EUROGRAPHICS Workshop on Graphics and Cultural Heritage (2021)
A. Chalmers and V. Hulusic (Editors)

Virtual Dance Museum: the case of Greek/Cypriot folk dancing

A. Aristidou[1,2†], N. Andreou[1,2], L. Charalambous[1], A. Yiannakidis[1], and Y. Chrysanthou[1,2]
[1]University of Cyprus, Nicosia, Cyprus
[2]CYENS Centre of Excellence, Nicosia, Cyprus

Abstract

In this paper, we have designed and developed a virtual dance museum to provide the technological tools that allow for widely educating the public, most specifically the youngest generations, about the story, costumes, music, and history of our dances. The holistic documentation of our intangible cultural heritage creations is a critical necessity for the preservation and the continuity of our identity as Europeans. In that direction, we have employed a specially designed relational database schema that holistically structures the information within the database, and is ideal for archiving, presenting, further analyzing, and re-using dance motion data. Data have been retargeted to a virtual character, dressed with traditional uniform and simulated to achieve realism. The users can view and interact with the archived data using advanced 3D character visualization in three ways: via an online 3D virtual environment; in virtual reality using headset; and in augmented reality, where the 3D characters can co-inhabit the real world. Our museum is publicly accessible, and also enables motion data reusability, facilitating dance learning applications through gamification.

CCS Concepts

• ***Computing methodologies*** → *Motion capture; Mixed / augmented reality;* • ***Applied computing*** → *Digital libraries and archives; Interactive learning environments;*

1. Introduction

Cultural heritage is the mirror of a nation; it reflects its origins, evolution through time and values. The culture of a nation manifests the identity of people belonging to a certain social group, but at the same time gives indications on the influences that arise between groups at different stages, and under different administrations (religion, conquerors). A nation's culture consists of both tangible and intangible assets. Tangible creations refer to physical artifacts, such as artistic creations and built heritage, while intangible artifacts comprise of a range of non-physical assets, such as collective knowledge of skills, practices, expressions, art, fashion, and others that do not have a tangible form. Over the last two decades, and due to the recent technological advances, a significant effort has been devoted by archaeologists and researchers for the conservation, preservation, and documentation of mainly tangible assets [KDD*14, BPMYSYT*19, SGII06, AGII08, BFG*12, ZCBRC07, IGS05, IAGK09]. However, even though tangible and intangible creations are of equal importance - as stated by UNESCO, intangible cultural heritage (ICH) is the mainspring of humanity's cultural diversity and its maintenance guarantees the continuity for creativity - the digitization of intangible creations has only recently begun [SAS*12, KGCL18].

In this work we focus on documenting, visualizing, and disseminating aspects of one of the most valuable intangible creation: our folk dance heritage. Greece and Cyprus, among other countries in the region, have a rich repertoire of folk dances which reflects socio-cultural influences from the neighbouring Mediterranean countries. However, due to is intangible nature, folk dancing suffers from being endangered due to wars, the moving of populations across the world, economic and other forms of crises, modernization and globalization, but most importantly, because these fragile creations are modified over time through the process of collective recreation, and/or changes in the lifestyle, which slightly modify the story-telling. The fast pace of life, busy schedules and other sources of entertainment leave younger generations disengaged from traditional performing art productions, making dissemination and conservation of folk dancing particularly challenging. Currently, folk dances are preserved and transferred from generation to generation, usually in an informal manner through social gatherings, festivals, and traditional weddings, or more formally through dance schools and folklore organizations. The few cultural institutions on the island find it challenging to capture the interest of the youth, while other dances are gaining popularity. Furthermore, each performance is highly subjective, as no archive of original performances exists and the interpretation relies heavily on the dancer.

Such intangible assets cross ethnic boundaries and are communicated from generations to generations, leading to variations during the transmission along generations, locations as well as over the

† Corresponding Author

years. Although each folk dance has a basic structure consisting of a predetermined set of steps and overall style, folk dances are pliable in the sense that each performer will typically improvise, thus, enrich the dance with individual characteristics, encouraging variations. Therefore, no single ground truth exists for a folk dance. Consequently, even if dances are formally disseminated by systematic lessons, they will still contain characteristics arising from the personal interpretation of the instructor. Situations such as the current pandemic, which permit human interactions, make the transmission more challenging, thus call for alternative ways to document and disseminate intangible assets such as folk dances.

Digitizing cultural heritage, e.g., [ASC14a], is only a means to an end, since it serves the purpose of safeguarding the heritage through the years, but does not explicitly encourage dissemination. The rapid technological development has introduced captivating ways to archive, exhibit and disseminate cultural aspects, while allowing users with minimal knowledge to interact with the exhibits. In recent years, great attention has been given in the use of digital technologies on-site from museums, or online in the form of websites [Haw04]. In fact, even from 2002 it was observed that the visitors to virtual museums' websites outnumbered that of physical museums, indicating that virtual museums have an important role to play in safeguarding and disseminating historical and cultural assets. For instance, the British Museum [BMU21] has partnered with the Google Cultural Institute and created an online platform based on WebGL technology that allows users to interact and explore tangible cultural assets. Furthermore, they have created 3D models of the artifacts using SketchFab [BMS21]. On the other hand, a number of museums which are part of the Berlin's state museums [SMB21], have created panoramic web-based museum tours which allow users to interactively learn and visit the museums through a desktop PC, a tablet, or smartphone. However, these efforts concern tangible cultural heritage and do not cover intangible assets. In contrast to tangible assets, which can be demonstrated as physical artifacts in museums or reconstructed as 3D virtual models, intangible assets need to be re-produced and systematically recorded, to serve as reference for future generations. Equally important for the rich dance culture of a small island such as Cyprus, is to disseminate worldwide, bypassing border restrictions.

In this work, we lay the grounds for the first publicly accessible virtual dance museum specifically dedicated to the preservation and documentation of intangible cultural heritage creations, which freely gives end-users around the world the opportunity to explore the Greek and Cypriot folk dance heritage through interactive technologies. While our museum targets a wide range of audience, we focus on the youngest generations which will serve as future transmitters to the generations to come. Our museum, acts as a complement to walled museums and offers the benefit of not having borders. We have built our museum upon an already collected dance database [DMC21], which consists of a range of Greek/Cypriot folk dances, among other dance performances. Our virtual dance museum aims at documenting and preserving not only the dance itself, but several metadata related to it, which holistically describe the content and story-telling of the dance, plus other information about the performer, clothes, and technical details about the data acquisition. To this end, we built a database schema, similar to that suggested in [ASC19], and collected the required metadata, for the case-dances used in this museum, in collaboration with our associate partners (dance and folklore experts). This is a critical component of our museum, since folk dances usually portray daily activities of the natives. Such examples are the *Tatsia dance* (Cyprus), which symbolizes the sieve through which flour passed to be cleaned from the bran, and the *Drepani dance* (Cyprus) which imitates the characteristic harvesting movements. In fact, the stories are accompanied with tangible assets such as costumes and props. Thus, digitizing dances often requires that other cultural assets are digitized as well. To address the problem of neglect towards cultural heritage, we introduce interactive technologies aiming to draw the interest of unfamiliar users. In addition, we wish to capture the interest of people throughout the world and familiarize them with the dance heritage of Greece and Cyprus. Our work finds applications which are both educational as well as entertaining. One such example, is a virtual game in which the player earns points by successfully mimicking a virtual teacher, which also serves as a tool for safeguarding folk dances, e.g., [ASC*15].

