legislation. But these pseudonymized data have to be handled with care. There's always a risk of re-personalization of the data, if too much of it is processed [36]. Hence, data which could potentially identify the user, such as IP-addresses should be deleted after the end the usage process.

The data analysis by the clinic, i.e. to determine the progress in training, requires the transfer of the relevant logged data from the technical provider to the clinic. If transferred data is personal or not depends on the knowledge of the recipient [31, p. 11]. Thus concerning the transfer, the technical provider has to obey data protection legislations, even if the logging itself was no procession of personal data. The article 15 III of German Tele-Media Law specifically only permits the internal procession of user profiles. Therefore, concerning data categories, that are meant to be transferred to the clinic, the technical provider needs the consent of the patients.

But the right to transfer alone is not sufficient, as it leads to a correspondent collection of data on the other side. The clinic thus also needs an enabling provision to collect and analyze the data [8, no. 27]. The collection and processing of personal data of the patients is permitted after article 28 VII of the Federal Data Protection Law, if it is necessary to accomplish the tasks of the clinic in the treatment relationship. This is yet to be determined by the project. At the moment, the clinic needs the consent of the patients.

In a privacy friendly designed system, although the hypervideo platform is realized externally, no patient data leaves the clinic. The data is only processed in a personalized form, if the clinic needs to analyze it for each patient individually. Therefore, the consent of the patients is needed for the data procession done by the clinic and the transfer of the logged data to the clinic. A valid consent calls for an accurate and comprehensive information about the purpose of procession, the categories of data and the recipients [42, no. 70-76]. On the other hand, data, which is only used to i.e. improve the usability of the platform can be logged pseudonymously and processed without limitations.

4. RELATED WORK

Several tools exist, which are capable of producing and playing hypervideos, but they are either not implemented with recent technologies or lack certain needed features for our scenario.

4.1 Authoring Tools for Hypervideos

First authoring tools for hypervideos were designed and implemented in the 1990s, but most of the tools found in the literature are from the early 21st century. In addition to higher computing power, more sophisticated video formats and editing tools became available. The tools found vary widely in their characteristics. The most important and most recent tools can be described in detail as follows:

Advene [3, 4, 5] is a tool for active reading in videos. "One of the results of active reading applied to audiovisual material can be hypervideos, that we define as views on audiovisual documents associated with an annotation structure" [3]. One linear audio-visual document (video) is used as a main medium, annotations are rendered to different views.

Hyper-Hitchcock [39, 38, 40, 41] is an authoring tool for the creation of detail-on-demand video. "Detail-on-demand video is a form of hypervideo that supports one hyperlink at a time for navigating between video sequences" [41]. The main medium is video, additional information is also provided as video. Choice elements for navigation between the video scenes are the key frames of the linked videos. It is not possible to define hotspots for navigation.

Klynt [21] is a web platform for visual storytellers. The desktop editor has a visual storyboard to create a scene graph consisting of video scenes or multimedia pages. Multiple media formats can be added to the videos which are then played in an HTML5 player. Clickable buttons are added to scenes which show additional information or load another scene. The integration of social networks and Google maps is possible.

LinkedTV respectively VideoHypE [35, 9] is a tool for "supervised automatic video hyperlinking". A video can be selected for which then are shots defined. These are arranged in an overview. Chapters can be defined from the shots. It is possible to select, name, and categorize entities. Therefor, hyperlinks can be specified which link to websites. VideoHypE is part of the implementations of the LinkedTV project, for further information see [23].

