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Using Visitor Flow Visualization to Improve Visitor Experience in Museums and Exhibitions

Robert Strohmaier, Gerhard Sprung, Alexander Nischelwitzer, Sandra Schadenbauer.
University of Applied Sciences FH JOANNEUM, Graz, Austria. 2015.

Abstract

Within this paper we propose an approach to visualize the flow of visitors through an exhibition in space and time with the goal to assist curators and other museum professionals at the crucial task of analyzing visitor experience at exhibitions in museums.

Detailed information about and deep insights in the preferences of visitors are crucial to improve the visitor experience of exhibitions. Accordingly visualizations of visitor paths and trends must be capable to present data in meaningful and understandable ways. Therefore we present several solutions to visualize trends and repeating patterns in visitor behavior as well as most frequently used exhibits. In connection with the exhibition's floor plans and deep knowledge about the visitor interactions at each exhibit several interesting and sometimes surprising trends can be identified.

Beside the visualization techniques itself this paper describes how data can be collected when interactive computer-based exhibits are used in museums. As an example the process of gathering data is described based on a scenario of an existing exhibition in which the data was not just utilized solely for visitor tracking for its own sake. Nevertheless based on this data we are able to visualize the probability of choosing a distinct exhibit depending on gender, age, time, season or weekday.

Finally, an outlook of ideas, how data can be gathered in the near future with new technologies for interactive and as well as for non-interactive exhibits is included.

1. Motivation

One of the most important motivations of this paper is to visualize visitor flows to identify the most frequently used exhibits and furthermore to generate meaningful as well as intuitive visualizations based on this data. Another one is to show how to use data which already exists within an exhibition.

This paper mainly consists of two parts. The first part deals with possibilities of gather and use data which already exists within exhibitions. The second part shows visualization approaches based on the data of the traveling exhibition “Heart over Heels”.

Using the aforementioned data visitor flows were visualized to gather meaningful findings about several aspects of the exhibition “Heart over Heels” such as most common visitor paths through the exhibition. Furthermore we tried to design an approach which can also be applied to other museums and exhibitions.

2. Preconditions

Techniques to track visitors in exhibitions and museums range from personal observation studies (Yalowitz, Bronnenkant, 2009) to highly automated technical systems. In the area of automated technical systems mainly mobile technologies like Bluetooth (Ellersiek, Andrienko, Andrienko, Hecker, Stange, Mueller, 2013; Conte, De Marchi, Nacci, Rana, Sciuto, 2014; Martin, Ho, Grupen,

Muñoz, Srivastava, 2014) or indoor positions systems using wireless local area network access points like the EAGER system (Gutwill, Ma, Meyer, 2014) seem to be promising. Beside these techniques systems based on observation by video cameras (Brunelli, Lanz, Santuari, Tobia, 2007) are used to gather insights into the movement of visitors. Radio frequency identification (RFID) systems (Müller, Kälin, 2009) to collect information about movement and length of stay in rooms or specific areas of museums are also very promising.

Visitor related data for this paper was gathered with RFID technology which is applicable for interactive computer-based exhibits. Beside the chance to raise visitor experience when using interactive computer-based exhibits, various visitor-related data regarding the usage of exhibits can be generated. These data-sets that can be collected depend on the type of interactivity as well as the content of the exhibition. They may range from counting visitors using simple logging of begin- and end-time of an interaction up to explicit knowledge about visitors and their interaction patterns.

However, the approach described is not just based on the use of RFID technology solely for visitor tracking for its own sake. We describe a whole scenario of an existing traveling exhibition which utilizes RFID technology for interactive exhibits to empower visitors to generate their own content and to collect their own data. This visitor generated content is important for the visitor experience during and after the exhibition visit and is needed to achieve the exhibition's goals. The generated and collected data sets are analyzed regarding their ability to draw conclusions on the paths of visitors through the exhibition and should give insights in optimization of the placement or of types of interactions of specific exhibits. The analysis of the data collected can be seen rather as quantitative investigation with the focus on evaluation of computer-based exhibits rather than evaluating visitors (Hooper-Greenhill, 2006).

The visualizations shown within this paper are applicable also for data generated in another way as described in the next chapter. The main goal of the visualizations shown in the following chapters was to create meaningful spatial-temporal diagrams to show visitor flows and to identify the most frequently used exhibits within the exhibition.

3. Gathering data for visitor tracking as side effect

As mentioned above the data we analyzed was not logged intentionally for this purpose. Primarily it was used to improve the visitor experience within the traveling exhibition "Heart over Heels" designed and realized by "FRida & freD – Graz Children's Museum" (http://www.fridaundfred.at/) and equipped with interactive computer-based exhibits developed by the Digital Media Technologies research group (http://dmt.fh-joanneum.at) at the institute of Information Management at the University of Applied Sciences FH JOANNEUM (http://fh-joanneum.at/iin) in Graz, Austria. In order to gain more detailed insight in this exhibition it is described in the section below.

