Va.Si.Li-Lab as a collaborative multi-user annotation tool in virtual reality and its potential fields of application

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ABSTRACT

During the last thirty years a variety of hypertext approaches and virtual environments – some virtual hypertext environments – have been developed and discussed. Although the development of virtual and augmented reality technologies is rapid and improving, and many technologies can be used at affordable conditions, their usability for hypertext systems has not yet been explored. At the same time, even for virtual three-dimensional virtual and augmented environments, there is no generally accepted concept that is similar or nearly as elegant as hypertext. This gap will have to be filled in the next years and a good concept should be developed; in this article we aim to contribute in this direction and also introduce a prototype for a possible implementation of criteria for virtual hypertext simulations.

CCS CONCEPTS

• **Information systems → Collaborative and social computing systems and tools**; *Multimedia information systems.*

KEYWORDS

virtual reality, virtual hypertext, authoring system, virtual reality simulation

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1 INTRODUCTION

Software for interpreting, visualizing, using and authoring of hypertext is probably one of the most frequently used applications within any information system. However, this is independent of the application scenario, whether in a private [40] professional [28] or academic [59] environment. In addition, [30, 63] provides a broad overview on this topic. Besides, various hypertext concepts have been presented, introduced, and prototyped over the last thirty years. In this context, the approaches of spatial [47], taxonomic [39], and sculptural hypertext [24] are particularly important developments. These individual concepts, with the extensions mentioned, encapsulate the basic concept of hypertext, the visualization of nodes, the relation of nodes represented by edges, the visualization of information within nodes, and the linking of these nodes [11]. This simple and still complex as well as elegant and world-changing concept of hypertext has started a victory journey, which cannot be missed today. Moreover, there is also a modern possibility of annotating information units within hypertext systems [1]. These information units can adopt a manifold appearance in virtual environments and range from texts, text segments, images, image segments, video and audio representations as well as their segments via web pages in a browser all the way to individual 3D objects or more complex constructs, such as virtual agents or assistance systems, among others.

However, as with any concept that has been around for a long time, it is important to think about whether the concept is still appropriate when increasingly recent technological advances are considered. Within this context, the current development in the virtual and augmented reality field can be especially considered. As we look into the literature, we quickly realize that there are not too many virtual reality (VR) – (e.g. [35]) and even fewer augmented reality (AR) applications (e.g. [51, 58]) that explicitly implement any of the hypertext concepts mentioned before (c.f. [33]).

In this paper we aim to apply the ongoing development, in particular in the field of VR, as an opportunity to identify criteria for the appropriate use of hypertext systems as virtual simulations (Section 2). After this identification, we classify already existing VR tools into these criteria and enable a comparability (Section 3). Afterwards, we present our Va.Si.Li-Lab-approach[1] [34] for implementing hypertext in VR environments (Section 4) and exemplify possible application scenarios in Section 5. Afterwards, we provide an outlook on future extensions and conclude with a summary (Section 6).

2 VIRTUAL REALITY ENVIRONMENT AS HYPERTEXT SIMULATION

Virtual reality environments are as flexible as they are versatile in terms of design, implementation and interaction possibilities. Not only in the area of games (e.g. [13, 31]), training and teaching (e.g. [18, 60]) or simulation-based learning (e.g. [34]) virtual reality applications are of great importance. Regardless of the different application fields, a VR environment needs a number of features to make different aspects of hypertext representable, editable and usable. These features are not exhaustive and certainly not all applications, in view of their application focus, require a complete implementation of all the following criteria:

A) **Platform independence**
There are different ways of interacting with virtual environments, which rank on the immersion scale between mixed and virtual reality on the one hand and all the way to pure browser interaction on the other. In order to setup and offer different learning scenarios, a large variety of access and interaction channels are required. In addition, it is important that directed as well as undirected interactions are supported.

B) **Scenario editing feature**
In order to be able to map different situations, it is important that scenarios can be designed flexibly and dynamically. This implies the creation of scenario and participation parameters, the construction of a sequence of possible situations, the composition of the periphery, the appearance of the environment, the inclusion of objects, and the implementation of action spaces for the execution of events. Furthermore, the integration of multimodal media should be possible, which includes the use of audio, video and animations.

C) **Multimodal data model**
Since the process of running simulations can involve a variety of goals, it is important to be able to collect, store, and reuse a wide variety of data as it is generated. In order to enable this, a database-supported data model is required, which can optimally dynamically accommodate and map different recorded data sets. This includes, in particular, the recording of speech, movement and interaction data as well as the observation of eye positions and body postures.