Critical reflection: The tools described in this subsection are capable of producing annotated interactive non-linear videos to a certain extent. They do not provide all functions needed to create a hypervideo as described in our scenario and outlined in the requirements. Editors for a table of contents, tools to create navigation elements like button panels, and forms to edit keywords for scenes and annotations are not always provided. Furthermore, most of the tools were implemented to show new annotation principles or to combine editing principles, and therefore usability was rarely taken into account. Klynt provides a GUI similar to those known from Adobe products like Adobe Premiere. It furthermore provides a scene graph view, where scenes can be linked with hyperlinks. Advene allows to create hypervideos based on active reading (annotating) and generated rules. Thereby, different new authoring paradigms are proposed. Hyper-Hitchcock allows the creation of non-linear structures, but the only type of medium that can be used is video. This contradicts the intention of creating rich media presentations consisting of different types of media. All four authoring paradigms from [12] can be found in tools and systems for hypervideos.

4.2 Players for Hypervideos

Navigation and player controls vary widely in player implementations for hypervideos. Some new controls and navigation elements are shown in Joscha Jägers prototypical implementation of the "Open Hypervideo Player" which was implemented in HTML5, JavaScript, CSS, and SVG [22]. Most players (except those described otherwise below) were implemented as standalone players for desktops.

The Hyper-Hitchcock player [39, 38, 40, 41] is realized as a stand-alone player for detail-on-demand videos. A non-linear structure and alternative playback paths are defined by several types of links which are represented by the keyframes of linked videos. This form of video offers no clickable hotspots in the video. Controls of the player GUI are buttons for play, stop, and navigation as well as a timeline with a keyframe preview. All videos are displayed in the main video area.

Advene [3] provides two implementations/views for playback. A static view can be described as a "definition of a hypertext document, whose temporality is imposed by the user visualising [sic] it" [3]. In a dynamic view "the temporality of the resulting document is mostly imposed by the audiovisual document. Of course, they also offer some kind of interaction opportunities and the user normally always has the possibility to interrupt playing, [...] but we can imagine kiosk-like approaches where all video controls are deactivated" [3]. Thereby, one audio-visual document can be navigated via timeline or URLs. Neither choice elements which have influence on the video structure nor hotspots provide interactivity to the viewer. The GUI of the player offers standard controls, hyperlinks, an URL stack, navigation links, and a position indicator for navigation in the video. Annotations are shown around the video and as overlay over video. They are mainly text-based.

The Klynt player [21] is implemented as a Web player in HTML5. It provides different customized buttons as overlays on the video for navigation between video scenes and for the display of annotations. These may contain more buttons, images, text, videos, or other web based contents. Furthermore, it is possible to add a Google maps menu consisting of a map with markers which are then linked to video scenes. Other navigational elements are presentation-like screens with buttons to other screens or to video segments. These elements allow the creation of hypervideos with focus on different media types.

The player from the LinkedTV project [33] is designed as a second screen application for desktops, smart phones and tablets. The first screen is used to play the video while the second screen can be used to control the main screen. Furthermore, it is possible to navigate to another chapter in the presentation. The second screen has an interface which shows "detected entities of the video grouped by persons, objects and locations" [33]. Different external control interfaces are available or under development.

Critical reflection: The players described in this section show differences in presenting the additional information and in provided controls. The Hyper-Hitchcock player and Klynt have one single area, where the main video and additional information are shown. The latter are either shown as smaller overlays or they replace the video. The annotations are grouped in different areas around the main video or may be displayed as overlays in the video area in Advene. LinkedTV provides a second screen where annotations are shown according to the contents of the first/main screen. Standard controls like play and pause are implemented in Advene, Klynt, and the Hyper-Hitchcock player. Advene provides different links and a position indicator in addition. Furthermore, the Hyper-Hitchcock player offers a timeline with keyframe preview. Rectangled hyperlink areas are implemented in Klynt. Menu-like structures can be displayed in the Klynt player. Different elements and functions described in this section are needed in our player for annotated interactive non-linear videos, too. Important features are clickable hotspots, basic player controls, and menu-like structures.

