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Cultural Heritage Cube

A conceptual framework for visual exhibition exploration

Florian Windhager
Department of Knowledge and Communication Management, Danube University Krems
Austria
florian.windhager@donau-uni.ac.at

Eva Mayr
Department of Knowledge and Communication Management, Danube University Krems
Austria
eva.mayr@donau-uni.ac.at

***Abstract*: Cultural heritage exhibitions commonly have to arrange a high amount of diverse artefacts and associated information in architecturally complex facilities. This constellation issues challenges to both: exhibition designers who have to find ways to deal with spatial restrictions and visitors who often experience cognitive overload and museum fatigue due to the high amount of information available. Against this background, the article is focusing on the question, how information visualization can serve as advance organizer, to make the organizing principles of cultural heritage exhibitions (like common topics, themes, geographical or temporal origin) transparent to the visitors. For this purpose, we extend the visualization method of time geography to an interactive visualization framework of time topography, which can support the interactive exploration of conceptual and physical cultural heritage exhibition spaces in parallel.**

Keywords: cultural heritage visualization, digital humanities, advance organizer, time geography, visual analytics;

I. INTRODUCTION

"The past is a foreign country, they do things different there", Leslie Poles Hartley put down on paper in 1953 [12, 18]. Having inherited this artefact together with a breathtaking multitude of other things done different, we want to dedicate the current piece of paper to the question, which challenges inter-country communication between past and presence is facing today - and how it could benefit from a different perspective on its own constellations, leveraging new methods of interactive information visualization.

Museums and exhibition spaces cover a vast array of topics and types of things, mostly foreign to visiting audiences: from objects of natural heritage to the tangible and intangible aspects of cultural heritage, displaying developmental traces from archaeological artefacts and ancient artworks to objects of zeitgeist and matters of current concerns. By doing so, heritage institutions always have to cope with a basic form of asymmetry, generated by growing amounts of highly diverse artefacts and curators rich knowledge on the one side, and the bottlenecks of the visitors cognitive potentials on the other side.

Visitors most often visit a museum for leisure purposes: as a family or school outing, for entertainment and recreation [3, 4]. Though learning is part of the visiting experience for most visitors, it is not their main purpose [20]. To support this informal - and often incidental - learning process, it is not enough that museums display exhibits with small labels. To effectively learn something, relevant information has to be selected on an individual basis, has to be evaluated and integrated with the other information present at the site or existing in form of prior knowledge. These cognitive processes of informal learning often have to happen under aggravating circumstances: the prominent wish to see "everything" has to encounter complex conceptual and physical exhibition architectures, as well as limited visiting time and finite attention spans [21]. As a ubiquitous result, museum fatigue shadows the scene: Perceptive and cognitive overload confluence into a strong reduction of visitors' attention towards exhibits, learning motivation and receptivity [6].

As this is the basic threat for every exhibition designer and curator, several approaches have been fielded to tackle this issue. Exhibit clusters, for instance, can provide zones of perceptual similarity (e.g. by thematic affinity, geographic or temporal proximity, etc.) and thus facilitate the elaboration of general concepts [7], exhibit arrangements along time- and storylines deliver path-like structures to leverage narrative information integration [1], interaction engages visitors to overcome a passive mode of perception and encourage active behavior [13, 14], whereas advance organizers can support conceptual orientation and information integration on different levels of a learning process.

Being one of the first who took on this last method within the domain of educational psychology, Ausubel [2] suggested the use of advance organizers as effective means to improve the construction of mental models: Learners are provided a conceptual structure before a learning unit in which they can integrate the learning material later on. Advance organizers were shown to be especially effective in non-linear, unstructured learning environments [19] and, therefore, have high potential for museums as well. Visitor research shows that advance organizers in the form of texts for conceptual orientation presented before a museum visit can support informal learning, too [8].

Exhibits for conceptual orientation are usually included in each exhibition nowadays. However, this information is often presented only textually and cannot compete against the exhibits' attraction power; consequently it receives only little attention from the visitors [10]. In contrast, information