2. Related Work

Virtual Museums: Virtual museums can take several forms but revolve around a common axis: they are "digital spatial environments, located in the World Wide Web or in the exhibition, which reconstructs a real place and/or acts as a knowledge of metaphor, and in which visitors can communicate, explore and modify spaces and digital or digitalized objects" [PL14].

Various museums are putting efforts in digitizing their artifacts by creating 3D virtual equivalents in order to provide hybrid museums which enhance the physical presence through a series of virtual interactive activities [WCW06, KAC08]. In that aspect, researchers have explored the use of Virtual Reality as a means of enhancing the experience of visitors while being at the museum. For instance, the British Museum has digitized its artworks online, enabling users around the world to interact with them. In particular, they have scanned or created 3D models for their physical artifacts, and with the use of SketchFab, the models have been exhibited into their website. Petridis *et al.* [PWM*05] present a review of techniques which allow visitors to effective interact and visualize museum artifacts using Virtual Reality (VR) and Augmented Reality (AR). Along these lines, Nisiotis *et al.* [NAB19] developed a virtual museum prototype to examine the affordances of VR. Patias *et al.* [PCS*08] described all necessary aspects for the creation of an e-museum for contemporary arts, while Zaharias *et al.* [ZMC13] evaluated whether the use of interactive technologies contribute to a greater user experience and learning effectiveness, and concluded that there are no statistically significant differences in the learning performance, but there is a significantly higher satisfaction in terms of user experience. More recently, Selmanović *et al.* [SRH*20] evaluated a 3D virtual reconstruction context as a medium of interactive digital storytelling, and investigated whether virtual reality can further contribute to the user immersion. For a more detailed and comprehensive evaluation in the field of virtual museums, refer to the work of Sylaiou *et al.* [SLKP09]; in that work, virtual museums were divided in 3 categories: *brochure* used to inform visitors about the museum's operations, *content* which promotes museum

collections, and *learning* museums that are websites which aim to educate and motivate the visitor. In another recent study, Alivizatou *et al.* [ABKT*17] examined existing resources that deal with ICH creations, identifying the gaps and constraints of the current technology, and proposed methods that could be employed for improving the transmission and safeguarding of ICH.

Another aspect is purely online-virtual museums. Virtual museums differ from online databases, which are discussed later, since not only they act as a storage of cultural assets, but also engage and educate the visitor through a plethora of immersive activities. However, previous efforts revolve around the development of virtual museums to exhibit tangible assets. Currently, there are only few websites that exhibit information about intangible creations. Some examples are the Cyprus Food Virtual Museum [CFV21], which documents, studies, and presents the gastronomic heritage of Cyprus; and The National Museum of Dance [NMD21] which allows visitors to access information about the museum and ongoing exhibitions through an online website. However, the current form of the latter does not exhibits dance creations, nor enables interactive applications, dissemination or virtual tours. The closest to virtual museums for intangible assets, in particular folk dances, are motion databases. Despite the usefulness of motion databases for research and safeguarding of folk dances, they do not serve the purpose of holistically documenting and disseminating such intangible assets. That is because important aspects, both physical, such as clothing and props, and supplementary information regarding the performers, capturing environment and other metadata describing the dance, are not properly decoded and stored. Yet, properly organized motion databases play an important role in archiving dances, and pave the way towards the development of virtual exhibitions and museums.

Motion Databases: The current state of motion capture technologies and computer graphics tools enables various forms of recording, storing and visualization of dance performances. Video recordings, the most intuitive way to capture dances, offer several benefits in terms of affordability, quality, convenience, etc. However, they have several disadvantages concerning the lighting and the perception of depth. Furthermore, the video format limits re-usability and does not enable fascinating applications for AR/VR. Motion capture technology, on the other hand, overcomes such limitations by acquiring three-dimensional information, which combined with computer-editing software allows for realistic reproduction. Motion capture data provides extensive insights, in particular for occluded regions missed in video recordings. Furthermore, this technology allows viewing the performer from an arbitrary angle, enabling further analysis and emerging applications. A limiting factor of this technology is its cost, which makes it beyond the financial reach of expert dance practitioners. Nonetheless, various research institutions are equipped with such technology, and therefore combine efforts with dance experts to digitize dance performances with motion capture equipment.

One of the most popular motion databases is the one created by the Carnegie Mellon University [CMU21] and contains, among others, a number of dance performances. However, it is not a database specifically designed for dance, it does not include paired audio, nor it contains interaction between dancers, which is a common phenomenon and highly affects the performance itself. To account for the former, Li *et al.* [LYRK21] have developed a database which is named AIST++ and contains both motion captured data, as well as audio and multi-video, enabling fascinating applications through multi-modal exploration of dances. Similarly, Kang *et al.* [KTL*21] ensembled a database which consists of music and paired audio which were further labelled with signatures from professional artists. In addition, in order to develop a style-based motion synthesis model, Zhuang *et al.* [ZWX*20] constructed a motion database consisting of motion and audio, split into two dance categories: modern and curtilage. To model interactions between dancers, Kundu *et al.* [KBM*20] have utilized YouTube videos from which they obtained 3D skeletons using a pose detection algorithm, in order to develop a motion database. It is common for dance databases to include performances from limited dance categories such as salsa, rumba, samba. More people are familiar to such dance categories compared to folk dances. The MIXAMO dataset [ADO21] contains common dances such as rumba and salsa, performed by characters with different proportions. However, all aforementioned databases only contain various formats of the dances, but no accompanying metadata descriptors that are critical for the documentation of cultural heritage creations.

Digitizing folk dancing is of particular interest since folk dances are in danger of being retired from the active repertory. Therefore, good records will facilitate the preservation and reconstruction of fading dances, and enable younger generations to learn and appreciate them [SGA06]. In this direction, Aristidou *et al.* [ASC14a] have designed and maintain a publicly accessible digital dance library, that currently stores more than 180 dance performances, where users have access to high-quality 3D dance motion capture data. In contrast to other motion databases, this folk dance database [DMC21] offers a wide range of formats including video with audio, several forms of motion capture formats, including the SMPL format [LMR*15], which enhances the skeleton with a naturally deforming mesh, and useful metadata information that provide further insights regarding the performer, location, etc. These are particularly important, since no original performance exists. Therefore, they can be used to identify patterns and explore other aspects of the culture.