5. SIVA SUITE

The SIVA Suite consists of three parts (see Figure 1). Multimedia instructions are created in the authoring tool called SIVA Producer. Its key features are project management, a scene graph, annotation editors, a table of contents editor, and an export function. Exported projects are uploaded to the server application which provides a user, a group, and a video management as well as diagrams and functions for the analysis of logging data. The player can work in two modes, it either downloads the instruction from the server and works in offline mode, or it downloads a control file and required multimedia files when they are needed. Key features of the player are the video playback, the display of time triggered annotations, a table of contents, a keyword search, and a logging function. The latter pushes logging data to the server for further evaluation when a connection exists.

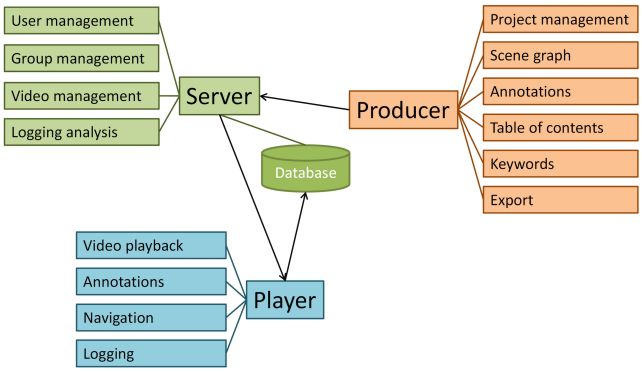

Figure 1: Components of the SIVA Suite and their features.

5.1 SIVA Producer

The authoring tool called SIVA Producer was improved in different areas compared to the version presented in [29]. The previously used video framework JMF was replaced with VLCJ and missing features were implemented. The export and the settings dialog were simplified. The text editor was replaced by our own implementation. The color layout of the whole application was unified, tooltips and more precise labels were added to the buttons. The menu bar was extended with additional functions like a graph checker. The editor for the markings in the video which display an annotation after a user click was revised as well. Figure 2 shows the GUI of the SIVA Producer and the scene graph of the training.

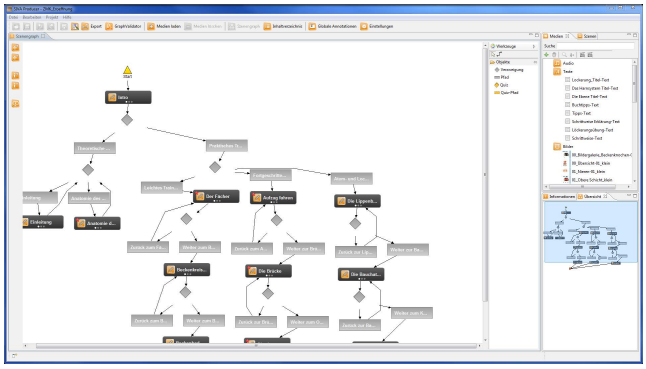

Figure 2: The scene graph editor with the training video.

5.2 Server Application

The server application is used to manage users, user groups, and videos (see Figure 3). A rights management is implemented to ensure that the visibility of videos is restricted according to the demands of the author of a video. Certain materials have to be protected from unauthorized access to protect the copyright. The server furthermore provides the back-end for the logging functionality as well as interfaces to export the logged data in different formats.

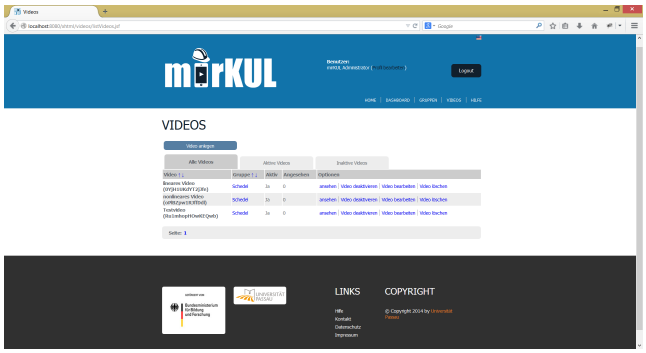

Figure 3: The video overview in the server application.

