Narrative Semantic Media for Contextual Individualization of Ambient Learning Spaces

David Bouck-Standen, Alexander Ohlei, Thomas Winkler, Michael Herczeg
Institute for Multimedia and Interactive Systems
University of Luebeck
Luebeck, Germany
email: [bouck-standen, ohlei, winkler, herczeg]@imis.uni-luebeck.de

***Abstract*— Digital conservation and transformation of cultural content and cultural property are constantly increasing. In our research project Ambient Learning Spaces, funded for seven years by the German Research Foundation, we developed a user-centered scenario to individualize and personalize user experience through the use of what we call Narrative Semantic Media. In this context, museum exhibits installations and objects like fossils are digitally augmented into interactive objects for the visitors. Using the visitor's personal mobile devices, our solution embeds the visitor into a flexible, self-adapting narrative structure motivating a self-directed discovery, which creates an Ambient Learning Space inside the museum. The applications we develop running on visitors' mobiles connect to our web- and service-based platform, the Network Environment for Multimedia Objects, a framework that also collects usage and interaction statistics, which are used to personalize the visitors' user experience.**

Keywords-Museum; Narratives; Semantic Media; informal learning;

I. INTRODUCTION

In contemporary approaches, aspects of our cultural property are more and more commemorated by the means of digitalization. Today, any physical object can somehow be transformed into digital media, such as texts, scans, pictures, audio, video footage, or 3D objects [1][2]. These media can be attributed and interconnected within a dynamic information model. For such information models, semantic classification systems for museums, already exist [3].

The transformation from physical to digital space changes the means and expectations, by which exhibits are preserved, augmented, interconnected, and made accessible. Consequently, this will enrich, support and change human perception and receptions of the exhibits. Therefore, the individual visitors play an increasingly important role and should be given the opportunity to critically create their own perspective of the museum and it exhibits [4]. Thus, they become actively and individually involved recipients.

For more than five years, the Institute for Multimedia and Interactive Systems (IMIS) at the University of Luebeck has been developing digitally enriched learning environments for schools and museums in the research project *Ambient Learning Spaces (ALS)* [5], supported by the German Research Foundation (Deutsche Forschungsgemeinschaft, DFG). In context of ALS, body- and space-related human-computer interaction, as well as the concept of cross-device interaction (XDI), builds the conceptual foundations. For this purpose, a family of connected learning applications has been developed as the frontend systems for visitors and curators. Providing these applications, we focus on self-directed learning with interactive media [6].

In the backend, the *Network Environment for Multimedia Objects (NEMO)* is the platform for all ALS applications [7]. NEMO stores all media created by learners in a specific semantic model, which supports the use by ALS applications and reflects the respective applications context. The ALS applications' run on mobile or stationary devices and access NEMO as a contextualized repository. Media created in NEMO can be interrelated inside NEMO and will be presented to the visitors as augmentations of the physical exhibition on different interconnected digital devices like smartphones, tablets or large stationary multi-touch screens [6]. For the visitors, this creates an individual multi-perspective experience of the exhibitions based on personal dynamic narrative paths.

Narratives have always played a central role in museum didactics. It has been first of all "stories" that, physically, verbally, and later also technologically enhanced, guided the visitors through the exhibits [8] on a more or less linear path. In our project, we chose two very different museums as project partners. As testbeds for field studies, we are working closely together with the *Günter Grass-House* (GGH), dedicated to late Nobel Prize winner Günter Grass, and the *Museum of Nature and Environment* (MNU). Both museums belong to the foundation "Die Lübecker Museen" located in the Hanseatic City of Luebeck in Germany and require applications, which allow a personal view of the exhibition in a multi-perspective way [9]. Thus, any narrations may no longer consist of the same and expected, but rather the unexpected, alternatives, or evolutions. Museum visitors shall be able to actively construct and deconstruct their individual and contextualized stories through their interaction in the physical museum space.