Motion analysis for folk dancing: Motion analysis plays an important role in organizing large motion databases, and in creating interactive dance learning applications through gamification. Once all the data is collected, it is vital to organize dance motions properly to allow for further use. There are many methods in the literature that enable motion clustering and organization [BWK*13, KN14, ACOH*18], while some others are specifically designed for folk dance creations [ASC14b, FKNT16, ASP*18, RDD*18]. Aristidou *et al.* [ASC19] propose deeper algorithmic ways for contextual analysis of dances. By exploiting geometric and stylistic correlations between motions they organize large databases and compare dances to unveil similarities which portray potential influences and reflect the evolution of dances in space and time. More recently, a number of works facilitate the development of appealing applications in virtual environments, wherein automatic evaluation, in terms of pose and rhythm, can act as feedback for e-learning ap-

plications [SNAMT20]. In that manner, Jang *et al.* [JKKK17] use LMA for automatic dance motion evaluation in an interactive virtual gaming, whereas other works focus specifically on folk dancing [ASC*15, LG14, LT16, KDU*15, CSTK18].

3. Data Acquisition

In this section we briefly describe the data acquisition process followed in order to construct our motion database.

3.1. Data

In this work we used motion capture data that are publicly available through the Dance Motion Capture repository [DMC21] of the University of Cyprus. As stated by Stavrakis *et al.* [SAS*12], the database was created by inviting a number of expert dancers to perform several dances that have been recorded using an eight camera PhaseSpace Impulse X2 motion capture system (at 480Hz) that surrounds the dancing stage. The aforementioned optical system uses active LEDs to capture and reconstruct the pose of the dancer over time, it maintains correct human proportions and naturalness, but is limited to the recording of one actor at a time. Note that, all dances used in our virtual dance museum, can be downloaded from the online repository in many different formats. Dances are available as video files (in .mp4) where the dancer is recorded using a high-definition camera and sound can be heard on the background as an indication for the beat. Other stored data includes the .c3d format, which records the movements of the sensors that were placed on the dancer; and the Autodesk MotionBuilder Actor data (in .fbx format), a three-dimensional object, synchronized with the motion of the sensors. The latter allows for convenient retargeting of the motion to any character. Furthermore, the .bvh format is also available, that is commonly used in the animation field, while recently, data have also been stored in the SMPL format, that is a richer representation which additionally encompasses body/mesh deformation of the performer. Finally, the raw motion capture data has been post-processed and retaregetted to a 3D model with standard body proportions, the wooden mannequin. This model has been chosen due to its playful appearance, so as to be more attractive to the younger generations, and also for practical reasons since it does not contain the details of the face and hands, which we are not capable of capturing at the current stage.

It is important to note that for the same dance, each performer adopts a different interpretation. To holistically document folk dances, we keep track of such aspects, by accompanying each dance with a brief description and metadata which form an important element of the virtual museum.

3.2. Metadata

Metadata refers to the documentation of the data which complement the main data and provide further description in regards to the history of dance, its evolution over time, its music and attire. Thus metadata enable a holistic approach towards the documentation of dance data. Metadata are vital for electronic applications since they conveniently allow the user to locate information and resources, providing a means of organization. Hillman *et al.* [HIMB08] suggest that metadata falls into five categories: descriptive, structural, administrative, reference and statistical. Descriptive metadata relates to the identification and discovery. Structural metadata concern the containers of data and relations between them. Administrative concern the management of the resource, access rights, etc. Reference metadata concerns the quality and contents, and statistical data characterizes the techniques used to collect and process statistical data.

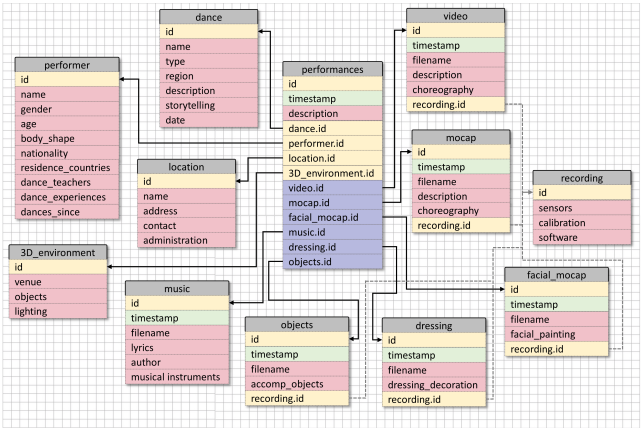

Figure 1: *Illustration of the database schema employed to holistically describe the dance, taken from [ASC19].*

Metadata contain rich information, particularly important for folk dances to which original performances do not exist. They contribute in forming solid knowledge around the performance and can facilitate further cultural, anthropological and ethnological studies. Their definition requires combined efforts among researchers and folk dance experts. Guided by Lourdi *et al.* [LPN07], who performed extensive research on metadata schemas specifically to folklore collections, Aristidou *et al.* [ASC19] proposed a database schema (see Figure 1) that holistically describes folk dance creation. In this work, we did not have the capacity to acquire all the proposed data and metadata, and thus in our virtual museum we show only a subset of those. These are:

- *Dances*, in the form of textual descriptors. These include the storytelling, region, date that dance became known, type and history,
- *Performers* appearing in the captured data. It should be emphasized that such metadata play a key role since any performance will always reflect the interpretation, emotions and style of the performer. For that reason we keep track of characteristics relating to their body proportions and physical measurements, age, gender, nationality, countries of residence, dance teachers, years of experience relating to the specific dance, dance background and years of experience with other dance genres,
- *Locations* where these dances have been performed,
- any *accompanying objects* such as costumes and props. Since folk dances usually portray the everyday activities of a certain time period, props and costumes play an important role. Costumes convey several socio-economic characteristics and vary across locations. The accompanying props supplement the storytelling,

Figure 2: *The home page depicted in this figure welcomes the visitor and shows various images of cultural dance groups in action.*

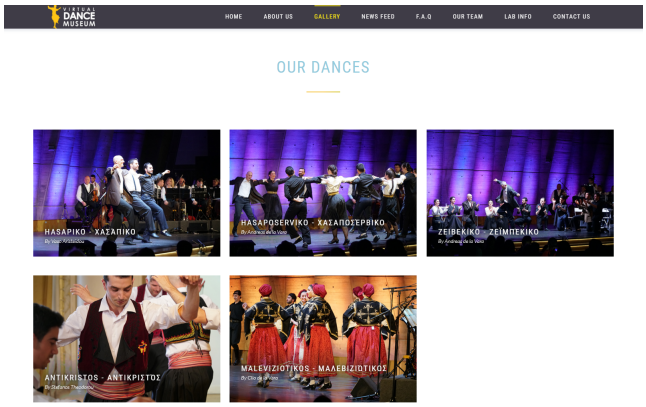

Figure 3: *The gallery section with images and brief descriptions of the 5 dances displayed in the current case study. The images are taken from live performances and depict dancers which are members of the cultural groups we have partnered with.*

- the *Technology* used for capturing such as the system, sensors, calibration parameters, etc.