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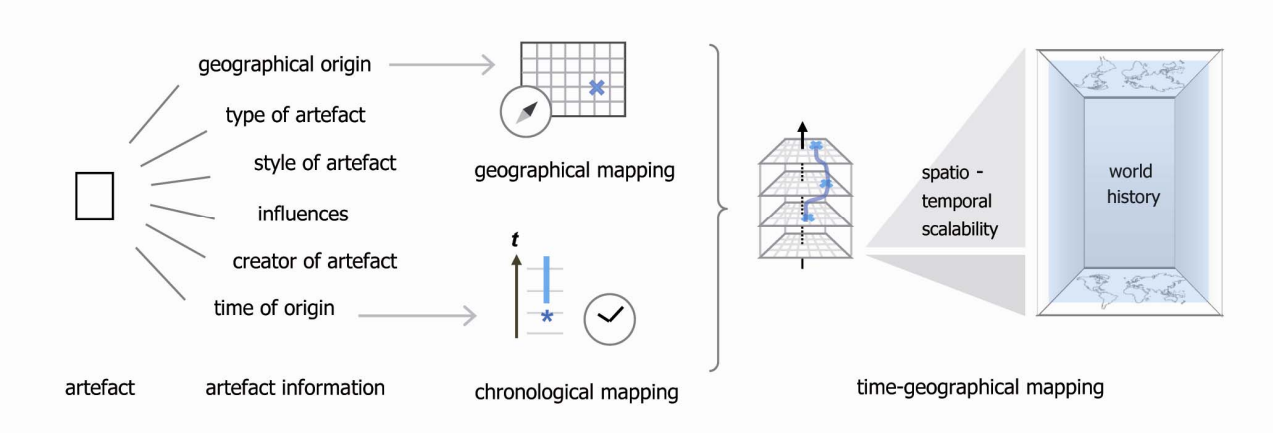

Figure 1: Cultural heritage artefacts are often associated with rich information, including data on place and time of origin, which could be visualized within the freely scalable visualization framework of time geography.

visualizations and new media applications which allow for interactivity often receive high attention. Therefore, we want to turn to the potential of information visualization methods "to amplify cognition" [5] also within the museum domain - and present an application for a visually oriented advance organizer, which roots are located in the human geography domain.

II. Time-topographical Information Visualization as Advance Organizer

It is challenging for museums to display the different connections between exhibits. Take, for example, an art exhibition: by which kind of information should they be grouped (see Figure 1, left hand side): Should artworks be grouped by the place or the time from which they origin, by the artist, or by the topic addressed? As an exhibitions' educational message usually can only be reconstructed by movement through space [24], an exhibition's curator has to decide which relation between the exhibits is most important and determines the exhibition layout. Advance organizers, which can visualize additional conceptual connections, are usually placed in entrance halls or at the beginning of a show floor. Two methods which are featuring most prominently in museums to serve as visual advance organizer are maps and timelines. In the following, we want to introduce an integrative method which has been absent in the range of visualization strategies for cultural heritage visualization until now [9] - and which shall be extended to a freely adaptable cultural heritage visualization framework further down.

A. Time geography

The notation of time geography was introduced by Hägerstrand [11] to visually analyze the spatial dynamics of various entities over time. To achieve this purpose, two methods became conceptually intertwined: cartography as method to map arrangements on geographic surfaces and chronography as method to map arrangements of events along timelines. The resulting figures are so called space-time-cubes: Geographic maps, which serve as horizontal layers, get orthogonally intersected with timelines, so that three-dimensional cubes are unfolding, where the vertical dimension is open to envision space-time. As such, these "space-time-aquariums" provide a notation, by which geographically and chronologically structured information can visually merge. Depending on the specific scaling of the space or time dimension, space-time-cubes can cover only small sections of space time – such as short regional chains of events – or at the maximum scale they can cover space as world history (see Figure 1, right hand side).

Within this scalable framework, the position of any physical entity can be located and visualized over various time phases [16]. The resulting patterns with regard to a single object are space-time-trajectories, which visualize movements as characteristic traces or tracks. While a non-moving object produces a vertical trajectory, moving objects plot curved paths into the cube, which envision the characteristic space-time behaviour of historical entities – and which could be analytically resolved into more basic visual elements. Whereas time-geography originally aims at the visualization of human life paths, this method can also be applied to artefacts which are exhibited in museums, such as weapons, bones, artworks, etc. Relevant basic elements of their space-time-paths for example encompass the space-time-points of their origin (in case of complex artefacts also the phase of its assembly), their time-geographical movements, and relevant events, including: possibly known effects and in case of losses their point of disappearance and retrieval or reconstruction.