D) **Avatar design**
To ensure the utmost realistic, individual, and most importantly, distinguishable participant contribution, the design, modification, and reuse of avatar appearance is required. As a result, each active user in a virtual environment can appear with a virtual counterpart to interact with other users as well as with content.

E) **Multi-user and multi-mode feature**
In a simulation, the ability to interact with multiple persons using the virtual environments simultaneously is of paramount significance. In order to use the simulation in a well targeted approach, it is also necessary to be capable of assigning the individual persons with roles adapted to the scenario, which is admittedly optional.

F) **Mutual interaction features**
Regardless of whether a simulation is performed with one participant or several, the ability for users to interact with each other and with objects should be provided. This includes the interaction capabilities of audio-visual communication with each other, the usage of gestures, the ability to use and move objects, as well as the modification of the environment, if the scenario parameters enable this.

G) **Quantitative evaluation**
All information acquired in a simulation regarding movement, spoken speech, interaction with objects, as well as other information depending on the scenario, needs to be stored in a structured way, assigned to the scenario and the users. Moreover, this also includes the reconstruction, the composition as well as the post-processing and the export of the gathered information in order to provide it for further analysis.

H) **Qualitative evaluation**
Not all results can be determined quantitatively and include many situational components, which are not or only with some effort possible in a retrospective evaluation. In order to evaluate the simulation qualitatively, it is necessary to provide the possibility of a real-time observation by a third user, which – even without direct interaction with the simulation – can be monitored.

I) **Visualize, browse, and interact with content-information**
Regardless of the application and the parameters of usage, it is essential that information such as text, images, videos, etc. are presented in a meaningful, usable and clear manner, to avoid "problems with hypertext [...] of disorientation while navigation the information space." [37, p. 298] These include the possibility of filtering, the limitation of too much information, the possibility of pagination to visualize further information as well as an intuitive interaction feature. The interaction includes, in addition to a selection feature, the possibility of entering data as well as the composition of new or existing elements.

J) **Individualization of object and environment parameters**
A virtual environment becomes like a working desk, filled with applications, with personal settings for fonts, font sizes, colors, and frequently used features and functions. Beyond

[1] Va.Si.Li-Lab: **V**R-L**a**b for **Si**mulation-based **Le**arning

that, however, it is equally important to be able to design and modify one's own appearance, namely the virtual avatar.

K) **Privacy, data protection, restrictions and access permissions**
Related to the ability to visualize and provide information, there is inevitably the need to be able to define constraints on which information is available to which users, and which can also be modified. For this purpose, functions for the valid display of content are just as essential as the guarantee of data protection and the existence of an access control system.

L) **Automatic environment shaping through Active Learning**
In times of ChatGPT and active learning [49], it is evident for a virtual environment, in which every user operates, to be automatically adapted and reshaped by the user's interactions and activities, so that the functions and applications can be used in an optimized and personalized manner.

While this list is certainly not exhaustive, it does allow for a first, more systematic evaluation of existing applications that strive to, or at least imply to, integrate the notions of hypertext and VR. This will be done in the following section.

3 RELATED WORK

Since there are various forms of visualization [3] and applications in the field of VR [5, 46], we focus on applications that have at least a fully-immersive component. For this reason, tools such as *SecondLife*[2], *OpenSimulator*[3], as well as tools such as VEMA (Virtual Eletrical MAnual) [57], which are only available as desktop virtual reality, are not included. In addition, the tools we are comparing are mostly in the context of STEM (Science, Technology, Engineering, and Mathematics) [43], since there are a lot of fully-immersive VR applications in this context. Furthermore, for the purpose of a homogeneous comparison, we selected tools from this area.

All the following tools will be described in a basic sense and their implementation of the criteria mentioned in Section 2 will be indicated whether they have been fully implemented, partially implemented or not implemented, which will also be summarized in Table 1. In general, we show that the tools studied here do not satisfy the features J–L.

In the first tool that we consider, pupils are educated about the hardware structure of computers [14]. Here, within a virtual environment, *Bill's Computer Workshop* is mapped to experience an understanding of hardware interactions. *Bill's Computer Workshop* tends to be able to run on multiple platforms (A), but it does not appear to have a scenario editor (B) or a multimodal data model (C). Regarding the avatar creation, no statement can be given, as the project is not available (D), although a multi-user capability (E) is not described. In addition, however, interaction with the virtual environment is possible (F) along with information, but in a limited form (I), as well as quantitative and qualitative evaluation (G, H).