In our prototypical implementation, we use web-based systems to provide museum visitors with this personal narrative experience. In general, regarding the user interfaces, these systems are browser-based, with device-specific extensions. Our solution allows museum curators, as well as other museum professionals, to construct the digital augmentation of their physical exhibitions. Inside the museum, visitors will use InfoGrid as one of our ALS applications on their own mobile devices they are already

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accustomed to [10]. InfoGrid [11] augments physical objects of the exhibition with digital media, e.g., by augmented reality (AR) and guides visitors through the exhibition by what we call *Narrative Semantic Media (NSM)*. Museum visitors will also use the InteractiveWall [6], a software system for large multi-touch displays containing applications, e.g., displaying media from ALS.

Our solution utilizes a concept of semantically enriching media in a particular way. All media handled through NEMO are modeled as NSM. NSM consists of media, such as text, still images, audio, video footage, or 3D objects, which NEMO stores as binary data. In NEMO, they are enriched by semantic attributions. The semantic attributions consist of a basic set of annotations, which are used internally by NEMO, as well as an extended set of annotations, which are specific for the context the media object is dedicated to. This context is projected into the semantic model for, e.g., the GGH or MNU, which we focus upon in more detail below. The semantic annotations describe the content and define its place in the semantic model. Although pedagogical and user-related implications with regard to narrations exist, in this contribution we focus on the technical solution.

In this contribution, in Section 2, we regard related work. In Section 3, we illustrate our research scenario. In Section 4, we outline the system architecture. In Section 5, we describe the use of narrative semantic media in museums, and discuss results from the pre-evaluation and validation in Section 6. In Section 7, we present the conclusion and outlook.

II. RELATED WORK

With our work, we focus on dynamic individual narratives, as well as the question of the possible influence of technology on the self-conception and the role of museums. Visitors entering a museum will come with substantial knowledge with potential references from and to the museum. However, depending on the individual, the type of museum, the exhibition, the level of visitor's knowledge will range from complete novice to expert. Therefore, the most satisfying exhibitions for visitors will be those that resonate with their own experience and provide information in ways that confirm and enrich their personal view of the world. Conflicting perceptions induce personal critical reflections that may change knowledge and opinions. Visitors want museum visits to be inspirational and uplifting, emotionally developmental in some way, but also to be picked up with their existing points of view [12].

By digitally individualizing narrative structures inside the museum, new productive relationships between the curator and visitors may be established, especially if in the process of individualization a visitors profile is used to automatically provide the visitors with media potentially referring to the visitors' knowledge and expectations. At the same time, however, the massive use of multimedia systems in museums are seen critical because of the potential decrease in the role and power of physical objects in museums [13].

With our work, we focus on using the outcome of the process of digitalization of museum content. According to Hyvönen [14], publishing linked Cultural Heritage collections creates a major challenge for interoperability. With the applications developed in ALS, we present a solution to make use of digital media collections to extend physical exhibitions with digital content. For museum visitors, we provide applications, which enable visitors to interact with the digitally augmented exhibition in an individual multi-perspective experience. Enhancing a physical exhibition by the means of AR has already been accomplished in various related works. As in 2008, Miyashita et al. already presented an AR museum guide [15], this approach is not new, but the approach presented in this article embeds the visitors into a flexible, self-adapting narrative structure and thereby performs the augmentation. This also distinguishes our work from digital story-telling, like the approaches of Vayanou et al. [4], Antoniou et al. [16], Boy et al. [17], or van Dijk et al. [18]. These approaches, e.g., have in common to require data to be created or especially prepared for use in narrations. Although certain elements of our solution have been inspired by digital storytelling, our approach automatically generates a narration from semantically annotated media with only minimal annotations to the artefacts.

Using NSM through NEMO, the visitor's experience is individualized, making use of a knowledge management platform architecture, as Dragoni et al. outlined [19]. Distinguishing our solution from the approach of Blumenstein et al. [20], the visitors own mobile devices will be integrated seamlessly into the museum's technological ecology while accessing NEMO, interconnecting to other technical museum systems. We also use the mobile devices to identify the museum visitors and thus, personalize their museum experience. Other ways of identification will be possible.