Apart from these options of fine-grained time-geographic imaging – which naturally depend on rich historical artefact data – the most basic coordinates often are time and location of exhibit origin. Given any historically structured exhibition, these artefact data points now can be re-positioned in time and space. The result will be a

characteristically distributed point cloud in a characteristically scaled space-time-cube (see Figure 2, left hand side), which can be further explored and visually analyzed (see chapter 2.3). The effect of such re-positioning procedures for the visitor's intellectual experience corresponds to the described effects of advance organizers. Before entering the real exhibition spaces, with all its informational diversity, a coherent exhibition model of reduced complexity could be offered. As such, it delivers a well defined overview first and can serve as cognitive schema or skeleton, which is capable to grow and take up the flesh of more detailed information, when zooming into the exhibition by individual walkthroughs.

B. Time topography

Before turning towards possible methods of interaction with a space-time-cube, a generalizing extension of the framework as outlined so far has to be ensured. Geographical mapping is not the only method which could help to re-position exhibits in relevant conceptual contexts; various extensions of the time-geographical framework are possible. Aligning with the given scaffold of the space-time-cube, these extensions use the vertical time axis as well, but replace the method of horizontal geographic mapping by other information visualization techniques.

For instance by turning to fairly common exhibition topics like natural history, history of arts, or history of nations, the geographic space-time-cube, as conceptualized above, can display valuable exhibit information. Still it cannot be considered to deliver the most appropriate mapping method, when the evolution of whole populations, art forms or dynasties has to be visualized. While the chronological distribution still plays a decisive role, the topographical distribution could be better visualized within a conceptual space of diversity. Now, instead of geographic maps, maps of association, affiliation or social closeness figure as ground layer. The evolution of life, fine arts, or any given topic can now be visualized as historically staggered cluster map (Figure 2, middle) or as branching tree, which unfolds over specifically structured topic maps (see Figure 2, right hand side).

As information visualization methods like social, semantic or multi-topographical network analysis have seen significant methodical and technological advancements in recent times [7, 17, 23], they can be leveraged and coherently integrated into an extended framework of time topography. With this extended framework, which allows exhibition designers (and visitors) to select various mapping methods to re-position their exhibits in conceptually illuminating space-times, we consider to present an innovative solution to visually structure and organize theoretically unrestricted types of exhibition data.

C. Visual analytics for interactive exhibition exploration

Visual analytics is the science of analytical reasoning facilitated by interactive visual interfaces and appropriate visualisation techniques [22]. Here, visual and analytical methods are intertwined to support the exploration of data and discovery processes. Within this framework, the user is not merely a passive element who interprets given visualisations and installations, but is instead the core entity which drives the process of analyzing data and interacting with them.

Visual analytics methods are especially suited for application with large data sets to support users in gaining an overview on and exploring these data. An exhibition-based space-time-cube would necessarily include different structuring properties (i.e. horizontal layers, temporal frames, exhibition parts, etc.) and, therefore, requires intuitive and easy interfaces for museum visitors. By applying visual analytics methods to an exhibition space-time-cube visitors

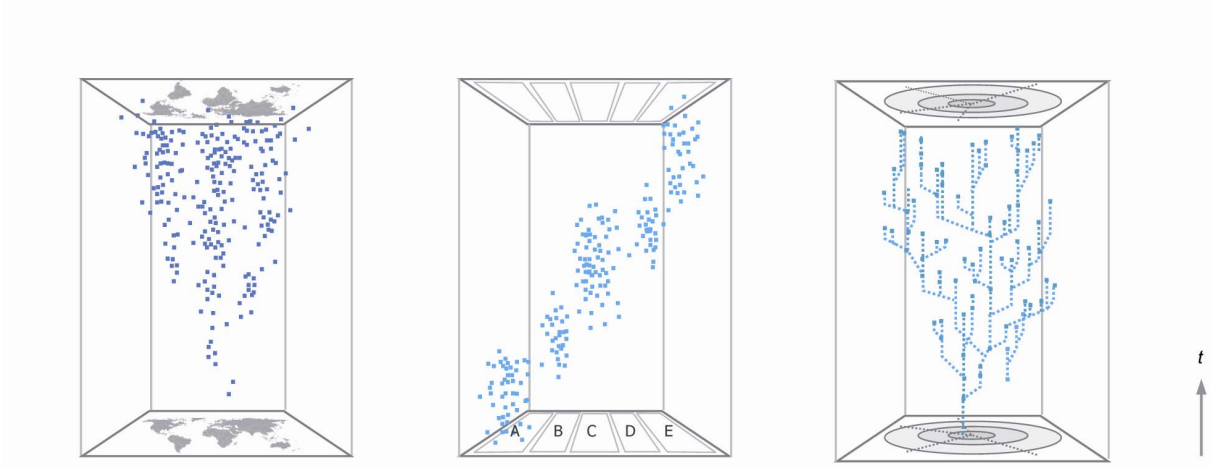

Figure 2: Selection of space-time-cubes, showing different artefact distributions in topographical space-times. From left to right: geographic space-time, categorial space-time of different styles, and historical-genetic space-time.