4. Virtual Museum

"A virtual museum is a digital entity that draws on the characteristics of a museum, in order to complement, enhance, or augment the museum experience through personalization, interactivity and richness of content" [Wik21]. Virtual museums take various forms; they are particularly well-suited for dances, since the variations across locations and performers, as well as alterations in time, can act as footprints to the captured digital assets.

4.1. The online repository

In recent years, it has been shown that a major part of our lives, but also of the marketing world, belongs to the internet. In that way, we have created - in conjunction to the danceDB database [DMC21] - a web platform, to bridge the gap between technological advancements and cultural heritage, so that technology works as an ally in the preservation and dissemination of these traditional dances that make our heritage intangible and irreplaceable. Visitors can access our web platform through `http://dancemuseum.eu/`; Figure 2 illustrates the home page of our virtual dance museum. The web platform contains information about the target of the virtual museum, our motion capture lab, our associate partners, our team, and contact information. It also contains a news feed section which allows the visitors to keep track of any changes taking place within the museum, and a section that contains answers to frequently asked questions to further ease the experience of users.

The main exhibition can be found in the Gallery section, of which a snapshot can be seen in Figure 3. Currently, our platform accommodates five folk dance creations, that are: the Greek Hasapiko, Hasaposerviko, Zeibekiko, the Cypriot Antikristos, and Cretan Maleviziotikos. The user can navigate through the menu, consisting of images of the dances, to preview a brief description. By clicking on a menu entry one can get the complete information stored. Figure 4 shows a case example for the Cypriot Antikristos dance. Data and metadata are presented in a clear and distinct manner, in a user-friendly designed page. For each dance entry, we employed SketchFab as a means of visualization of the 3D animated

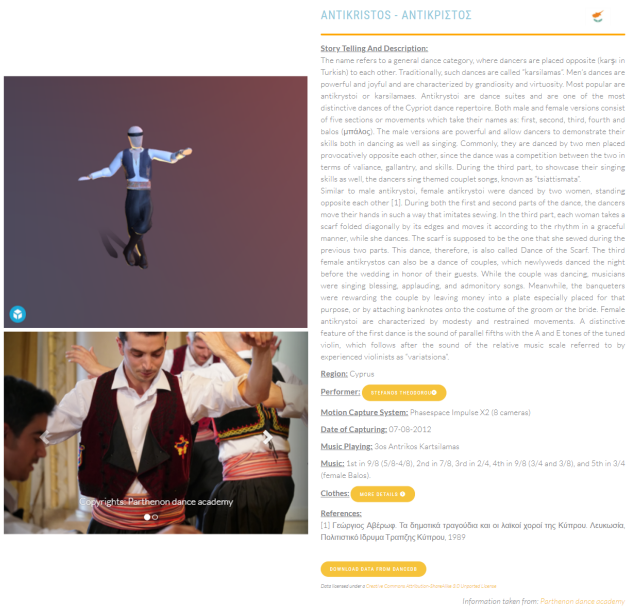

Figure 4: *For each of the 5 dances we have created a separate page, to host the 3D model and corresponding metadata. Here we can see the example of the Cypriot Antikristos dance.*

model. Our model, the 3D wooden mannequin, is dressed with a traditional costume. The model viewer allows the visitor to engage with the dance and interact by freely moving around or inside the 3D scene using a mouse, touch manipulation or other input device. It also incorporates the accompanying music to provide a holistic visualization with further insights on the tempo and speed, as well as the style. Furthermore, for each dance we integrate an image gallery (the images have been provided by our associate partners) which shows dancers performing the specific dance that have been taken during live performances. On top of that, the visitor can get

Figure 5: *The top row shows images taken from live performances. Guided by the clothing worn by the performers we have simulated clothing which we used to dress the wooden mannequin (second row). These closely resemble the original clothing.*

supplementary information on the storytelling and description of the dance, details about the region, the performer, the music, and costumes. These metadata assets have been collected in collaboration with dance academies, folklore organizations and individual dance performers with years of experience. The website forms a solid foundation for visualization and interactions with the data. For visitors willing to gain direct access to the various formats of the dance offered, we also provide the link to the danceDB database, where the dances can be downloaded under a Creative Commons Attribution-ShareAlike 3.0 Unported License.

4.2. Costumes

Even though costumes are complementary to the dances, in reality they play an important role. They form a key element of the storytelling, giving indications on the origins of the dance, the socio-economic status of the region of origin and its habitats. Furthermore, costumes complete the 3D model and allow the visitor to holistically perceive the dance. In order to enhance the visitor's experience by making our 3D models more realistic, we have dressed the 3D wooden mannequin with the appropriate garments, as seen in Figure 5. We have designed the digital equivalent to the traditional suits, guided by the images taken from physical performances. The result is a simplified traditional uniform, which resembles the original suits closely. The cloth has been simulated in Autodesk Maya and attached on the mesh of the wooden mannequin. The cloth deforms and reacts to the movement of the character in a natural way.

4.3. Visualization of dances

To visualize the 3D exhibits we have chosen the SketchFab model viewer, which is the most popular and common platform to share

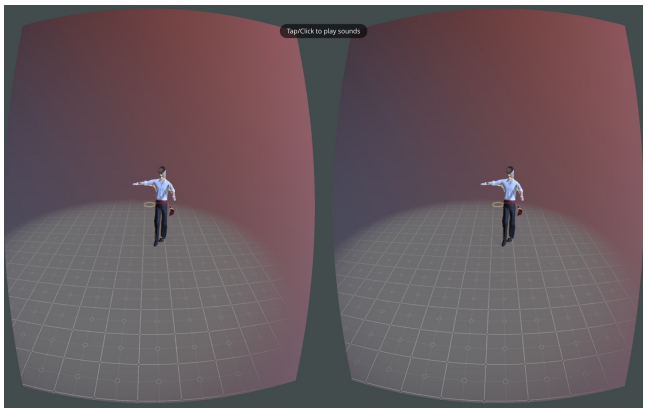

Figure 6: *Hasaposerviko dance as previewed using VR headset.*

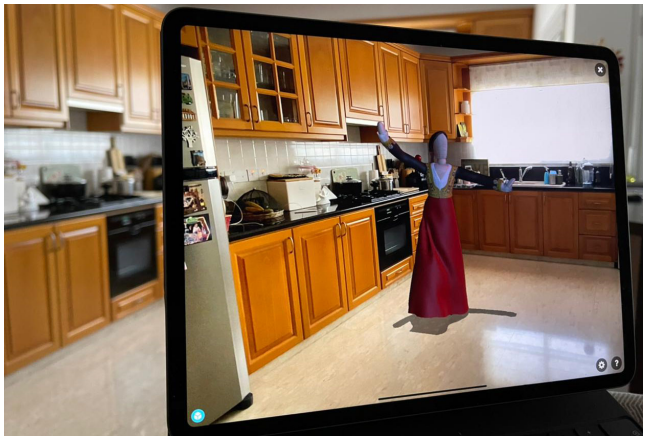

Figure 7: *The Cretan Maleviziotikos dance overlaid into the real world though the SketchFab AR feature. The exhibits can be overlaid anywhere, using a smartphone or tablet.*

3D, VR, and AR content. To provide its features on the web, on mobile and desktop browser, or AR/VR headsets, thus allowing multiple forms of interaction, it uses WebGL and WebXR technologies.