III. SCENARIO

Although this work presents a backend solution, we examine the following scenario of human-computer interaction to illustrate the backend work:

Maureen O'Grady enters the Günter Grass-House through the shop entrance and buys a ticket. Next to the cash register, she notices a poster advertising the mobile app InfoGrid. Becoming even more curious, she downloads and installs the app on her smartphone. Upon startup, InfoGrid is asking some questions related to personal data and preferences. Maureen answers them, e.g., by selecting "literature", "graphic art" and "sculpting" from a list of semantic tags suggestions. She also specifies that she has an hour time left for her visit to the GGH, She finishes this phase after just a minute and finally starts the tour "Günter Grass: My Century" within InfoGrid.

Maureen leaves the shop while InfoGrid displays a hint indicating that she can always use the digital tour of "My Century" wherever she notices a depicted graphical symbol inside the exhibition. For now, she puts her smartphone away and continues through the courtyard and from there through a glass door into the foyer. On the right wall of the foyer, a large shelf with numerous items is attached, the "Cosmos Grass". This is a collection of various items Günter Grass made or collected by himself. A sign says, "Please touch". At the table in the middle of the room, the "Curator's Table", her smartphone suddenly vibrates. She pulls it out of her pocket and follows the instructions on the screen of InfoGrid. Holding her smartphone in a way that the camera captures the

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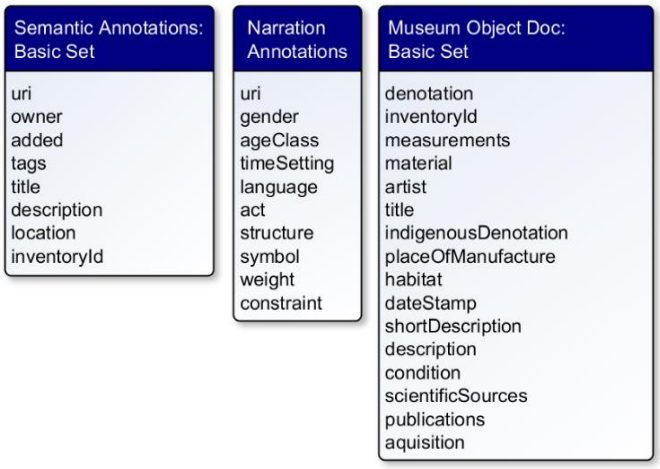

Figure 1. Overview of annotation sets for NSM.

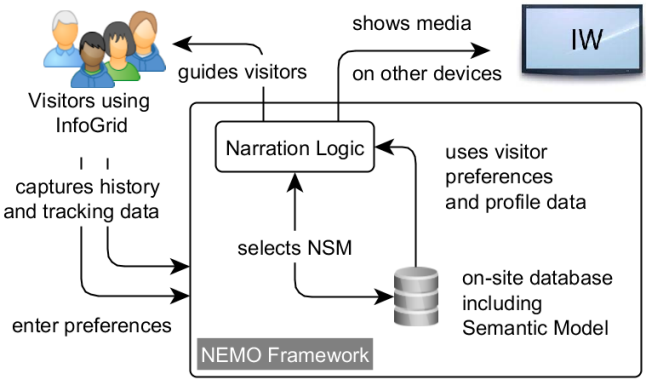

Figure 2. Based on visitors' preferences, history and tracking data, NEMO selects NSM in order to guide visitors with InfoGrid and additionally controls media displayed other devices in the museums.

Curator's Table through her smartphone, she can see the sculpture of "Seven Birds" standing right up on the table like being real. Intuitively she tries to grab the virtual sculpture. Walking around the table, she looks at the high resolution virtual sculpture from all sides. Then, she puts the smartphone back into her pocket and, after taking a closer look at the "Cosmos Grass" and despite another symbol for "My Century", for which she has not taken out her smartphone again, she continues into the next room.