Introduction to the exhibition "Heart over Heels"

Aiming at children at the age of six years and older as well as at families and preschoolers the traveling exhibition "Heart over Heels" provides a modular exhibit design with around 80 different hands-on exhibits. Theme of the whole exhibition is the human body and furthermore people's needs, abilities and desires. (FRida & freD et. al. 2014)

Up to 25 of those 80 hands-on exhibits are designed as interactive computer-based exhibits. Up to 17 of these 25 exhibits are equipped with radio frequency identification (RFID) readers which enable visitors with special RFID cards (shown in figure 1) to save the data and content they generate during

their visit. Because of the modularity of the exhibition and the different settings at different locations the number of exhibits is described as “up to” numbers within this paragraph.

Figure 1: Visitor RFID card placed at the registration terminal (entrance area)

Visitors can move around freely within the exhibition. There is no specific order in which the exhibits have to be visited. Exhibits sharing a common topic (e.g. how do muscles work, what is the cardiovascular system, etc.) are grouped in rooms. Visitors have different possibilities to interact at the interactive computer-based exhibits placed within these rooms. For example exhibits enable visitors to figure out how high they can jump (shown in figure 2), how well they can balance on a small bar. Visitors can take pictures of themselves or listen to their own heartbeat and save it as an audio file. The various types of interaction with the interactive exhibits can be categorized by the following interaction patterns:

- Interaction on touchscreen (e.g. point and click, gestures, fill out forms, etc.)
- Interaction with arcade buttons
- Physical interaction (e.g. jumping, stretching, balancing, running, cycling, etc.)
- Taking pictures (e.g. of own mimic, of a costume)
- Hearing/listening (e.g. listen to own heartbeat)

Figure 2: Exhibit “Quickness of the legs”

During the use of the interactive computer-based exhibits equipped with RFID readers the visitor generated content (e.g. photographs, quickness, reaction time, etc.) and other exhibit related data (e.g. start of interaction) is stored in a database. The collected data is mainly used to print a personalized booklet at the end of the visit for each visitor. Visitor generated content is also accessible online for museum visitors on a password protected website. Both the booklet as well as the website are designed to enrich visitor experience during and especially after the museum visit.

The collected data was evaluated regarding its usage for visitor tracking and serves as the basis for the visualizations within this paper. Some very important conclusions about the visitor behavior can be drawn form the data collected. In order to visualize visitor flow the order of visited exhibits is important. Also date and time visitors equipped with RFID cards who enter the exhibition are available.

Apart from RFID equipped exhibits visitors can also interact with traditional non-computer-based hands-on exhibits as well as with computer-based exhibits without RFID readers. Visitor related data for traditional hands-on exhibits does not exist. However, for computer-based exhibits without RFID readers at least limited conclusions about visitor behavior (e.g. start of interaction) can be drawn.

To enable a clear interpretation of the following visualizations and get a better overview about the exhibition “Heart over Heels” in table 1 all interactive computer-based installations are listed including their type of interaction, visitor generated content, physical activity level and the input interface for the interaction. Interactive computer-based exhibits without RFID readers are written in italics. Text not written in italics refers to interactive computer-based exhibits equipped with RFID readers. More detailed information about the exhibition “Heart over Heels” can be found in FRida &

freD et. al. (2014) and by watching a video about the exhibition available on YouTube (http://youtu.be/fF8Cj7eLihI).

ID	Name	Type of Activity	User Generated Content	Physical Activity Level	Interface
i01	I decide	Look at pictures Point and click	Personal preferences	Low	Touchscreen
i02	Televised need fulfilment	Watch videos Push buttons	Personal needs	Low	Arcade button controller
i03	*Bathtub Game*	*Quiz* *Push buttons*	*- none -*	*Low*	*Arcade button controller*
i04	*Quacky sound collage*	*Move and place tangible objects*	*- none -*	*Low*	*Tangible objects*
i05	Toothbrush game	Brush teeth Swipe gestures	Accurateness	Low	Touchscreen
i06	*Little Professor Game*	*Adventure game* *Point and click*	*- none -*	*Low*	*Touchscreen*
i07	Question and Answer Game	Quiz Point and click	Questions of interest	Low	Touchscreen
i08	Detective profiling	Fill out a form	Personal data	Low	Touchscreen
i09	World stage	Costume yourself Push buttons	Picture of yourself	Medium	Arcade button controller
i10	Hand-eye-coordination	Sports game Push buttons	Reaction time	Medium	Arcade button controller
i11	Balancing bar	Sports game Balance on a bar	Balancing time	Medium	Balance bar
i12	*Lip reading*	*Video quiz* *Point and click*	*- none -*	*Low*	*Touchscreen*
i13	*Hearing test*	*Audio quiz* *Point and click*	*- none -*	*Low*	*Touchscreen*
i14	*Breezy journey into the lungs*	*Adventure game* *Breath*	*- none -*	*Low*	*Breath-powered fans*
i15	*Deck chair cave*	*Puzzle* *Point and click*	*- none -*	*Low*	*Touchscreen*
i16	Bicycle tour into the forest	Sports game Cycling	Endurance	High	Ergometer
i17	Flexibility	Sports game Push buttons	Flexibility	Medium	Special arcade button controller
i18	Quickness of the legs	Sports game Push buttons	Jump height	Medium	Special arcade button controller
i19	Sprint	Sports game Run	Quickness	High	Photo-electric guard
i20	Dancing Test	Sports game Jump back and forth	Sense of rhythm	High	Dance mat
i21	Wallball	Sports game Throw ball	Strength	Medium	Force sensor
i22	Facial muscles	Watch video Point and click	Picture of yourself	Low	Touchscreen
i23	Pulse check	Hear own heartbeat Point and click	Heartbeat (audio file)	Low	Electronic stethoscope
i24	Personal Security Game	Adventure game Point and click	- none -	Low	Touchscreen
i25	*Pump station*	*Sports game* *Step in rhythm*	*- none -*	*High*	*Stepper*