Using the SketchFab application kit, the visitors can explore and interact with our 3D dancing models (see Figure 4). Apart from the 3D viewing, it also allows for visualization within a virtual environment through a headset console. This creates an artificial, yet immersive world which feels real to the user. A snapshot of the user's view through the headset can be seen in Figure 6. Furthermore, the dances can be exhibited using AR technology. This feature allows users which do not have access to a specialized headset to enjoy fascinating and immersive applications that increase their engagement. AR offers an enhancement to the real world that is overlaid by computer-generated perceptual information. The visitors can preview the dances in AR using a mobile device or a tablet. Figure 7 illustrates a snapshot of the Maleviziotikos dance augmented through a tablet device.

To provide immediate access to the 3D models using mobile de-

vices and tablets, we have also generated QR codes compatible with Android and iOS devices, which direct the users to the 3D models within the SketchFab application. Note that this requires that the SketchFab application is already installed on the device.

We believe that the aforementioned features offered by SketchFab are ideal for the purposes of our virtual museum. With the use of state-of-the-art technology the visitors can engage with the intangible artifacts while being immersed and fully-present. If the environment is further enhanced with traditional buildings, we believe that the users can activate their imagination and even be able to travel in time.

5. Discussion

5.1. User Survey

To evaluate the performance of our virtual dance museum we have conducted a user survey. We have invited $N = 40$ people from different age groups (ranging between 18-60 years); note that the number of participants N does not include incomplete responses or random answers that were discarded from the evaluation (random answers are considered those for which the answer took less than 5 seconds to submit). Participants were asked to visit and interact with our virtual dance museum and then complete a survey, allowing us to gain insights on the subjective notion of perceived enjoyment and knowledge transmission taking place within our museum. We targeted both Cypriots and Greeks, as well as people around the world with different dancing background and AR/VR knowledge. To gain a better understanding on the collected data, we gather additional information with regard to the background of the participant, the device and the operating system used.

Guided by the research of Barbieri *et al.* [BBM17], our survey focuses on two main axes: *usability* (system efficacy) and *learnability*. In terms of usability, we have designed eight questions to evaluate the capacity of our museum system in terms of its effectiveness, efficiency, and the overall experience. On the other hand, the learnability axis, consisting of six questions, examines the quality of our interface in terms of clarity and content completeness, user friendliness, and engagement with our dancing models in the 3D virtual and AR environment. We have also evaluated technical aspects of the web platform, such as browser consistency and mobile compatibility.

5.1.1. Usability

In terms of usability, the results of the user survey indicate that participants were able to access our virtual dance museum using a range of devices (personal computers, smartphones, and tablets), and browsers (Google Chrome, Safari, Firefox, etc.). In general, participants were satisfied with the design and accessibility of the museum. Furthermore, the overall results indicate that the participants are quite satisfied with the page navigation and museum interactivity, as well as interaction with the 3D model, and AR experience. The participants were asked to rate the design of the pages on a scale of 0-10, where 0 indicates poor design and 10 stands for extremely good. In addition, using a similar scale approach the participants were requested to provide scores in terms of the ease of use, page loading times, interactivity with the museum, navigation

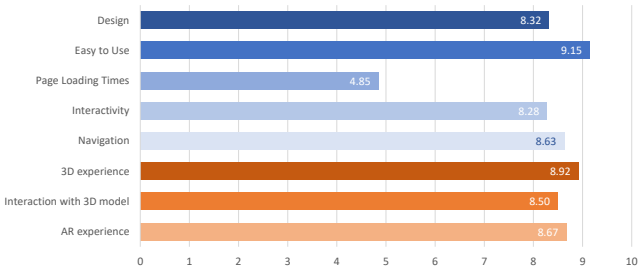

Figure 8: *User survey outcomes regarding the usability component of our virtual museum. We report the average results on a 0-10 scale for each factor, with 0 being the lowest score and 10 the highest.*

through the pages, the level of enjoyment of the 3D experience, satisfaction with the degree of interaction with the 3D model and AR experience. Figure 8 illustrates the results of the survey in terms of the usability factor. The user study has also revealed a limitation, regarding the loading times of the 3D model in SketchFab. This is due to the large size of the 3D exhibits (∼500MB), resulting from the cloth simulation and the long duration of the dances. One possible solution is to use less polygons to represent the character and clothes, at the cost of lower quality. Another temporal remedy is to use a progress bar while loading to clarify that the models are loading and give clear indication on the remaining time. Moreover, due to memory limitations, some smartphones do not have the capacity to load the large-sized 3D exhibits, posing a restriction in the use of the 3D models. For the same reason, the AR functionality is not always available to users accessing the museum through a smartphone. We observed that the participants were more satisfied when accessing our museum through a tablet.

5.1.2. Learnability

The participants were next asked to evaluate the learnability component of our virtual dance museum. In particular, they were asked to rate the content completeness, clarity of content and level of interaction on a scale of 0-10, where 0 represents the lowest score. Based on the responses of the participants, we can observe a consistency among the answers, indicating that the level of knowledge transmission is appropriate, while overall the users feel engaged with the museum. The results concerning the learnability aspect can be seen in Figure 9. Another important finding of this survey is that participants believe that the 3D model is able to convey the content of the dance better than a video, supporting the use of 3D models (see Figure 10).

5.1.3. User suggestions

The final section of the user study allowed participants to provide us with custom feedback. We have received several positive and supportive comments about our initiative to design and develop this virtual dance museum prototype. In addition, we got comments specifically for the Maleviziotikos dance, pointing out that the clothes attached on the 3D mannequin (long dress touching the ground) make it hard to distinguish the dance movements, and thus learn the steps of the dance. This limitation should be taken into

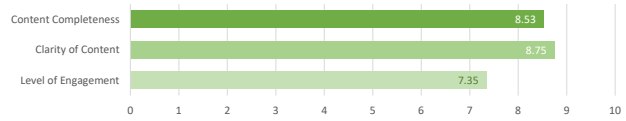

Figure 9: *User survey outcomes regarding the learnability component of our virtual museum. We report the average results on a 0-10 scale for each factor, with 0 being the lowest score and 10 the highest.*

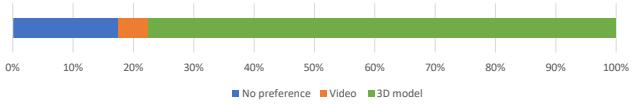

Figure 10: *User survey outcomes regarding the preference among a 3D model and video visualization for the dance exhibits.*

consideration in future works when attaching clothing to virtual characters, especially traditional uniforms that in some cases are particularly rich and complex. A means to overcome this issue is by making the clothing transparent, or allow cameras viewing from wider angle. Finally, the participants have expressed their interest in more direct engagement with the exhibits through interactive applications, games, quizzes, etc. As part of the evolution of the museum, we wish to integrate numerous interactive applications which will enhance the transmission of knowledge in an entertaining way. In Section 5.2 we briefly discuss some ways that can be used to further increase the engagement of the user e.g., by providing e-learning through gamification.