The second system is *Maroon* [45], which is implemented as an interactive laboratory with an experimental setup in Unity. For this purpose, Maroon has been designed to simulate physical experiments. Since Maroon was implemented in Unity, it is basically possible to use it on different platforms (criterion A) and the interaction with objects (criterion F) is also guaranteed. However, Maroon lacks of the multi-user feature (criterion E) as well as Avatar design (criterion D). Since no data is recorded (criteria C and G) and the scenarios can only be edited manually (criterion B), in the final analysis only qualitative evaluations (criterion H) can be performed. In addition, since no information can be visualized or interacted with, feature I is not applicable.

A third system is *HandLeVR* [36], which provides a virtual environment for training professional skills in vehicle painting in Unity. HandLeVR is only implemented for this scenario and offers several extensible use cases for it. It is only single-user capable (E), no avatars are required (D), but the simulation can be parameterized in the context of the application and can also capture recordings (B, C). This allows a quantitative (G) and qualitative (H) evaluation. Feature I, in turn, can only be fulfilled to a limited extent, since only static information can be presented, but these can be interacted with.

With *FLAIM* [19] a fully immersive VR learning solution is offered for simulation-based learning in hazardous and emergency situations. Since it is a commercial product, there is limited information that can be provided about the individual properties, but its application is limited for the given scenario.

In addition to listing other commercial tools for emergency response and firefighting, [9] also introduces its own solution, *Immersive multi-user firefighter-training scenarios*, hencforth denoted by IMUFTS. IMUFTS is a prototype and describes an implementation using multi-user training methods and full-body avatars together with motion-capture-based VR technologies. Since the underlying simulation room must be equipped with cameras, portability is only possible with great effort (A). However, it comprises a data model (C) and uses avatars (D) and provides a multi-user (E) and an interaction option (F). Based on the data model, quantitative (G) evaluation should be equally possible as qualitative (H). However, any scenarios must be created manually just as with other tools (B) and no information (I) is visualized.

In another context, the project of [8] combines the complex application areas of architecture with VR to provide a tool for crime prevention. This prototype based on immersive learning experience aims to provide a deeper understanding of Crime Prevention Through Environmental Design (CPTED) concepts and to optimize the traditional CPTED-curriculum. As a result of its implementation in Unity, (criterion A is basically fulfilled, but all others not, with the exception of (criterion F – however, this assessment depends on the application design.

Next, *Immunology learning VR* [65] presents a prototype in the learning context of immunology, also addressing the issue of storytelling and the transfer to everyday circumstances by using virtual environments. Since it is implemented in Unity, there is the possibility of platform independence (A), but the other features are lacking, with only a qualitative evaluation being considered (H). Also in the medical field, the *Interactive virtual reality medical simulator* (iVRms) is used in [27] to support learning about the topic of retrosomatic musculature starting by showing a video that exemplifies an operation and afterwards enabling the users to perform

[2]https://secondlife.com/
[3]http://opensimulator.org

the demonstrated operation. Since it is also implemented in Unity, (criterion A is fulfilled, however, a dynamic scenario editor (B) is not available, although a multimodal data model (C) as well as an iteration option (F) are available. Furthermore, output of avatars (D), multi-user support (E) and information interaction (I) are not available, although this is necessary in the given simulation context. However, an evaluation is at least partially possible (G, H). In addition, the prototype of [53] allows students to learn and study together in the context of neuroanatomy (NEURO). Implemented in Unity (A), it does not meet any criteria except for interacting with objects (F) and the evaluation criterion (G, H).

EVE:SME[4] is a multidisciplinary application, which presents a simulation environment in the areas of physics, biology, chemistry, as well as further capabilities of consumption of, e.g., recorded lectures. This *Simulation Multiple Environment* (SME) meets (criterion A because of being developed in Unity. Moreover, there is a multimodal data model (C), an interaction function (F), and a basic way to interact with information (I). Since a database is used, a quantitative evaluation (G) is also possible.