Table 1: Interactive computer-based exhibits

Collected and aggregated data

Based on the above described exhibit theme combined with the setting of RFID cards for visitors and RFID readers at computer-based exhibits shown in table 1 we gathered and aggregated to following data which can be clearly connected to each of those visitors:

- Visitors with a unique id
- Sequence of visited exhibits of each visitor
- Day and time of the start of the visit
- Sex of visitors (based on voluntary disclosure)
- Age of visitors (based on voluntary disclosure)

Furthermore there is also logging data of all of the computer-based exhibits available. Even exhibits without RFID readers, and therefore without the possibility to clearly identify visitors, generate data like the start of an interaction:

- Start of interaction at an exhibit
- Day and time of the start of interaction at an exhibit

This aggregated data allows us to analyze and identify the exhibits a visitor interacted with. Moreover we are able to analyze the visitor generated content described in this section and we can use, adapt and extend the ideas of Müller and Kälin (2009) such as measuring the amount of visitors per room of an exhibition and following their path from room to room.

Restrictions

Please note, that the data collected can be used to analyze how often the interaction at a specific installation was started by a visitor. It cannot be analyzed if a unique visitor interacted with an exhibit more than once. Clear identification of a visitor at an exhibit without RFID reader is not possible. The data collected, however, allows us to show how many times a computer-based exhibit was used in total. The length of stay at a specific exhibit cannot be analyzed due to the lack of these data. These restrictions occur because the data was designed to meet the requirements of the exhibition setting and not necessarily with the aim of doing visitor research. As described before the data is sufficient for some analysis in the area of visitor tracking.

Venues and data samples

The travelling exhibition “Heart over Heels” was shown at six different venues with varying exhibition length. For this paper we can utilize data of four different venues across Europe and one venue in the Caribbean. In table 2 the sample size of each venue is shown. Please note that the number of samples correspond just to visitors equipped with an RFID card. It is not possible to draw a conclusion based on this sample size to the total number of visitors for each venue. Also people without RFID cards can visit the exhibition and interact with non-computer-based hands-on exhibits as well as with computer-based exhibits.

Venue	Sample size for visualization (n)
Graz, Austria	23.518
D'Abadie, Trinidad	2.346
Dresden, Germany	23.117
Bremen, Germany	14.172
Dortmund, Germany	27.779

Table 2: Venues of the exhibition “Heart over Heels”

4. Visualizing an overview about the data

First of all we give an overview about the collected data. To accomplish this, traditional and common known techniques like the sequenced bar chart and a heat map (Rogowitz, Treinish, Bryson, 1996) are used. The data used for this and the further visualizations was collected at the venue of Dortmund in Germany. We used this data because of the largest number of samples (n = 27.779) shown in table 2.

Overview about the sequence of visited exhibits

Before giving detailed information on the paths of visitors across the exhibition an overview about the sequence of visited exhibits is shown in figure 3. Within this visualization all exhibits equipped with RFID readers are shown in the sequence in which they were visited. As visualization technique a simple sequenced bar chart is used. The first vertical bar stands for the entrance to the exhibition and shows the total amount of visitors with RFID card. The second vertical bar shows the distribution of the total number of visitors across the exhibits which were visited first. The third vertical bar shows the distribution of the total number of visitors across the exhibits which were visited second and so on. Within each vertical bar visualized as bar segments are the single exhibits. The exhibits are labeled with their abbreviations shown in table 1. As an example within the second vertical bar can be seen that the most frequently visited exhibit right after entering the exhibition was the exhibit labeled with the abbreviation i19 (“Sprint”). Bar segments labeled with the word “Exit” shows the amount of visitors who left the exhibition.