5.2. Limitations and Future Directions

Our work has some limitations. Firstly, at the moment we cannot capture the movement of the fingers, nor the facial expressions. Hand and face/emotion tracking is very important in some dances; these small details contribute significantly to the realism of the animation. One solution is to capture these aspects separately and add them in a later time e.g., [Ari18]. At the current stage, danceDB offers single dance performances. However, our folk dance repertoire consists of multiple group or paired dances. In the near future, we expect to be able to acquire the movement of multiple performers allowing us to enhance our database and museum. Nevertheless, the main limitation of the current optical motion capture technology is the requirement that the performer wears a special uniform or clothes that fit on the performer's body. Nonetheless, there are many instances in folk dancing where the dancer wears a traditional costume that contributes to the choreography (e.g., in the Turkish dervish dance, the dancer maintains balance from the clothes). In the future, we will investigate methods to simultaneously capture the human mesh and clothes. Then by disentangling the pose from the clothes, we will achieve a more faithful reconstruction of the pose in the context of the dance, and eliminate the need for simulating the clothes. Finally, in this work we had a relatively small number of participants in our study ($N = 40$), making it challenging to draw safe conclusions about the users' experience and learnability. In future releases (when more data will be available), a larger number of participants will be invited, with a wider demographic dispersion, to get a better picture of the current limitations, and understand the benefits of using extended reality as a medium of interactive digital storytelling e.g., [TA08].

There are several application that can be integrated into our virtual museum, based on existing or ongoing works, to enhance the provided experience, e.g., motion and dance analysis [AC13, ASP*18], contextual analysis [ASC19], emotion analysis [ACC15], etc. Such analyses will enable to exploit the correlation between dances, indexing and retrieving similar motions from large datasets (without the need of manual labelling and annotation of data). It will also enable portraying of the chronological and geographical evolution of dance, and unveil potential cultural similarities between dances of neighboring countries, using an interactive 3D environment, overlaid with maps etc. Several e-learning applications can also be developed [ASC*15], where the user (whom the movements will be captured using a low-cost motion capture device) must imitate the teacher movements, to get a real-time qualitative and quantitative feedback. Other emerging applications involve the design and development of a 3D dance platform for e-learning of dances in gamified virtual reality environment [SNAMT20], so that the users learn how to dance and follow the rhythm, using a virtual reality headset. Our ultimate target is to build a highly immersive VR/AR platform to host a highly-interactive interactive virtual dance museum. All these will enable interactive applications that will intrigue and hold the interest of the visitors.

6. Conclusions

In this paper we present a prototype platform for an online virtual dance museum, the first of its kind specifically designed to exhibit intangible cultural heritage creations. We use emerging technologies in virtual and augmented reality to provide an enhanced and immersive experience to the visitors, which comes at hand at any time of the day, no matter where in the world the visitors reside. The technologies used allow the visitor to directly perceive characteristics of the dance, including accompanying music, clothes and other important metadata information with regards to the description and storytelling of the dance. We aim to continuously enhance our virtual museum to provide enjoyable and productive experiences to our visitors.

Acknowledgements

Special thanks to all the dancers who performed in our lab, and the Parthenon Academy of Dance (Paris, FR) for their valuable contribution in collecting the required metadata information. This work has been supported by the RESTART 2016-2020 Programmes for Technological Development and Innovation, through the Cyprus Research Promotion Foundation, with protocol number P2P/JPICH_DH/0417/0052. This project has also received funding from the University of Cyprus, the European Union's Horizon 2020 Research and Innovation Programme under Grant Agreement No 739578, and the Government of the Republic of Cyprus through the Deputy Ministry of Research, Innovation and Digital Policy.

References

[ABKT*17] ALIVIZATOU-BARAKOU M., KITSIKIDIS A., TSALAKANIDOU F., DIMITROPOULOS K., GIANNIS C., NIKOLOPOULOS S., AL KORK S., DENBY B., BUCHMAN L., ADDA-DECKER M., PILLOT-LOISEAU C., TILLMANE J., DUPONT S., PICART B., POZZI F., OTT M., ERDAL Y., CHARISIS V., HADJIDIMITRIOU S., HADJILEONTIADIS L., COTESCU M., VOLIOTI C., MANITSARIS A., MANITSARIS S., GRAMMALIDIS N.: Intangible cultural heritage and new technologies: Challenges and opportunities for cultural preservation and development. In *Mixed Reality and Gamification for Cultural Heritage*, Ioannides M., Magnenat-Thalmann N., Papagiannakis G., (Eds.). Springer International Publishing, Cham, 2017, pp. 129–158. doi:10.1007/978-3-319-49607-8_5.

[AC13] ARISTIDOU A., CHRYSANTHOU Y.: Motion indexing of different emotional states using lma components. In *SIGGRAPH Asia 2013 Technical Briefs* (New York, NY, USA, 2013), SA '13, ACM, pp. 21:1–21:4. doi:10.1145/2542355.2542381.

[ACC15] ARISTIDOU A., CHARALAMBOUS P., CHRYSANTHOU Y.: Emotion analysis and classification: Understanding the performers' emotions using the LMA entities. *Comput. Graph. Forum 34*, 6 (Sept. 2015), 262–276. doi:10.1111/cgf.12598.

[ACOH*18] ARISTIDOU A., COHEN-OR D., HODGINS J. K., CHRYSANTHOU Y., SHAMIR A.: Deep motifs and motion signatures. *ACM Trans. Graph. 37*, 6 (Dec. 2018), 187:1–187:13. doi:10.1145/3272127.3275038.

[ADO21] ADOBE: MIXAMO dataset: https://www.mixamo.com, 2021. [Online; Retrieved July, 2021].

[AGII08] AGAPIOU A., GEORGOPOULOS A., IOANNIDES M., IOANNIDIS C.: A web based GIS for the byzantine churches of cyprus. In *Proceedings of the Conference on Virtual Systems and MultiMedia Dedicated to Digital Heritage* (Limassol, Cyprus, 2008).

[Ari18] ARISTIDOU A.: Hand tracking with physiological constraints. *The Visual Computer 34*, 2 (2018), 213–228. doi:10.1007/s00371-016-1327-8.

[ASC14a] ARISTIDOU A., STAVRAKIS E., CHRYSANTHOU Y.: Cypriot Intangible Cultural Heritage: Digitizing folk dances. *Cyprus Computer Society journal «Pliroforiki»*, 25 (April 2014), 42–47.