Next, *TeachLivE* [12] (TLE) enables realistic interactions with believable virtual humans, analyzes verbal and non-verbal interaction data its users and helps to implement research-based teaching methods. Besides, the *virtual BIM reviewer* (VBR) [62] presents an immersive implementation, which allows several participants to work together on engineering tasks in order to train a mutual collaboration. VBR is also implemented in Unity (A), but does not have a dynamic scene editor (B) and no capability to interact with information (I). However, there is a multimodal data model (C) as well as the possibility to interact and communicate with multiple users (E) and to interact with objects (F). While an avatar cannot be changed, a personalized user image can be placed over the avatar (D) and evaluation possibilities (G, H) also exist. Also operating in the training sector is [10]'s immersive authoring VR tool (IA-VR), which enables users to learn how to maintain machines or construct them. For this purpose, an instructor records movements, which can then be mapped as a choreography and can be repeated by the trainees. IA-VR is also implemented in Unity (A), includes a scenario editor (B) and also meets all other criteria, except for avatar design (D), multi-user scenarios (E), and information interaction (I).

Regarding languaculture learning, [61] present an immersive solution based on a model of the *Forbidden City*. The application is commercial and has been implemented for the mentioned purpose. Therefore, it satisfies few to none of the defined criteria. With the "Interactive Pedestrian Environment Simulator" [41] (IPES) a system is presented, which aims at improving interaction observation and analysis of cognitive abilities in a virtual environment by creating urban environments in which scenarios can be simulated. This tool is again implemented in Unity and thus meets feature A. However, it misses a scenario editor (B), a multimodal data model (C), an avatar designer (D), a multi-user mode (E), and the information interaction function (I). Nevertheless, interaction (F) and quantitative evaluation capabilities (G) are both given.

Finally, in a space simulation named "Titans of Space" [15] users have the possibility to move freely in the solar system and have a virtual guided tour with information, among others, on the distance to star systems. The aim of the simulation is to find a correct path to a destination [44]. The application is also implemented in Unity (A), but it lacks the other criteria, while qualitative evaluation options (H) are given.

Table 1 gives an overview of the comparative analysis of the tools considered so far. It shows that criteria B, C, D, I-L are hardly fulfilled by these systems: editors of virtual scenarios are mostly missed as are data models of multimodal communication (for a formal version of such a model in the context of VR see [34]). Avatar design (D) is also a special case as it relates to enabling avatar diversity and self-representation [64], both of which are required in VR systems especially in the area of learning and teaching in social contexts. Criteria I-L could be classified as more technical, but Criterion I, for example, points out that interaction with 3D representations of information units could be an important component of VR systems – again in the context of learning. This analysis shows that more powerful systems based on VR that incorporate hypertext-relevant concepts such as interaction with information units are still not available. We now show that the recently developed system Va.Si.Li-Lab [34] fills this gap with respect to the majority of these criteria and can therefore be used as a starting point for exploring and developing the notion of hypertext in the context of the metaverse.

4 VA.SI.LI-LAB

Many tools meet few to none of the criteria listed in Section 2. To close this gap, we start from Va.Si.Li-Lab, as a prototype for the use of hypertexts in 3D virtual environments based on collaborative interaction with both hypertexts and agents. In addition, up to now, annotation software has focused on storing and managing the results of annotation processes, but not on the data of these processes themselves. Va.Si.Li-Lab is being developed as a system that incorporates VAnnotatoR [33] and therefore allows both the annotation results and the annotation process data relevant to the creation of that data to be collected and managed. In this way, it becomes possible to reconstruct annotation processes starting from annotation results, namely with regard to the processes of their creation. The annotation process as a whole thus becomes comprehensible as a virtual, reconstructable hypertext process.

Va.Si.Li-Lab combines two areas, annotation and visualization of information entities such as texts, images and their relations, as well as interaction with these entities (e.g. portals, navigation, preview mode) and recording of all user actions such as their movements and object interactions. The first is ensured by the integration of the VAnnotatoR and enables the visualization of texts, images and other content (virtual browser) as well as the possibility to sort and group objects (virtual boxes), which has already been presented in previous works [32]. Through the reuse of existing work, we reduce a re-implementation overhead while being able to focus on the second aspect: the collaborative use of virtual environments and the annotation of actions, movements as well as object interactions. In a previous implementation of VAnnotatoR [1], the possibility of collaborative and simultaneous annotation of multimodal information units was already enabled by outsourcing this using TextAnnotator [2] (see Figure 2). Through this, users of VAnnotatoR– each for himself in his own virtual environment – can perform annotations while TextAnnotator transfers them to

