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Mobile On-Site Content Editing for Interactive Installations

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Abstract

Nowadays interactive installations and public displays have become part of our daily lives, for example in retail stores, at bus and train stations as well as in museums. The content which is shown on this displays is often created at a desktop computer and then remotely deployed on a target device. Content which may appear well optimized on the desktop display may look maladjusted in the target environment. By providing a mobile editor component to optimize the adaptation on-site, content can be created faster and in a higher quality whereby the content is optimally fitting the specific target environment. In this thesis VEII (Visual Editor for Interactive Installations) is presented - a toolkit which combines the features of a content management system and a content composing tool with a platform which enables non technical experts to create smart environments, extended by a component to adapt content on-site while getting immediate feedback from the target display. Furthermore, the toolkit enables users to create interactivity using sensors without any technical expertise by providing behavior rules. Users can adapt the rules within a text-based story where easy understandable UI elements are embedded that represent important parameters of the actual implementation.

Kurzfassung

Heutzutage sind interaktive Installation und öffentliche Bildschirme Teil unseres alltäglichen Lebens, beispielsweise im Einzelhandel, an Bus- und Bahnstationen sowie in Museen. Die Inhalte, die auf diesen Bildschirmen dargestellt werden, werden oft auf einem Desktop Computer erstellt und dann auf einem externen Zielgerät angezeigt. Inhalte, die auf dem Desktop Monitor gut angepasst erscheinen, können auf dem eigentlichen Anzeigebildschirm falsch aussehen. Durch die Bereitstellung einer mobilen Editor-Komponente für die Optimierung der Inhaltsanpassung, werden Inhalte schneller und mit höherer Qualität erstellt, wobei der Inhalt optimal an die Zielumgebung angepasst ist. In dieser Arbeit wird VEII (Visueller Editor für Interaktive Installationen) präsentiert - ein Toolkit, das die Funktionen eines Content-Management-Systems und einem Präsentations-Werkzeug mit einer Platform verbindet, die es technisch unerfahrenen Personen ermöglicht, intelligente Umgebungen zu erstellen. Zusätzlich wird das System um eine Komponente erweitert, die es ermöglicht, Inhalte vor Ort anzupassen und dabei eine unmittelbare visuelle Rückmeldung von den Änderungen auf dem Anzeigebildschirm zu erhalten. Weiterhin ermöglicht das Toolkit Benutzern, durch das Bereitstellen von Verhaltensregeln, ohne technisches Expertenwissen Interaktivität zu erzeugen. Die Benutzer können diese Regeln anpassen, da die Implementation in einer text-basierten Geschichte dargestellt ist, welche mit einfach verständlichen und anpassbaren Kompenten ergänzt wird. Diese Komponenten repräsentieren wichtige Parameter der Implementation der spezifischen Regel.

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1 Introduction

Nowadays interactive installations and public displays are situated in our daily environments. Most of them are set up in public spaces e.g train stations or airports and we perceive them as a normal part of our daily lives. Thereby they provide different information about the weather, news or advertisement. Furthermore, interactive installation in form of projector based installations are also a big part of art exhibitions. Another way where digital content is overlapping with our daily lives is the upcoming trend of using media facades where whole buildings got superimposed with projected content to attract peoples attention. Searching, creating and composing content is mostly done on desktop computers and then deployed on the target device depending on the hardware used to set up the interactive installation. Due to different factors such as screen resolution, projection surface or the distance to the projection, the deployed content may appear different on the target display than expected during the creation at the desktop computer. Creators do therefore need to go through several cycles of content creation, adaption and deployment on the target display. This approach is neither efficient in time nor promotes high content quality. Furthermore, making public installations interactive is often connected to a costly creation and deployment process. Creators need to hire specialists who create custom installations which, once installed, are static and not adaptable. Additionally, an installation is often a one time acquisition, so after the installation met its purpose, it often can not be reused for another project.

To target the problem of creating content and deploying it in different environments a toolkit was developed to compose content in a user interface-mix of a CMS-system and a Microsoft Powerpoint-like approach with the capabilities of editing and adjusting content on-site through a mobile device. By using the system authors can prepare their content on a desktop computer by adding different media like rich text, images, video and audio to one or multiple content slides. Afterwards they visit their installation with a mobile device to customize the displayed content on-site. Using typical touch screen gestures, they can for example move, scale and rotate the selected content and adjust it to the installation specific circumstances while all changes are instantly mirrored on the target display. To enable creators to provide interactivity on their own the VEII toolkit provides an easy and understandable way for non-programmers to create and adapt behavior rules for digital content. Creators can easily transform content like moving, showing, scaling and animating by using behavior rules together with all kind of external hardware like pressure-sensors, accelerometer-sensors, NFC-technology or distance-sensors. Therefore, the VEII toolkit is connected to the meSchup platform, a system which enables the creation of smart environments to non-programmers by minimizing the technical

boundaries. Through the VEII toolkit and the meSchup platform interactive installations become easy to establish and remain very adaptable as well as reusable.

Motivation

Currently the meSchup platform minimizes the technical boundaries for non technical experts to create a smart environment but does not provide an easy and understandable way for non experts to create content and to provide interactivity using the sensors connected to the meSchup platform by themselves. The focus of this thesis is to create a toolkit which provides the missing functionality and therefore enables non technical experts to create and deploy content in their smart environment using desktop computers as well as mobile devices to adapt the content on-site. Thereby to enable the user to interlink physical interaction with interactive digital content. To achieve this the toolkit was implemented and then evaluated within two studies where the usability with non technical experts as well as cultural heritage professionals was tested.