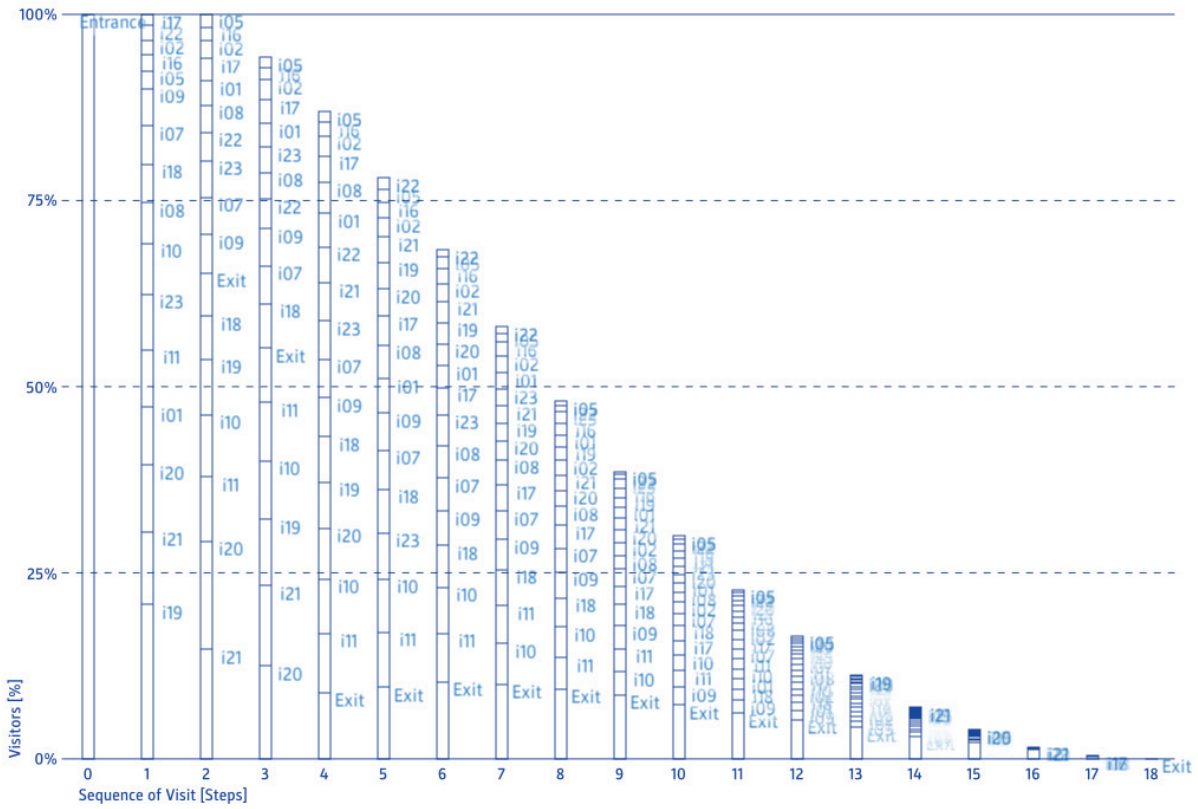

Figure 3: Sequence of visited exhibits

It is interesting to see that most visitors interacted with at least with three computer-based exhibits with user registration by RFID during their whole visit. Around 50% of the visitors interacted with seven exhibits before they left the exhibition. How many other computer-based exhibits without

RFID registration or how many non-computer-based hands-on exhibits they interacted with cannot be measured based on the underlying data. Also other research results in the area of visitor studies state that visitors typically view around 20 to 40 percent of the exhibits within a museum. Depending on their own visiting style people are going to filter exhibits regarding their very own mind-sets on the basis of different aspects (Rounds, 2004).

On the other hand only some visitors interacted with all 17 computer-based exhibits with user registration by RFID. Although this diagram may seem confusing one possible interpretation can be that there are too many exhibits within the exhibition. Visitors are not able to interact with all of them. If they are satisfied with the exhibition, they might come back and visit the exhibition more than once. Unfortunately this interpretation is just an assumption and cannot be measured with the underlying data sets. This aspect might be further researched by a visitor evaluation Hooper-Greenhill, E. (2006).

Visitor interactions at each exhibit

To enable a clear overview about the total number of interactions at all computer-based exhibits a heat map was generated. Please note that the number of interactions does not necessarily cohere with the number of unique visitors at an exhibit. Visitors can interact with those exhibits more than one time. Also not all of the installations shown in the visualization are equipped with an RFID reader. So the clear identification of a visitor is not possible at every installation.