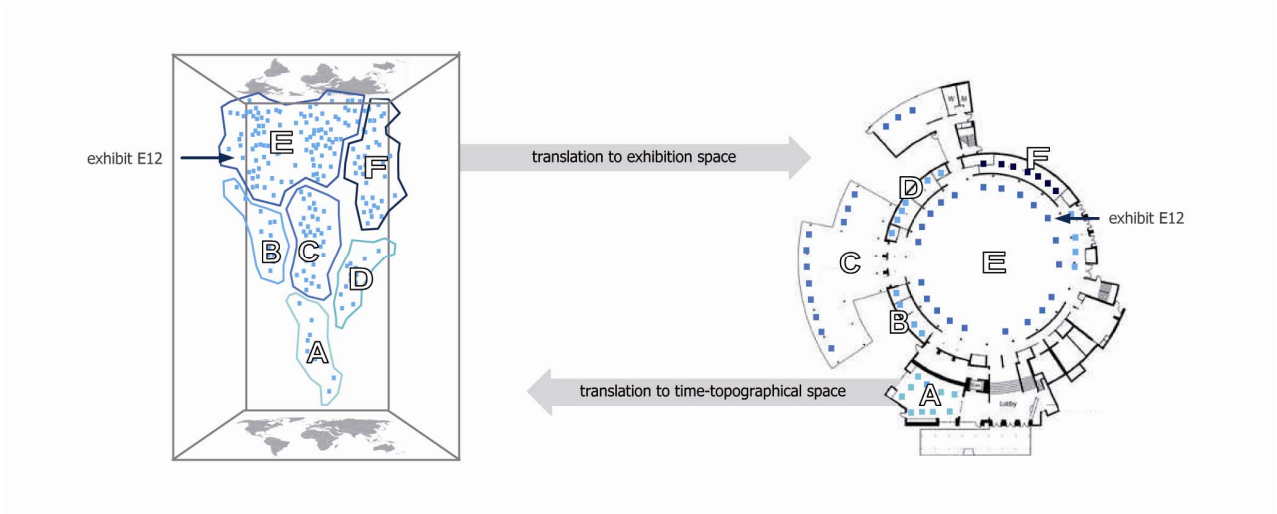

Figure 3: Interlinking time-topographical (left) and physical (right) exhibition layouts.

are enabled to interactively orient themselves in the exhibitions' geographical and topographical space-time. They can navigate through these spaces, zoom in and out, filter, select exhibits, retrieve further information, discover connections between different exhibits and build up a cognitive framework which later helps them to integrate the exhibits and the information at the museum in their enacted knowledge structure.

D. Interlinking time topography and exhibition topography

Maybe the most demanding challenge, is the task to offer and establish an interlinkage between (the arrangement of) the time-topographical exhibition space and (the arrangement of) the real exhibition space.

Time-topographical visualizations allow a translation and re-positioning of given exhibits in meaningful space-time arrangements, but have to be re-translatable into the real (spatial exhibition) arrangements again, to achieve best enduring effects. Thus a public terminal in the entrance area, which allows for time-topographical exploration of the exhibition, has to ensure the link back to the real spatial topography of the exhibits arranged on the exhibition site, where all the details will be discovered on the move.

Technically spoken, to interlink the exhibition with the space-time-cube in a one-sided manner, a Linked View should be deployed between the time-topographical exhibition model and an architectural model of the exhibition layout. Linked views offer (at least two) different views on an identical set of elements by varying visual layouts or rules of arrangement. If these views are furthermore set up for interactive exploration (user-driven methods of linking and brushing), the selection of an element in the first view causes the highlighting of the element in the other view. This allows the cognitive translation of arrangements from one layout to the other – and possible re-translation (or multiple cyclic elaborations) in terms of an enriched return to the former way of viewing.

As shown in Figure 3, this visual interlinkage of exhibit layouts can allow for the formation of a "bilingual" ("bispatial") mental model, which can guide and enrich visitors' experience in the time-topographical and the real-topographical framework. Thus it can help to navigate in the face of cognitive and factual exhibition walkthroughs.

As the outlined approach of a visual "exhibit positioning system" could be implemented on various media devices and on various levels of pervasiveness or richness, the following chapter will map out the various options and stages of technical realization.