On the wall of the next room Maureen slowly passes the InteractiveWall. She notices how the wall's display suddenly changes, just as she approaches the screen. Instead of the general information displayed before, a media gallery with images and videos gets visible. The gallery is showing Günter Grass with some of his tools in his sculpture workshop. Maureen is thrilled to see how Günter Grass actually created the sculpture "Seven Birds" she had previously viewed from all sides as a 3D object in InfoGrid. She continues her way through the GGH smiling, as sculpturing is a special interest of her as she told InfoGrid earlier.

Finally, Maureen makes her way to the exit. From a distance, she sees how another visitor passes the InteractiveWall screen and the content changes again. Curious, she comes closer and sees that completely different media have been displayed for the other visitor. He notices Maureen and they start a conversation about this phenomenon and their personal interests.

IV. System Architecture

Museum visitors can use InfoGrid, described in more detail by Ohlei et at. [11], to experience information tours at specific locations with their own mobile devices. These locations can be inside a museum building as well as in urban or rural areas. With the help of web-based ALS software, curators can create or edit these information tours. The visitors can download InfoGrid inside the museum through regular Android or iOS app stores. Once installed and started, InfoGrid connects to an instance of NEMO on-site and displays NSM. NEMO individually selects these NSM for each visitor, e.g., from personal preferences the visitors enter on startup of InfoGrid.

InteractiveWall, as introduced by Winkler et al. [6] is a web-based application, which runs on systems equipped with 32"-90" multi-touch screens. Each installation of the InteractiveWall is equipped with a Bluetooth LowEnergy beacon, which allows InfoGrid to detect the visitor's position in the physical exhibition. This supports the individualized display of content on the InteractiveWall through NEMO, e.g., when a visitor is in front of the installation.

NEMO is a web-based framework for ALS, described by Bouck-Standen et al. in more detail [21]. The NEMO API provides access for applications, such as InfoGrid, interacting through Web Services in an authenticated context over a secure connection. The NEMO framework decides which media is presented to the visitor depending on multiple algorithms.

V. Using Narrative Semantic Media in Museums

The scenario illustrates how InfoGrid guides the user through the exhibition. In the following, we describe how with the use of NSM, our backend solution provides the necessary media for display in InfoGrid.

At first, Figure 1 shows the annotation sets and included tags required for our setup. With the annotations from the basic set, the media is described with a subset of annotations of the Ontology for Media Resources [22], which is sufficient for our purposes. These are compatible with the basic Museum Object Documentation, which Dresch and Mainberger [22] examine as a link between the real museum collection and the digital reflection of a museum. This is also utilized in museum documentation systems [3]. These implement the relationship between the systems presented in this article to museum systems already established. In addition to semantic annotations, narrative annotations extend media, as depicted in Figure 1. These are required by NEMO in order to place NSMs on narrative paths.

In the following example, a narrative path has a fixed length l and consequently consists of l NSMs, which are selected by the NEMO applying to a story model. According to the visitor's settings, e.g., depending on the time she or he can spend inside the museum, l is varied. The visitors set the

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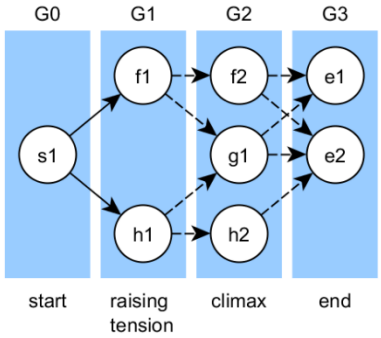

Figure 3. Exemplary narrative paths of length l=4 generated from a total of 8 NSM.

length *l* on startup of InfoGrid, when the application asks, how much time they would like to spend in the exhibition.