No.	Tool / Framework	Reference	A	B	C	D	E	F	G	H	I	J	K	L
1	EVE: Bill's Computer Workshop	[14]	satisfied	not satisfied	not satisfied	unknown	not satisfied	satisfied	satisfied	partially satisfied	partially satisfied	not satisfied	not satisfied	not satisfied
2	Maroon	[45]	satisfied	not satisfied	not satisfied	not satisfied	not satisfied	not satisfied	partially satisfied	partially satisfied	not satisfied	not satisfied	not satisfied	not satisfied
3	HandLeVR	[36]	satisfied	partially satisfied	partially satisfied	not satisfied	not satisfied	satisfied	satisfied	partially satisfied	partially satisfied	not satisfied	not satisfied	not satisfied
4	FLAIM	[19]	not satisfied	not satisfied	partially satisfied	partially satisfied	not satisfied	satisfied	partially satisfied	partially satisfied	not satisfied	not satisfied	not satisfied	not satisfied
5	IMUFTS	[9]	partially satisfied	not satisfied	partially satisfied	satisfied	satisfied	satisfied	partially satisfied	satisfied	not satisfied	not satisfied	not satisfied	not satisfied
6	EVE: CPTED	[8]	satisfied	not satisfied	not satisfied	not satisfied	not satisfied	satisfied	not satisfied	partially satisfied	not satisfied	not satisfied	not satisfied	not satisfied
7	Immunology learning VR	[65]	satisfied	not satisfied	not satisfied	not satisfied	partially satisfied	partially satisfied	not satisfied	partially satisfied	not satisfied	not satisfied	not satisfied	not satisfied
8	iVRms	[27]	satisfied	not satisfied	satisfied	not satisfied	not satisfied	partially satisfied	partially satisfied	partially satisfied	not satisfied	not satisfied	not satisfied	not satisfied
9	NEURO	[53]	satisfied	not satisfied	not satisfied	not satisfied	not satisfied	satisfied	satisfied	partially satisfied	partially satisfied	not satisfied	not satisfied	not satisfied
10	EVE:SME	[4]	satisfied	not satisfied	partially satisfied	not satisfied	not satisfied	satisfied	satisfied	partially satisfied	partially satisfied	not satisfied	not satisfied	not satisfied
11	VBR	[62]	satisfied	not satisfied	satisfied	partially satisfied	satisfied	satisfied	satisfied	partially satisfied	not satisfied	not satisfied	not satisfied	not satisfied
12	IA-VR	[10]	satisfied	satisfied	satisfied	not satisfied	not satisfied	partially satisfied	satisfied	partially satisfied	not satisfied	not satisfied	not satisfied	not satisfied
13	The Forbidden City	[61]	partially satisfied	not satisfied	not satisfied	not satisfied	not satisfied	partially satisfied	not satisfied	not satisfied	not satisfied	not satisfied	not satisfied	not satisfied
14	IPES	[41]	satisfied	not satisfied	not satisfied	not satisfied	not satisfied	satisfied	satisfied	partially satisfied	not satisfied	not satisfied	not satisfied	not satisfied
15	Titans of Space	[15]	satisfied	not satisfied	not satisfied	not satisfied	not satisfied	not satisfied	not satisfied	partially satisfied	not satisfied	not satisfied	not satisfied	not satisfied
16	VA.SI.LI-LAB	[7, 34]	satisfied	partially satisfied	satisfied	partially satisfied	satisfied	satisfied	satisfied	partially satisfied	satisfied	partially satisfied	partially satisfied	not satisfied
satisfied			13	1	4	1	3	10	8	1	1	0	0	0
partially satisfied			2	2	4	3	1	4	4	14	4	1	1	0
not satisfied			1	13	8	11	12	2	4	1	11	15	15	16
unknown			0	0	0	1	0	0	0	0	0	0	0	0

Table 1: Comparing VR-based systems according to the criteria of Sec. 2. Legend: satisfied ( ), partially satisfied ( ), not satisfied ( ), unknown ( ).

all collaborators, so that they are informed about the state of the annotation.