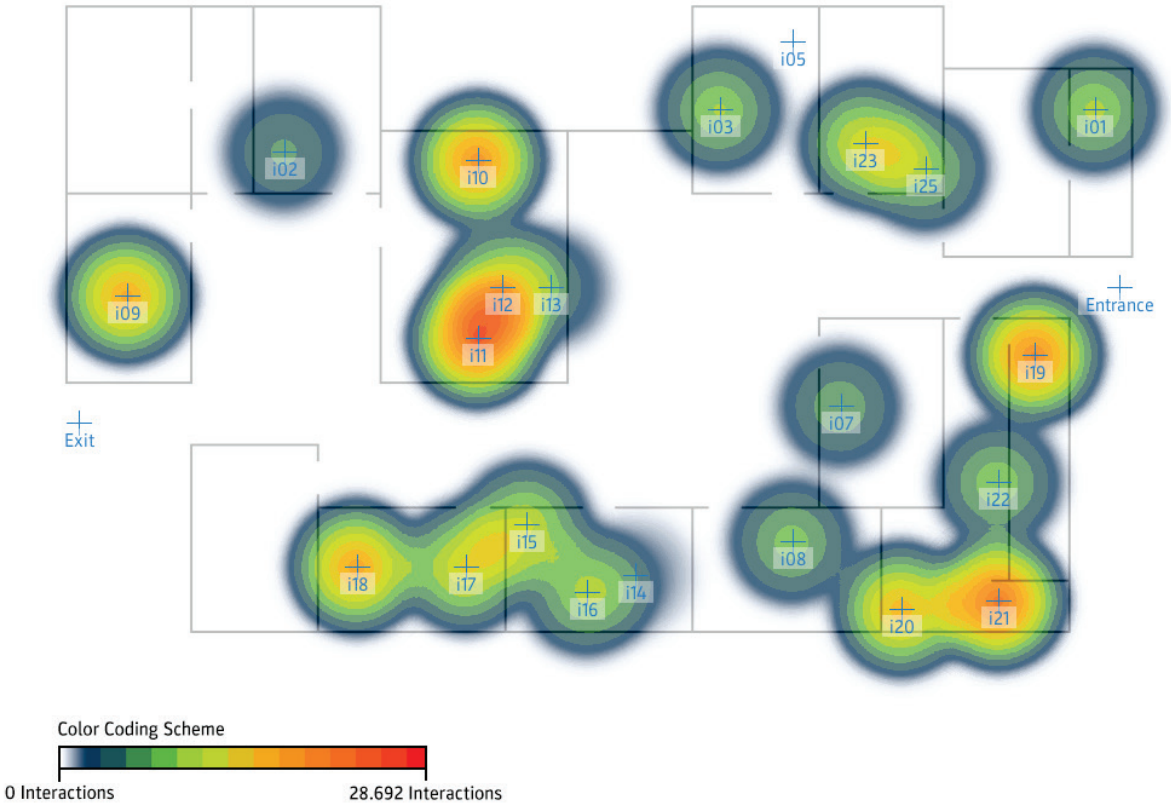

Figure 4: Number of interactions at each computer-based exhibit

As shown in figure 4 the exhibits where visitors can be physically active seem to be the most frequently used ones between all of the computer-based exhibits. With this knowledge in mind the most common paths of visitors across the exhibition are of great interest.

5. Visualizing visitor flows

The following visualizations are developed and generated on basis of the data described above. Besides our approach the visualizations can be used as well for other kinds of spatial temporal data. Because of the fact that there is no specific order in which the exhibits have to be visited, a many-to-many relationship of the sequence of exhibits during the museum visit occurs which will be the same for most other exhibitions and museums.

First approach: Spatial-temporal Sankey diagram visualization

Sankey diagrams belong to the category of flow diagrams and can visualize various kinds of sequences. In 1869 Charles Joseph Minard proved the possibilities to display multi-dimensional data within a Sankey-like diagram by visualizing Napoleon's Russian campaign of 1812 (Friendly, 2002) as shown in figure 5. Nowadays Sankey diagrams are likely to be used to visualize flows of energy or materials in networks or processes (Riehmann, Hanfler, Froehlich, 2005).

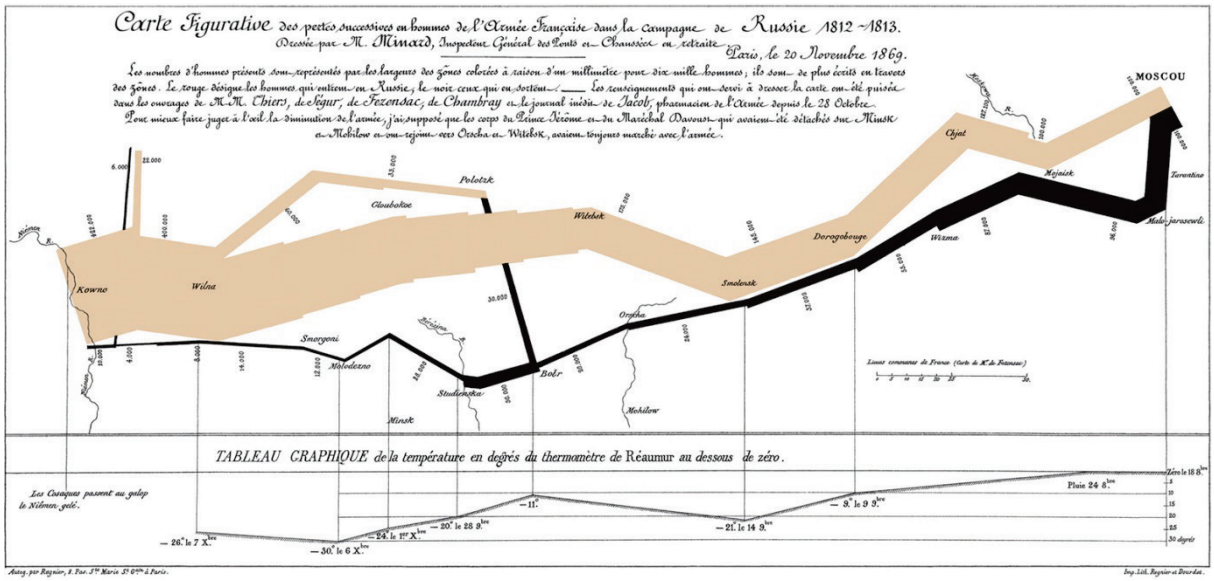

Figure 5: Charles Joseph Minard's visualization of Napoleon's Russian campaign of 1812 (Friendly, 2002)

Their ability to display flows of different kinds of weighted characteristics over a period of time made them very interesting for our approach to visualize visitor flows. Also in our domain we like to show this flow along time and, a little bit more specific, also corresponding to specific locations.

Within the first attempt an early stage of a Sankey-like diagram shown in figure 6 was designed, to prove if this approach will work. As the basis for this diagram the floor plan of the venue in Dortmund, Germany was used. This floor plan forms the lowest layer of the diagram. On top of this the single exhibits were marked. Finally the data was aggregated to a data set which shows the paths through the exhibition for each single visitor equipped with the exhibition's RFID card. In this first attempt the connections between the single steps (exhibits) are not weighted. So no conclusion about the number of visitors following a specific path can be drawn.