As

Figure 2 illustrates, NEMO selects Semantic Media based on the on-site data, semantic model and visitors input, interaction and usage history. By selecting a sequence of media and providing them to InfoGrid as a narrative path, the mobile app is able to guide the visitors by displaying the contents of the NSM to them according to their location inside the exhibition. During usage, InfoGrid continuously submits data about the visitor's interactions in a way that NEMO is able adjust the selection of media during the visitor's stay. Consequently, visitors do not necessarily follow a preset or given path through the museum, but are able to explore depending on their interest or intent raised by this digitally enriched exhibition. This can result in a possible change of the narrative path.

For the scenarios presented in this article, we focus on a basic story model based on arc of suspense [23]. This story model is characterized by an introductory start, a part of raising tension followed by a climax, an optional phase of falling tension (outro) and an end, as illustrated in Figure 3. Technically, this requires the NSM to be assigned into these phases to determine the position of an NSM on a narrative path. In this implementation, the annotation *act* (see Figure 1) positions an NSM with the values of *start*, *end*, *predecessor*, *successor*, and *context* at the corresponding position of the narrative path. There are no special annotations for raising tension or climax, to allow those phases to consist of an unlimited number of NSM. Thus, the suspense of a narration is implicitly modeled by the positions of NSM through the *act* annotation. Other annotations shown in Figure 1, such as e.g., *ageClass*, *gender*, *language*, or *constraint* are used in order to select NSMs according to the visitor's profile.

The creation of a new narrative for a tour through an exhibition begins with the selection of media from the pool of media the museum has already semantically annotated. At first, for the start of the tour, an NSM has to be selected, which Figure 3 illustrates as *s1*. In the example, the tour should end with *e1* or *e2*. For this, these media are annotated with the corresponding annotation. Consequently, Figure 3 shows, that a visitor can reach two possible ends.

Having defined the start and end or a tour, all NSMs have to be identified the tour may consist from. In this case, there are *5* NSMs from the pool of media, which are suitable for the exhibition at hand. In this example, the media named *f1* and *h1* have the same *structure* annotation, and are both as successors of *s1*. The NSM named *f2*, *g1* and *h2* are also labeled with same *structure* annotation, which is different from *f1* and *h1*. As a result, *f1* and *h1*, as well as *f2*, *g1*, and *h2* are grouped in two separate groups, *G1* and *G2* as Figure 3 shows. It can be observed from Figure 3, that starting from *s1* the narrative path branches out into *f1* or *h1*. As those NSM to follow *s1* on the narrative path are set manually, Figure 3 shows the transition as undashed arrows. For visitors starting at *s1*, NEMO determines which path to take. This depends on the semantic annotations mentioned above in context with the users' profile and history. If, e.g., *f1* and *h1* with a distinct *ageClass* annotation set were to distinguish different age classes of visitors, children would follow the path *p1=s1, f1*, whereas adults *p2 = s1, h1*, for example. Moving from *G1*, which contains NSM to raise tension, to the climax, which all NSM selected for *G2* represent, the transitions Figure 3 shows as dashed arrows are automatically determined by NEMO. For this, at first, *G2* is automatically aligned in sequence after *G1* due to *timeSetting* annotations of the NSM. As no other groups exist, *G3* containing both ends *e1* and *e2* follows sequentially after *G2*, and the transitions Figure 3 are calculated equivalently. Afterwards, for each path leading into *G2*, from semantic and narrative annotations, such as tags, location, or constraints, NEMO determines, which NSM follows on the paths *p1* or *p2*. In the exemplary abstract case shown in Figure 3, *p1*, e.g., may be extended by both *f2* and *g1*, as *g1* can be served both age classes mentioned above. This results in *7* possible narrative paths of length *l=4*.

At any point, other additional transitions could be defined manually by adjusting the *successor* or *predecessor* annotation in *act* of the corresponding NSM. This provides the means to directly adjust narrative paths.