With VA.SI.LI-LAB, we are now taking a significant step further by enabling the sharing of virtual environments. To achieve this, VA.SI.LI-LAB uses a modified version of UBIQ [20], which serves as the communication layer for interaction between users. As visualized in Figure 1, UBIQ uses a virtual structure of rooms where users can gather. Within these *rooms*, UBIQ transmits all information between users in the same *room*, allowing users to hear, see each other and share objects. Furthermore, (a) all information about spoken language, all movements as well as all object interactions are recorded via Ubiq, transmitted to all users in the same room, so that they are able to speak and collaborate with each other and (b) all mentioned data are stored in a database, anonymous and related to the scene, in order to evaluate them afterwards. Within a room, different *scenes* can be mapped and configured, and explicit annotations can be created via VANNOTATOR. Rooms and scenes are configured via a database and managed by super users (*Admin*).

VA.SI.LI-LAB fulfills most of the criteria of Section 2. Through the implementation in Unity, criterion A is fulfilled, which allows a flexible and portable reuse. At the same time, providing a multimodal data model (D), the ability to interact (F) with multiple users simultaneously and collaboratively (E) establishes the basis for evaluating implicit annotations in a quantifiable evaluation (G). Although scenarios can be parameterized and managed via the database, they still have to be created manually (criterion B). Furthermore, while it is currently possible to use avatars from UBIQ as well as Meta [7], modification is currently only possible to a limited degree (criterion D). In addition, the implementation of the environment individualization (J) as well as the implementation of data security and access permissions (K) is currently only possible within the use of VANNOTATOR. Finally, the function of automatic adaptation and optimization of the virtual environment, rearrangement of objects by means of active learning (L) is currently not implemented.

5 USE CASES

Virtual hypertext simulations using immersive VR technologies offer a variety of application possibilities which can be modeled in different use cases. In the long term, it would be desirable not to develop individual and independent applications that correspond to the multitude of use cases, but instead to design a hypertext framework that fulfills the individual requirements, which can be flexibly expanded, and which conceptually withstands technological change. Since there currently is no such application, and VA.SI.LI-LAB can provide as a blueprint and starting point for such an application, we describe the following several use cases, which we have selected because they are directly related to the availability of several criteria defined in Section 2.

Simulation-based learning

Simulation-based learning is a practice in which individuals can learn to accomplish real-world scenarios and tasks from simulated application contexts. Moreover, this type of collaborative learning has become more influential in recent years (c.f. [16, 26, 38, 48, 56]). In this respect, immersive VR technologies can help to implement a suitable approach for the perception and anticipation of scenarios (with regard to the individualization of avatars – criterion D). Moreover, it is crucial for a learning environment to be able to

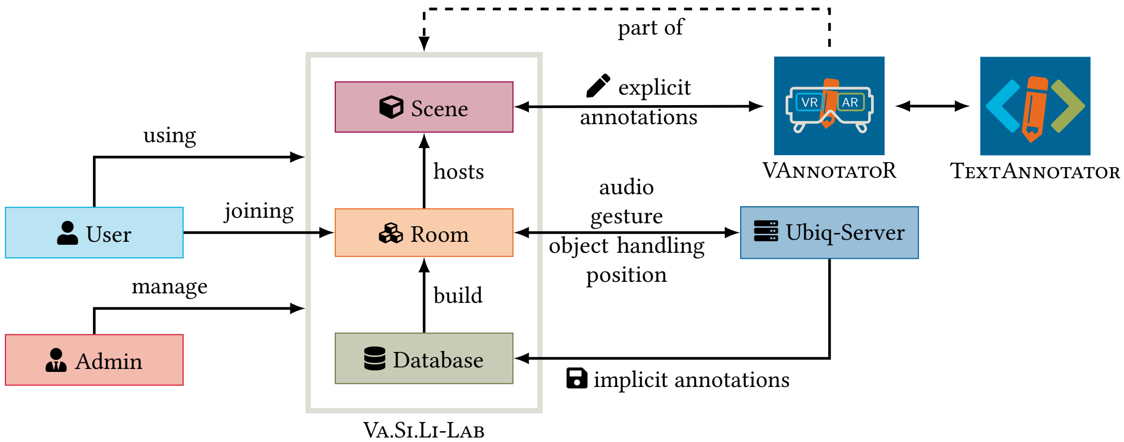


Figure 1: Va.Si.Li-Lab-components and their relations. Users enter Va.Si.Li-Lab and join available rooms with associated scenarios; these are generated based on information from the database, which can be edited by administrators, although the environment itself still needs to be created manually. While being in a room, users are informed about the respective scene which can be executed in different rooms. In the rooms, users can interact with each other, communicate, use objects, and move around. Within a scene, users can use VAnnotatoR to make explicit annotations on objects, texts or images. All actions within a room are relayed by the Ubiq-Server to all other users in the same room. At the same time, all information is anonymously stored in a database for later quantitative analysis.