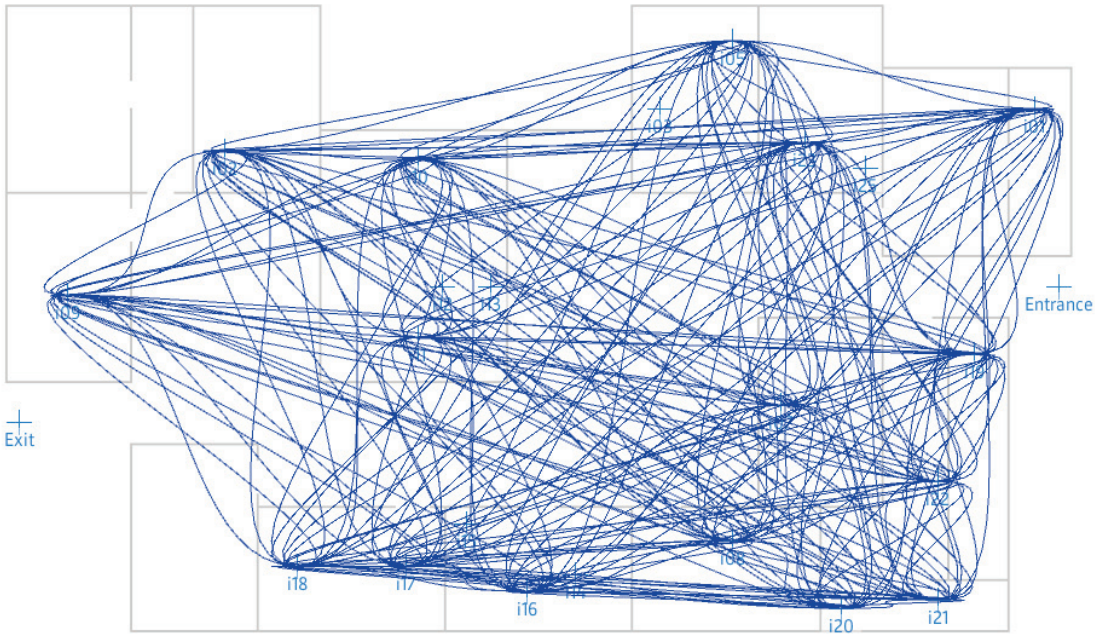

Figure 6: First approach - Spatial-temporal Sankey diagram visualization

This visualization served as a kind of prototype for the planed Sankey diagram. With the help of this prototype we figured out that this approach might not work with very heterogeneous data like the paths of the visitors in museums and exhibitions. Therefore we stopped working on this method.

Second approach: Spatio-temporal aggregated visualization of visitor flows

This not very meaningful prototype led us to the insight that it might be more promising to aggregate the temporal data. Therefore we determined the frequency of walking from one unique exhibit to another across all visitors.

With this technique (shown in figure 7) the visualization will not be overly crowded by all the different paths through the exhibition. At the same time common sequences of visited exhibits can be recognized. To visualize those paths a graph similar to the technique of flow diagrams (Aigner, Mikisch, Schumann, Tominski 2011) was developed. In order to visualize the flow of visitors the data of movement from one unique exhibit to another is grouped and weighted by the frequency this path was used by visitors. As a metaphor for the movement between exhibits an arrow was chosen. The arrowhead is pointing in the direction of the movement and the line strength and color show the amount of visitors who were walking along this path. Because of the fact that there is no required order of visiting the exhibits the arrow is split into two parts (see figure 8) to visualize visitor flow in all possible directions. In this manner all paths of all visitors of the whole exhibition period can be displayed on a floor map. The floor map was used to create a perfect link between the abstract data and the real world setting.