III. TECHNICAL IMPLEMENTATION

Technical implementations of time-topographical concepts could be enacted on at least two different levels, which would correspond to different media realms: (1) Computer-based visualizations in the museum's entrance hall allow the introduction of the space-time-cube as advance organizer, whereas (2) additional printed maps or space-based exhibition design can ensure the coherent utilisation of the time-topographical model for the visitors' experiences of the real exhibit arrangements in the given architectural museum spaces.

Whereas the first dimension also could be realized as a supplementing post-hoc measure in every given museum by itself, only a synchronous and narrow intertwining of conceptual information design and physical exhibition design is considered to allow for the best possible development of a coherent mental exhibition model, which again is considered as a precondition for effective cognitive processing in terms of information evaluation, elaboration, and integration.

A. Time topography as advance organizer

Time-topographical visualization applications can be implemented as interactive advance organizer on large public

screens (e.g., in the entrance area), on individual PC terminals (for the purpose of individual exploration), or on websites (for the public communication of science). As various tools already allow for the creation of interactive, time-topographical exhibition visualizations (e.g., [15]), the major challenge for curators and exhibition designers will be data migration and integration into advance organizers.

B. *Coherent exhibition design*

A coherent exhibition design aims on the alignment of the structural and sequential exhibition configuration with the conceptual orientation provided on the advance organizer. If the concepts and structures of the advance organizer are available during the visit continuously and stringently, visitors can more easily integrate the exhibits and the information into the mental model, which they built up in advance.

Time-topographical conceptualizations are already included in most coherent exhibition designs. They can be made more explicit and easy to decode by additionally including guiding systems (e.g., signboards and overview maps analogous to the ones used on the advance organizer), showroom design (e.g. colour coding, red threads), or detailed single exhibit information referencing back to the advance organizer.

Alternatively (or additionally) the advance organizer can be made accessible on mobile devices too. This would allow visitors to continue to navigate and orient themselves in the exhibition's conceptual, temporal, and geographical space, and to make connections to exhibits in other parts of the exhibitions. In addition, visitors could bookmark exhibits and information of personal relevance and interest, annotate thoughts, and take home this information for extended exploration.

Not only for these mobile applications, usability issues have to be taken into close consideration, as three-dimensional visualization methods always put up high challenges with regard to navigation, visual clutter and the readability of labels especially on small screens.

IV. Conclusions

Due to its conceptual nature, we consider this article to lay ground to the development of a conceptual and technological framework which can support visitors' experience in museums with regard to general information integration, informal learning, as well as the relocation of exhibits in space and time. Though only concrete implementations and evaluations will show the extent, to which these effects are achieved, we want to emphasize the relevance of conceptual elaboration as precondition to the successful implementation of various technological measures.

As outlined above, the time topographical framework has to be envisioned as freely scalable and adaptable scaffold, which is open to support cognition on any historically structured subject-matter and which can be technologically implemented using a great variety of exhibition design approaches. As long as the basic combination of spaces and time visualizations are implemented by the use of various information design technologies, we are sure that new kinds of coherent visitor experiences will emerge:

The main effect of the space-time-cube is its function as advance organizer. It allows visitors to build up a conceptual framework, in which to integrate the exhibits and the information presented in the exhibition. Thereby, they can more easily orient themselves in the exhibition's conceptual space, can more effectively evaluate the exhibit information based on the conceptual framework, and finally will acquire more enduring knowledge. Also, the exhibition design principles are made more explicit. Visitors are encouraged to decode the conceptual orientation of exhibits in the museum space, while they integrate the exhibit information into the framework built up by using the advance organizer.

In addition, this technology can raise expectations and interests before the visit. Interested visitors are more motivated to attend to the exhibition more closely and more processing capacities will be freed.

By situating the advance organizer in the entrance hall, it has different effects: First, it will not directly compete with the exhibits, but rather directs the visitors to them by providing conceptual orientation, as well as raising expectations and curiosity. Secondly, such a technological 3D-installation has high attraction power and motivates visitors to explore it. Thereby, it overcomes the shortcomings of textual advance organizers. As a public terminal it additionally can be explored in groups, allowing for discussion of concepts and conversational elaboration.

Last but not least, the space-time-cube opens up a flexible view on exhibitions: Curators are normally restricted to organize the exhibits using one or few organizing principles (e.g. time). In the space-time-cube in contrast, exhibits can be organized in their whole complexity, the organizing principles can be interactively changed, and allow visitors to get an idea on the multiple connections between exhibits of the past - as well as their interlinkage with visitors of the presence.

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