define and adapt tasks, roles of participants, goals (C), and to provide participants with the possibility of communication (e.g. verbal, textual, gestural – (F), interaction (e.g. modification of objects or object positions – (F)), authoring (annotation and commenting of objects and situations), as well as collaborative and therefore shared use of environments (E). In addition, an evaluation of both quantitative (e.g. *which objects were interacted with?*, *in which context?*, *with which linguistic statements?* - (G)) and qualitative (e.g. *how did the participants behave?*, *which observations were made?* - (H)) perspectives is necessary, enabling observers and researchers to reach conclusions about previously defined research questions [34].

Crime scene analysis

In order to understand crimes and their circumstances as well as to be able to analyze and evaluate facts, it is common practice to reconstruct a crime scene and its characteristics, also in VR (e.g. [21, 23]). Also this use case requires a flexible design of environments (criterion B), the parameterize generation (criterion C) and, optimally, the automated creation of scenes (e.g. [1] with subsequent detail adaptation, including the possibility to place information and objects and to enhance them with animations (I). In addition, with the reconstruction of crime scenes also an evaluation with the Crime, which can be performed by a qualitative evaluation capability (G) in connection with implicit movement and object annotations performed in the reconstructed crime scene (F).

Training and exercise

In schools, universities, professional training and continuing training, a continuous demand for the adaptation of new and more contemporary and better training and exercise possibilities for application areas of the various disciplines occurs (e.g. medicine [29], chemistry [17], learning in general [16]). Also in this case, a flexible database structure (C) and an editor for the scenario (B) creation with a possible collaborative utilization (F) as well as the potential of qualitative (G) and quantitative (H) analysis of data have priority, as well as the portability to different device types (A) in order to achieve the widest possible accessibility (c.f. [6]).

Virtual museums

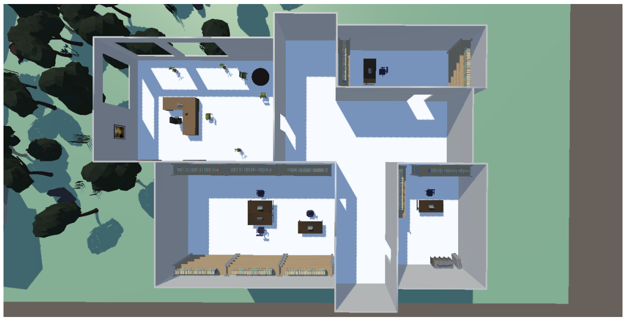
Museums are places where cultural artifacts are collected, which visitors usually have to *physically* visit. Here, virtual environments or virtual access to museum exhibits enable remote visits and enhanced interaction possibilities. There are currently a lot of such approaches (e.g. [22, 54, 55]). However, these are isolated solutions, which makes their overarching use and the uniform, integrative recourse to our cultural heritage difficult. Additionally, in order to be able to experience museum content in an authentic way, it is necessary to be able to generate a virtual environment (criteria G, C), as well as to use this environment on different platforms (A), and obviously to represent and interact with informations, multimedia content as well as extended references (I).

Historical Interactive Reconstructions

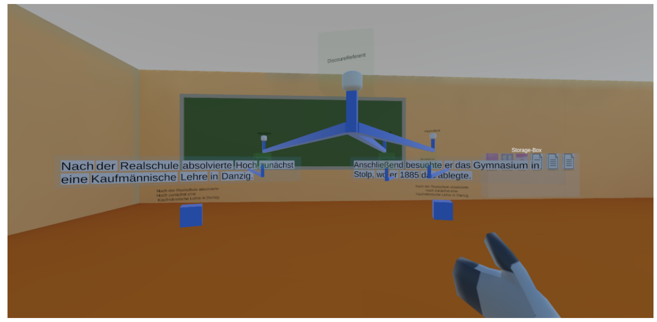
In many cases, historic buildings have not been preserved or are often at least difficult to access and therefore suggest making them accessible by means of virtual replicas. In this regard, there is, for example, the *Time Machine Project*[4] at the European level.