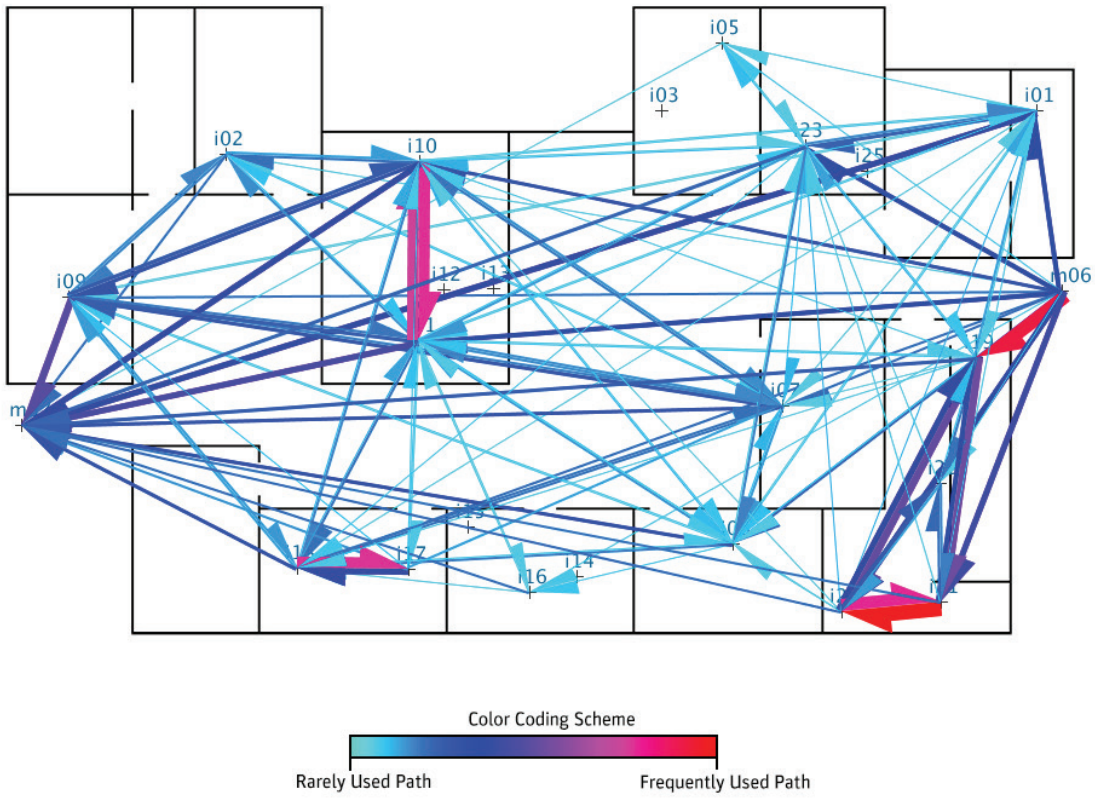

Figure 7: Second approach: Spatial-temporal aggregated visualization of visitor flows

Within the visualization shown in figure 7 and figure 8 a color coding scheme is used. The color red indicates the most common flows between exhibits whereas cyan displays the least common used paths.

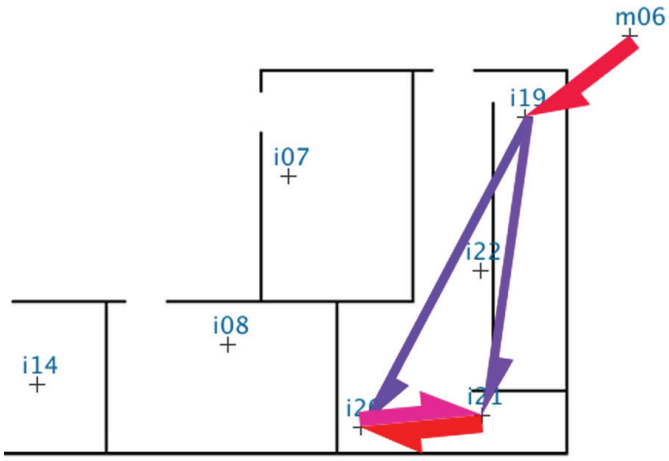

Figure 8: Arrowheads visualize visitor flow in all possible directions

Interpretations based on the approach of spatio-temporal aggregated visualization of visitor flows

Regarding Veron and Levasseur (1983) the accumulated path of the most visitors shown in figure 7 could be seen as a butterfly or grasshopper visiting style (Kuflik, Zvi, Zancanaro, 2012). In addition to

the visitor styles of Veron and Levasseur (1983) we propose the idea that visitors within this exhibition tend to use exhibits with a high level of physical interactivity. If a visitor explores his or her sense of rhythm (exhibit “i20”; very high level of physical interaction), it is very likely that this visitor also checks how fast he or she can run (exhibit “i19”; very high level of physical interaction) and how hard he or she can throw a ball against a wall (exhibit “i21”; high level of physical interaction). Whereas those visitors only sometimes visited exhibit “i22” where facial muscles can be explored during a computer-based exhibit where they have to watch a movie and afterwards are able to take a picture of their own face. We see playing with different facial expressions as rather low level of physical interaction. All of those exhibits are placed within the same room with the topic of fitness and muscles. Also the strong connections between exhibits “i10” and “i11” as well as between “i17” and “i18” can be seen in a similar way. So it seems most visitors tend to interact with exhibits with high level of physical interaction if they interacted with a similar one before.

Additionally the most common starting points of most visitors (exhibits “i09” and “i08”) can be identified. Beside these two exhibits other visitors chose to start elsewhere in the exhibition. This might be because of a too crowded area at the entrance zone of the exhibition as well as because of their expectations. In detail a qualitative investigation such as a visitor evaluation (Hooper-Greenhill, 2006) should be conducted and should be compared to the visualization to prove this. Finally common drop off points can be identified by the exhibits “i01”, “i09”, “i10” and “i11”.

Interactive spatio-temporal aggregated visualization of visitor flows

As shown in figure 7 conclusions about visitor flows in exhibitions can be drawn on the basis of the aggregation and visualization of spatio-temporal data. Certainly the visualization of the data of all visitors during the whole exhibition period could be improved. Therefore we propose an interactive solution for this technique. Filter methods to meet restrictions in visualizing visitor flows seem to be very promising. A more detailed examination regarding sex and age of visitors allows much more interesting insights as shown in figure 9.

Figure 9: Screenshot of an interactive spatial-temporal aggregated and filtered visualization of visitor flows

Combination of visualizations

To gain a deeper insight in the correlation between the most visited exhibits shown in the heat map in figure 4 and the flow of visitors shown in figure 7 a combination of both approaches was accomplished. In figure 10 also computer-based exhibits without RFID readers are considered.