5.3 SIVA Player

With the implementation of HTML5 in most browsers, even those for tablets and smart-phones, it is now possible to implement one player and use it for all platforms. This makes the maintenance and updates of our previously used players implemented in Flash [29] or for Android devices [28] unnecessary. Our new HTML5 player has a simplified layout with one main annotation area on the right side (see Figure 5) and one navigation area on the left side. Both can be hidden or shown separately. Annotations in the annotation area can be double-clicked and are then displayed in full screen mode while the video pauses. Central buttons are grouped according to their range of applicability. Those needed in a scene are positioned at the bottom, those for the whole video at the top of the player (see Figure 4). A logging functionality is implemented to track the user behavior for individual videos. The logged data are synchronized with the server.

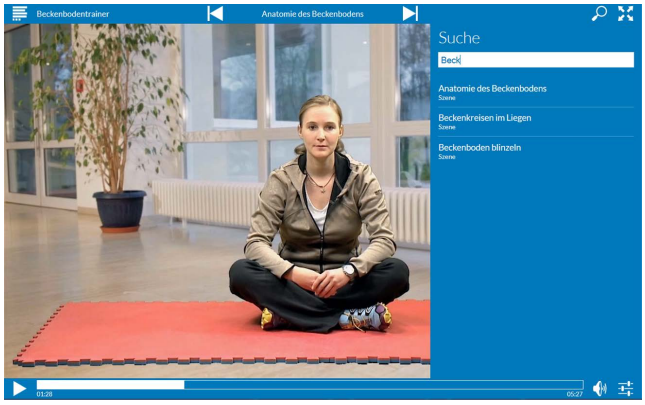

Figure 4: The player with the search area on the right side and the extended button bars at the top and at the bottom (full screen mode).

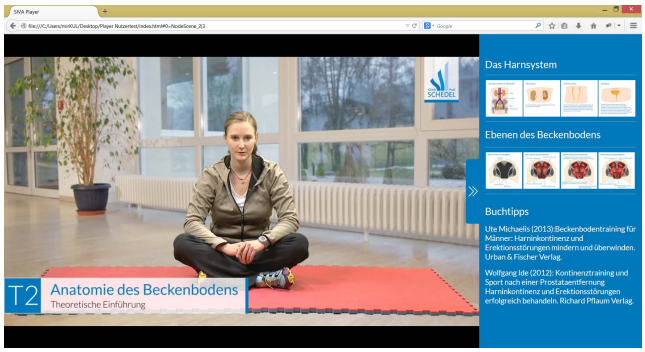

Figure 5: The player with the annotation area on the right side showing two image galleries and a text annotation.

6. DEMONSTRATION

In this demonstration, we show how the SIVA Suite can be used as a multimedia help system for a medical application. We use a rehabilitation scenario for our illustrations. We present the SIVA Producer, the new HTML5 player and its features, as well as the server application with focus on new functions in the medical scenario. With the new features, our software suite can be used for other applications like repair scenarios, introductions for new employees, or installation guidelines as well.

7. CONCLUSION

In this work, we first presented a scenario for the application of hypervideo in a medical environment. In cooperation with our partner clinic, we determined concrete demands for the hypervideo environment. As illustrated above, videos are an ideal mode to present motor processes for rehabilitation exercises. The hypervideo structure allows users to quickly access individual videos. To meet the requirements of the clinic, the existing software was extended. Needed features were the logging of user data, a training diary, an online and offline mode, logical elements in the underlying scene graph, and user controlled annotations. From the legal point of view, data protection regulations have to be met by using pseudonymization and anonymization. If personal

data is necessary, the clinic needs the consent of the patients. Within the project we develop the new hypervideo system based on the presented requirements. The design and key features of the software are outlined, as well as how the server, the authoring tool, and the player communicate. Extensions for previous work are described and new screenshots are provided. The application will be evaluated in several user tests and an extensive trial with patients.

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