[ASC14b] ARISTIDOU A., STAVRAKIS E., CHRYSANTHOU Y.: LMA-based motion retrieval for folk dance cultural heritage. In *5th International Conference on Cultural Heritage* (2014), Ioannides M., Magnenat-Thalmann N., Fink E., Žarnić R., Yen A.-Y., Quak E., (Eds.), vol. LNCS, 8740 of *EuroMed'14*, Springer International Publishing, pp. 404–413.

[ASC*15] ARISTIDOU A., STAVRAKIS E., CHARALAMBOUS P., CHRYSANTHOU Y., LOIZIDOU-HIMONA S.: Folk dance evaluation using Laban Movement Analysis. *J. Comput. Cult. Herit. 8*, 4 (Aug. 2015), 20:1–20:19. doi:10.1145/2755566.

[ASC19] ARISTIDOU A., SHAMIR A., CHRYSANTHOU Y.: Digital dance ethnography: Organizing large dance collections. *J. Comput. Cult. Herit. 12*, 4 (Nov. 2019). doi:10.1145/3344383.

[ASP*18] ARISTIDOU A., STAVRAKIS E., PAPAEFTHIMIOU M., PAPAGIANNAKIS G., CHRYSANTHOU Y.: Style-based motion analysis for dance composition. *The Visual Computer 34*, 12 (2018), 1725–1737. doi:10.1007/s00371-017-1452-z.

[BBM17] BARBIERI L., BRUNO F., MUZZUPAPPA M.: Virtual museum system evaluation through user studies. *Journal of Cultural Heritage 26* (2017), 101–108. doi:10.1016/j.culher.2017.02.005.

[BFG*12] BARIAMI G., FAKA M., GEORGOPOULOS A., IOANNIDES M., SKARLATOS D.: Documenting a unesco wh site in cyprus with complementary techniques. *International Journal of Heritage in the Digital Era 1*, 1_suppl (2012), 27–32. doi:10.1260/2047-4970.1.0.27.

[BMS21] The British Museum: Sketchfab account https://sketchfab.com/britishmuseum/, 2021. [Online; Retrieved July, 2021].

[BMU21] The British Museum: https://www.britishmuseum.org/, 2021. [Online; Retrieved July, 2021].

[BPMYSYT*19] BANG PING MAH O., YAN Y., SONG YI TAN J., TAN Y.-X., QI YING TAY G., JIAN CHIAM D., WANG Y.-C., DEAN K., FENG C.-C.: Generating a virtual tour for the preservation of the (in)tangible cultural heritage of tampines chinese temple in singapore. *Journal of Cultural Heritage 39* (2019), 202–211. doi:10.1016/j.culher.2019.04.004.

[BWK*13] BERNARD J., WILHELM N., KRÜGER B., MAY T., SCHRECK T., KOHLHAMMER J.: Motionexplorer: Exploratory search in human motion capture data based on hierarchical aggregation. *IEEE Transactions on Visualization and Computer Graphics 19*, 12 (Dec. 2013), 2257–2266.

[CFV21] Cyprus Food Virtual Museum: http://foodmuseum.cs.ucy.ac.cy/, 2021. [Online; Retrieved July, 2021].

[CMU21] CMU: Carnegie Mellon University MoCap Database: http://mocap.cs.cmu.edu/, 2021. [Online; Retrieved July, 2021].

[CSTK18] CHERNBUMROONG S., SUREEPHONG P., TABIA K., KHEMLANI Y. D.: Thai dance training game-based model. In *Proceedings of the 3rd International Conference on Digital Arts, Media and Technology* (2018), ICDAMT'18, IEEE, pp. 194–197.

[DMC21] DMCD: Dance Motion Capture Database: http://dancedb.eu, 2021. [Online; Retrieved July, 2021].

[FKNT16] FOTIADOU E., KAPSOURAS I., NIKOLAIDIS N., TEFAS A.: A bag of words approach for recognition of greek folk dances. In *Proceedings of the 9th Hellenic Conference on Artificial Intelligence* (New York, NY, USA, 2016), SETN '16, ACM, pp. 21:1–21:4.

[Haw04] HAWKEY R.: *Learning with Digital Technologies in Museums, Science Centres and Galleries*. Volume 9 of NESTA Futurelab series, Jan. 2004.

[HIMB08] HILLMANN I D., MARKER R., BRADY C.: Metadata standards and applications. *The Serials Librarian 54*, 1-2 (2008), 7–21. doi:10.1080/03615260801973364.

[IAGK09] IOANNIDES M., ALONZO A., GEORGOPOULOS A., KALISPERIS L.: Documenting, archiving, preserving and visualising digital cultural heritage: From concept to reality. *International Journal of Architectural Computing 1*, 7 (2009), 21–27.

[IGS05] IOANNIDES M., GEORGOPOULOS A., SCHERER M.: Standards in cultural heritage: The missing grammar for the digital documentation of the past. In *Proceedings of the International Conference for Documentation of Cultural Heritage* (2005).

[JKKK17] JANG M., KIM D., KIM Y., KIM J.: Automated dance motion evaluation using dynamic time warping and laban movement analysis. In *Proceedings of the IEEE International Conference on Consumer Electronics* (Jan 2017), ICCE'17, pp. 141–142.

[KAC08] KUNKEL T. D., AVERKIOU M., CHRYSANTHOU Y.: A web-based virtual museum application. In *Proceedings of the 14th International Conference on Virtual Systems and Multimedia* (2008), ARCHAEOLINGUA, pp. 275–277.

[KBM*20] KUNDU J. N., BUCKCHASH H., MANDIKAL P., V R. M., JAMKHANDI A., BABU R. V.: Cross-conditioned recurrent networks for long-term synthesis of inter-person human motion interactions. In *2020 IEEE Winter Conference on Applications of Computer Vision (WACV)* (2020), pp. 2713–2722. doi:10.1109/WACV45572.2020.9093627.

[KDD*14] KYRIAKAKI G., DOULAMIS A., DOULAMIS N., IOANNIDES M., MAKANTASIS K., PROTOPAPADAKIS E., HADJIPROCOPIS A., WENZEL K., FRITSCH D., KLEIN M., WEINLINGER G.: 4d reconstruction of tangible cultural heritage objects from web-retrieved images. *International Journal of Heritage in the Digital Era 3*, 2 (2014), 431–451. doi:10.1260/2047-4970.3.2.431.

[KDU*15] KITSIKIDIS A., DIMITROPOULOS K., UĞURCA D., BAYÇAY C., YILMAZ E., TSALAKANIDOU F., DOUKA S., GRAMMALIDIS N.: A game-like application for dance learning using a natural

human computer interface. In *Universal Access in Human-Computer Interaction. Access to Learning, Health and Well-Being* (Cham, 2015), Antona M., Stephanidis C., (Eds.), Springer International Publishing, pp. 472–482.