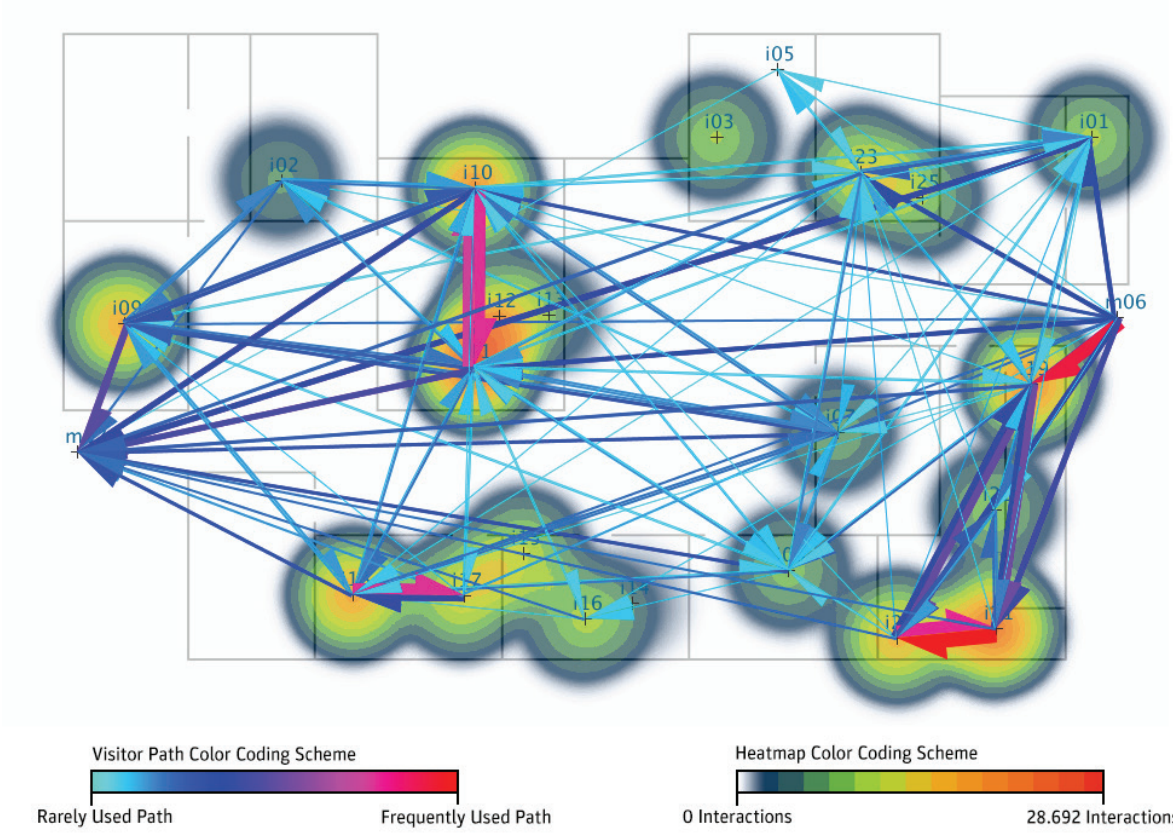

Figure 10: Combination of heat map and visitor flow visualization

6. Conclusion and further work

Within this paper we have shown that using already existing data from an exhibition might work to analyze some variables in the field of visitor tracking. The meaningfulness of the results depends mostly on the information within the underlying data sets. However, the approach of using existing data for visitor analysis and visualizing it in a meaningful way is an economic opportunity.

The visualization of visitor flows shown in figure 7 and figure 10 allows deep insights into the behavior of visitors in exhibitions such as common paths of visitors between some exhibits as well as most frequently used exhibits.

Interactive tools for filtering data as shown in figure 9 can provide more detailed information about visitor flows. Furthermore a combination of visualizations which give a general overview about data like the heat map with visualizations where more detailed conclusions about visitors can be drawn seems to be very promising as shown in figure 10. In order to find out about the details of single unique visitors other visualization techniques have to be analyzed and most likely to be modified. One very promising approach could be the use of space time cubes (Bach, Dragicevic, Archambault, Hurter, Carpendale 2014). Nevertheless the problem might occur that showing details of single visitors and giving the overview about all visitors might not work very well. As a possible and logical

next step a way to visualize both, the single visitor paths as well as the aggregation of the most frequently used paths, should be found.

If no data is available within an exhibition, the new technology of Bluetooth iBeacons seems to be very promising (Conte, De Marchi, Nacci, Rana, Sciuto, 2014; Martin, Ho, Grupen, Muñoz, Srivastava, 2014). Conte et. al. and Martin et. al. state interesting approaches which seem to be a starting point for further developments in this field. Compared to other common techniques for visitor studies like WiFi indoor positions systems (Gutwill, Ma, Meyer, 2014), observation by video cameras (Brunelli, Lanz, Santuari, Tobia, 2007) or RFID systems for visitor tracking (Müller, Kälin, 2009) iBeacons seems to be a really good and also inexpensive alternative. Beside visitor tracking these systems can further raise visitor experience if they are integrated within mobile applications for smartphones and tablets like interactive mobile museum guides or interactive treasure hunts throughout exhibitions.

7. Acknowledgments

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