The length *l>=4* can be chosen by the visitor. However, a predefined narrative path with *l=10* may be shortcut by visitors who lack time for completing the tour in full. In this case, the *act* and *structure* annotations make sure that the most important NSMs are included in the narrative path. In addition, NEMO is not limited to the story model introduced here.

The narrative path calculated by NEMO also depends on the visitor's physical location inside the exhibition. We detect the visitor's location using InfoGrid and Bluetooth LowEnergy beacons, which are positioned at key points of the installation, such as room entrances. If a visitor is near such a point of interest, NEMO triggers recalculation of the NSM distributed to the instance of InfoGrid of the respective user.

In Figure 4, we regard the world model of the GGH, which abstracts the museum, its exhibits, objects and research into digital space. This brings the late artist and writer Günter Grass into context with, e.g., persons he knew, was influenced by, and influenced upon, institutions, elements from his biography, elements from his world picture, and elements from his works. For complexity reasons, Figure 4 shows an overview of the model with focus on the sub-model used for

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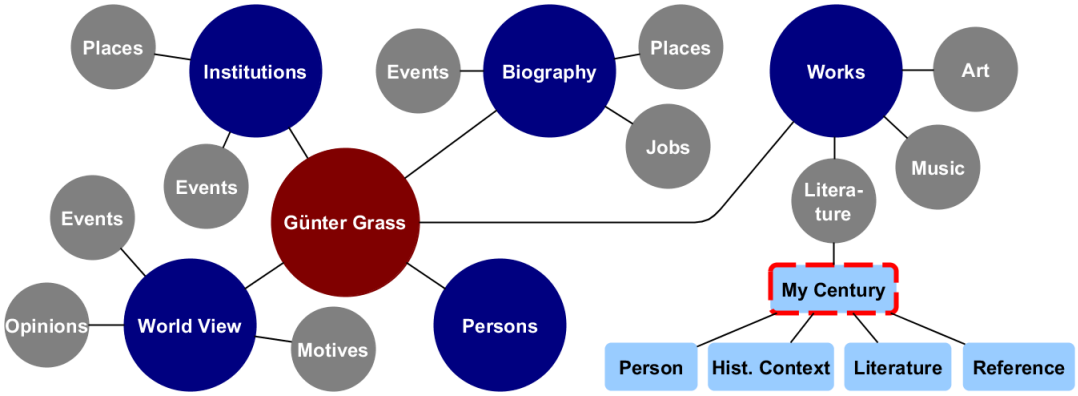

Figure 4. The museum model of the GGH from an overview perspective at the current state of research.
For the scenario presented in this contribution set in the GGH, we focus on the use of NSM in the "My Century" part of the model.

"My Century" in our scenario. For the Museum of Nature and Environment another model exists accordingly.

Grass "My Century" casts a retrospective review of the 20th century in a hundred stories and is narrated from the point of view of different people from all areas of German society, from an assembly line worker to a professor. Each story is accompanied by an artwork created by Grass and features crosslinks to persons, historic events, and other works of Grass, which are mostly hidden in textual hints or, e.g., allusions.

As the above process of creating a narrative path with the use of NSM outlines, a user is required to define NSM as *start* and *end* narratives. However, the process of selecting narratives between starting and ending narratives can be automated. We achieve this by using the semantic model created for the particular context the media is selected in. For example, for a certain year from "My Century", according to the semantic model (see Figure 4), NSM annotated from that year correlates to other NSM, not necessarily dated to the same year, and possibly annotated corresponding to the visitor's interest. Thus, the process of media selection for any other than *starting* or *ending* NSM, NEMO automates the selection, leaving annotations such as *ageClass*, *gender*, *language*, or *constraint* for manual retouch only.