[KGCL18] KICO I., GRAMMALIDIS N., CHRISTIDIS Y., LIAROKAPIS F.: Digitization and visualization of folk dances in cultural heritage: A review. *Inventions 3*, 4 (2018).

[KN14] KAPSOURAS I., NIKOLAIDIS N.: Action recognition on motion capture data using a dynemes and forward differences representation. *J. Vis. Comun. Image Represent. 25*, 6 (Aug. 2014), 1432–1445.

[KTL*21] KANG C., TAN Z., LEI J., ZHANG S.-H., GUO Y.-C., ZHANG W., HU S.-M.: Choreomaster : Choreography-oriented music-driven dance synthesis. *ACM Trans. Graph. 41*, 4 (Aug. 2021).

[LG14] LEE J., GOO B.: A study on the e-learning for korean traditional dance. In *Proceedings of the International Conference on Virtual Systems Multimedia* (Dec 2014), VSMM, pp. 240–245.

[LMR*15] LOPER M., MAHMOOD N., ROMERO J., PONS-MOLL G., BLACK M. J.: SMPL: A skinned multi-person linear model. *ACM Trans. Graph. 34*, 6 (Oct. 2015). doi:10.1145/2816795.2818013.

[LPN07] LOURDI I., PAPATHEODOROU C., NIKOLAIDOU M.: A multi-layer metadata schema for digital folklore collections. *J. Inf. Sci. 33*, 2 (Apr. 2007), 197–213.

[LT16] LARABA S., TILMANNE J.: Dance performance evaluation using hidden markov models. *Comput. Animat. Virtual Worlds 27*, 3-4 (May 2016), 321–329.

[LYRK21] LI R., YANG S., ROSS D. A., KANAZAWA A.: Learn to dance with AIST++: Music conditioned 3d dance generation, 2021. arXiv:2101.08779.

[NAB19] NISIOTIS L., ALBOUL L., BEER M.: Virtual museums as a new type of cyber-physical-social system. In *Augmented Reality, Virtual Reality, and Computer Graphics* (Cham, 2019), De Paolis L. T., Bourdot P., (Eds.), Springer International Publishing, pp. 256–263.

[NMD21] NMD: National Museum of Dance: https://www.nationalmuseumofdance.org/, 2021. [Online; Retrieved July, 2021].

[PCS*08] PATIAS P., CHRYSANTHOU Y., SYLAIOU S., GEORGIADIS C., MICHAEL-GRIGORIOU D., STYLIANIDIS S.: The development of an e-museum for contemporary arts. In *Proceedings of the 14th International Conference on Virtual Systems and Multimedia* (2008).

[PL14] PUJOL L., LORENTE A.: The virtual museum: a quest for the standard definition. In *Archaeology in the Digital Era*, Verhagen P., Earl G., (Eds.). Amsterdam University Press, 2014, pp. 40–48. doi:doi:10.1515/9789048519590-005.

[PWM*05] PETRIDIS P., WHITE M., MOURKOUSIS N., LIAROKAPIS F., SIFNIOTIS M., BASU A., GATZIDIS C.: Exploring and interacting with virtual museums. In *Proceedings of the 33rd Conference on Computer Applications and Quantitative Methods in Archaeology* (Mar. 2005), CAA'05, pp. 73–82.

[RDD*18] RALLIS I., DOULAMIS N., DOULAMIS A., VOULODIMOS A., VESCOUKIS V.: Spatio-temporal summarization of dance choreographies. *Computers & Graphics 73* (2018), 88–101. doi:10.1016/j.cag.2018.04.003.

[SAS*12] STAVRAKIS E., ARISTIDOU A., SAVVA M., HIMONA S. L., CHRYSANTHOU Y.: Digitization of cypriot folk dances. In *Proceedings of the 4th International Conference on Progress in Cultural Heritage Preservation* (Berlin, Heidelberg, 2012), EuroMed'12, Springer-Verlag, pp. 404–413. doi:10.1007/978-3-642-34234-9_41.

[SGA06] SMIGEL L., GOLDSTEIN M., ALDRICH E.: *Documenting Dance: A Practical Guide*. Dance Heritage Coalition, 2006.

[SGII06] SOFOCLEOUS E., GEORGOPOULOS A., IOANNIDES M., IOANNIDIS C.: The geometric documentation of the asinou church in cyprus. In *Proceeding of the 7th International Symposium on Virtual Reality, Archaeology and Cultural Heritage* (2006), VAST'06.

[SLKP09] SYLAIOU S., LIAROKAPIS F., KOTSAKIS K., PATIAS P.: Virtual museums, a survey and some issues for consideration. *Journal of Cultural Heritage 10* (10 2009), 520–528. doi:10.1016/j.culher.2009.03.003.

[SMB21] Staatliche Museen zu Berlin: https://www.smb.museum/, 2021. [Online; Retrieved July, 2021].

[SNAMT20] SENECAL S., NIJDAM N. A., ARISTIDOU A., MAGNENAT-THALMANN N.: Salsa dance learning evaluation and motion analysis in gamified virtual reality environment. *Multimedia Tools and Applications 79*, 33-34 (June 2020), 24621–24643. doi:10.1007/s11042-020-09192-y.

[SRH*20] SELMANOVIĆ E., RIZVIC S., HARVEY C., BOSKOVIC D., HULUSIC V., CHAHIN M., SLJIVO S.: Improving accessibility to intangible cultural heritage preservation using virtual reality. *J. Comput. Cult. Herit. 13*, 2 (May 2020). doi:10.1145/3377143.

[TA08] TULLIS T., ALBERT W.: *Measuring the User Experience: Collecting, Analyzing, and Presenting Usability Metrics*. Morgan Kaufmann Publishers Inc., San Francisco, CA, USA, 2008.

[WCW06] WALCZAK K., CELLARY W., WHITE M.: Virtual museum exhibitions. *Computer 39* (04 2006), 93 – 95. doi:10.1109/MC.2006.108.

[Wik21] WIKIPEDIA: Virtual Museum: https://en.wikipedia.org/wiki/Virtual_museum, 2021. [Online; Retrieved July, 2021].

[ZCBRC07] ZÁNYI E., CHRYSANTHOU Y., BASHFORD-ROGERS T., CHALMERS A.: High dynamic range display of authentically illuminated byzantine art from cyprus. In *Proceedings of the 8th International Conference on Virtual Reality, Archaeology and Intelligent Cultural Heritage* (Goslar, DEU, 2007), VAST'07, Eurographics Association, p. 87–92.

[ZMC13] ZAHARIAS P., MICHAEL D., CHRYSANTHOU Y.: Learning through multi-touch interfaces in museum exhibits: An empirical investigation. *Journal of Educational Technology & Society 16*, 3 (2013), 374–384.

[ZWX*20] ZHUANG W., WANG C., XIA S., CHAI J., WANG Y.: Music2dance: Dancenet for music-driven dance generation, 2020. arXiv:2002.03761.