These 3D reconstructions should ideally be multimodal and interactively annotatable. At the same time, in historical reconstructions it is important to identify which of their segments are authentic and which are constructed due to missing information. There are already implementations (e.g. [3, 42, 52]) in this area, which underline

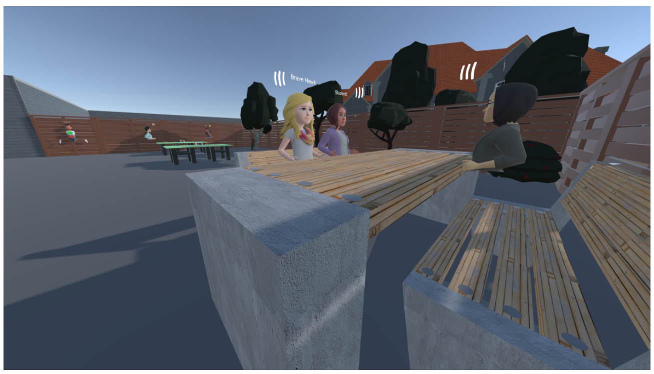
[4]https://www.timemachine.eu/



(a) An office environment scenario.



(b) Annotation of a sentence by means of VAnnotatoR.



(c) Several users, each represented by an Meta Platforms' avatar, are interacting in a schoolyard scenario. The users sit around a table and talk to each other where speech is visualized by icons close to the avatars. In the background, users can be seen as bystanders.

(d) A scene based on Ubiq's avatars interacting with each other while they are handling a document.

Figure 2: Exemplary application scenarios.

the need for a hypertext simulation for such purposes. Therefore, the reconstruction of historical buildings and the use of those also requires a database supported visualization (criteria C, I) and interaction with information (F) units as well as the possibility of a collaborative experience (criteria D, E).

The mentioned use cases are a subset of a broader spectrum of possible applications of virtualized hypertexts. This listing and its connection with the criteria of Section 2 indicates the extent to which Va.Si.Li-Lab can already be used as a starting point for their realization. Va.Si.Li-Lab is not yet ready made for this purpose as indicated by Table 1. However, by using VAnnotatoR and the architecture depicted in Figure 1, it stands out considerably in comparison to other systems. Obviously, especially criteria B, D, E, as well as I–L are not implemented by the majority of alternative systems. This suggests that these alternatives are more likely to result in isolated solutions because they do not support the required flexibility (B), avatar creation (D), multi-user capability (E), and interaction with information units (I).

Va.Si.Li-Lab is still at the beginning of its development, also with regard to the connection of the concepts of hypertext and virtual reality. It further development will regard the implementation of a scene generator (e.g. [25]) for scenario- and user-specific environments, which allows them to be shared and reused. In addition, the inclusion of increasingly immersive avatars (e.g., based on Unreal) is important to also increase the immersion of interpersonal interactions [50]. In addition, the implementation of criteria J and K is just as important as the integration of active learning and finally a broad user study that addresses the added value of virtualized hypertexts [7].

6 CONCLUSION

We discussed the usage of Va.Si.Li-Lab as a novel hypertext simulation environment. Va.Si.Li-Lab enables users to visualize information within virtual hypertext systems, to navigate between and interact with them as well as to perform annotations. During this process, all movement, interaction and communication data are recorded by Va.Si.Li-Lab and are thus available for subsequent research. In so far as Va.Si.Li-Lab is used as a virtualized annotation framework, it therefore enables the reconstruction of annotation results as well as of the data related to the annotation process: the results of annotation thus become as reconstructible as the process of their (interactive) creation. For ensuring further development and reuse of Va.Si.Li-Lab, it is published via GitHub[5] and is available under the AGPL license.

[5]https://github.com/texttechnologylab/Va.Si.Li-Lab

ETHICAL ASPECTS

The results of this paper have been prepared taking into account ethical aspects. We investigated Va.Si.Li-Lab in the context of its potential use as a platform for virtualizing a number of applications. This concerned its use as a framework for hypertext systems to design virtual environments, to represent multimodal content, and to annotate and interact with this content in a multi-user system. As Va.Si.Li-Lab currently exists as a prototype and its use has so far been carried out exclusively in supervised evaluations, it has been possible to ensure compliance with ethical standards. However, since Va.Si.Li-Lab is to be used as an open framework, a) future users – especially in scientific applications – must establish ethical control instances as well as b) have the possibility to block users in case of violations of the defined guidelines. This, of course, requires a moderation system and active moderation.

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