VI. Pre-Evaluation and Validation

We have carried out a pre-evaluation of our implementation under laboratory conditions with 5 subjects using a total of 50 NSM with both 3 starting and ending narratives. The evaluation was conducted using the arc of suspense as the story mode. In our tests, l was defined as $l \in \{3, 7\}$ and we configured NEMO to automatically create two tours per subject. The tours were displayed inside a web-browser and we collected the user's feedback according to the *Think-Aloud* method [24]. In all cases, the subjects experienced both tours and gave positive feedback. The NSMs were assembled to reasonable narrative paths that the subjects were able to comprehend. Under laboratory conditions, with 50 NSM and both 5 starting and ending narratives, NEMO was able to construct narrative paths of all lengths l with $l \in \{3, 10\}$. The test show that, apart from the duration a visitor is willing to spend on a narration, the upper boundary of l depends on the number of semantic connections between the NSMs. However, we have not defined a measure for the complexity of semantic correlations between NSMs to be able to make a general statement with regard to the capabilities of NEMO being able to always create a narrative path to the visitors' desire of length l. Although NEMO was able to generate the narrative paths in our test settings from only 50 NSMs, there may exist scenarios, where NSMs may not be connected to each other. A solution to this challenge may present itself by selecting a story model with a looser coupling between the NSM. The postmodern story model [25] allows more combinations between NSMs, as the model does not follow an arc of suspense. We have also implemented and evaluated this story model with the subjects and analogous to the setting described above. However, the subjects clearly indicated that they did not understand the concept of the postmodern story model and experienced the narrative paths generated by NEMO from the postmodern story model as "disordered" or "incomprehensible". Museum professionals from our project partners confirmed this observation.

The pre-evaluation shows, that NEMO creates individual narrative paths that the subjects are able to understand and follow. This influences the perceived quality of the narration. The pre-evaluation indicates that the parameters of perceived quality and length of narrative paths generated from NSM have to be considered together. It also suggests that (a) the quality of narrative paths perceived by visitors depends on both quality and quantity of NSMs available, on which the narrative paths are based and from which they are generated by NEMO, as well as (b) the complexity of the story model, which is also dependent on the type of audience.

For future evaluations, from the qualitative feedback and from the experience of our museum project partners, we derive that a questionnaire should focus on user experience and be accompanied by questions with regard to the visitors understanding of the story model, the visitors' perception of the narrative path in total, and the perceived quality of the NSMs selected by NEMO as to their motivation of self-directed discovery.

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VII. CONCLUSION AND OUTLOOK

In this contribution, we illustrate a system concept to provide an individualized museum experience. The goal is to augment physical museum exhibits with digital media in a personalized, flexible, and self-adapting narrative structure motivating self-directed discovery. Based on the scenario, we describe the use of technology to design an individual experience for visitors. Unlike other approaches of story-telling, NEMO generates narrative paths from Narrative Semantic Media, presented in this contribution. Thus, museum narrations consist of media as digital overlays and extensions to physical exhibits. Narrative Semantic Media is one focus of our research and a main concept throughout ALS. In NEMO, we use semantic annotations to classify and interrelate plain media within semantic models, and algorithms accessing the semantic models and the users' personal information, e.g., on interests or interaction history, in order to select semantic media for narratives. These media are enhanced for their use on dynamic narrative paths through narrative annotations, forming what we call Narrative Semantic Media. Having selected NSM for a narrative path for a thereby personalized user experience, NEMO depends on ALS applications, such as InfoGrid and the InteractiveWall. These frontend applications allow the users, in our scenario the museum visitors, to interact with NSM.

In our future work, we will also study the visitor's experience on-site with our project partners quantitatively and in more detail. Through the semantic relation of the stored data, visitors can discover new relationships between the museum objects or even urban structures outside the museum. Next to the visitors' experience, we will study the curator's experiences while using ALS systems. Furthermore, we will evaluate how curators build and how visitors use dynamic narrative paths throughout the museum. As InfoGrid and the InteractiveWall are part of the family of ALS applications, we plan to evaluate their interconnection with other applications, also in school context. In this context, the interconnection between multiple distributed instances of NEMO will be subject to further research and development.

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