Outline

This thesis is structured as follows:

Chapter 2 – Background: In this chapter, a short overview of the meSch EU project and the meSchup platform is given.

Chapter 3 – Related Work: In this chapter, related work in the field of ubiquitous displays as well as interfaces which have a focus on creating and deploying interactive installations are discussed.

Chapter 4 – Concept In this chapter, an description of the concept of this thesis as well as three different scenarios describing and illustrating the thesis purpose in detail are provided.

Chapter 5 – Implementation In this chapter, the technological components and the architecture as well as the graphical user interface are described. Furthermore we take a detailed look into the on-site editing component of editor and how we provide a simple way to create interactivity.

Chapter 6 – Evaluation In this chapter, two studies and their results which where carried out to evaluate the VEII toolkit are described.

Chapter 7 – Discussion In this chapter, the thesis and especially the VEII toolkit and results of the two studies are critically reflected.

Chapter 8 – Conclusion and Future Work In this chapter, conclusions which were drawn from the work within this thesis and the case studies are summarized and future work is discussed.

Abbreviations

In this thesis several abbreviations which may not be commonly known are used. Therefore, the following list is provided to clarify the used terms and to avoid confusions with similar abbreviations. If there are other abbreviations within a specific context, they will be described right before they are used.

Abbreviation	**Meaning / Description**
VEII	Visual Editor for Interactive Installations
SUS	System Usability Scale
UI	User Interface
JSON	JavaScript Object Notation
HTTP	Hypertext Transfer Protocol
REST	Representational State Transfer
API	Application Programming Interface
CHPs	Cultural Heritage Professionals

2 Background

This research is settled in the context of the meSch (Material EncounterS with digital Cultural Heritage) EU project. Furthermore, the Visual Editor for Interactive Installations (VEII toolkit) which was developed during the implementation part of this thesis is tightly connected to a middleware for Smart Spaces called meSchup platform. This chapter provides an overview of the meSch EU project as well as the meSchup platform and its connection to the Visual Editor for Interactive Installations.

2.1 MeSch EU Project

The meSch project is coordinated by the Sheffield Hallam University and is a cooperation of twelve different partners of six European countries which started working together in February 2013. The project is funded by the European Community's Seventh Framework Program "ICT for access to cultural resources" and will last for four years. The goal of the project is to contribute new ways to connect physical dimensions of museum exhibitions with digital cross-media information. Therefore, the participants of the meSch project design, develop and deploy tools which enable the creation of tangible interactive experiences. One of these tools is a platform which enables Cultural Heritage Professionals (CHPs) to create smart objects and intelligent environments and even compose embedded digital content without any technical expertise. Smart objects are objects that support the interaction with other smart objects as well as with people and the physical world. Intelligent environments are spaces which often contain embedded systems as well as different information and communication technology to enhance visitors experiences by creating interactive spaces through combining the digital world with the physical world. The meSch project follows the principle of co-design where designers, developers and stake-holders are equal partners in the process of creation and evaluation. The real-world evaluation of meSch technology takes place in three large-scale test beds within different museums in collaboration with the public and cultural heritage stakeholder[1].

[1] Official meSch EU Website, http://mesch-project.eu/ (last accessed on November 3, 2015)

2.2 MeSchup Platform

The VEII toolkit is based on the meSchup platform which is an external component build in the meSch EU project and the University of Stuttgart. One output of the meSch EU project is the meSchup platform which opens up the creation of smart environments to non-experts. Smart environments are settings in which technical elements like sensors, actuators, displays or other computational components where integrated seamlessly in everyday objects. The meSchup platform is build with a master-slave architecture consisting of a server- and multiple client-software and hardware components [KS15].

1. Server-software:
The server is running on a central computer node providing a web-based user interface. There users can configure devices and create behavior rules written in Javascript. Additionally, the server software provides a rule engine that triggers events and runs user-generated scripts, so called behavior rules, whenever sensor data from a configured device is received. Thereby smart behavior is realized based on the behavior rules that turns sensor events into actuator executions.

2. Client-software:
For each end device which is supported by the meSchup platform experts implement a platform specific firmware. Through this firmware the meSchup platform allows the abstraction from the device specific operation system as well as its hardware or communication technology and protocol. Users of the meSchup platform just need to install the firmware once on their devices to get control over its abilities. Each device with the firmware installed can be configured via the web interface of the server-software component.

The VEII toolkit communicates with the meSchup platform via a REST API. The VEII toolkit targets at providing an easy and understandable way to create behavior rules for non-programmers. Therefore, the toolkit supports non-programmers to create interactive digital content by using the content created within the VEII Slide Editor and combining it with behavior rules of the meSchup platform.

3 Related Work

This thesis is inspired by former research and to understand the state of the current research, this chapter discusses related work about ubiquitous displays and interactive installations.

3.1 Ubiquitous Displays

There exist many different and interesting approaches for ubiquitous displays in the literature. The Everywhere Display creates a ubiquitous graphical interface through a LCD/DLP projector supported by a motorized and computer-controlled pan-tilt mirror. Thus, the Everywhere Display [Pin01] is able to transform any surface into a projected screen whereby it is also able to automatically correct distortion by using its rotating mirror. The developers planned to add gesture recognition of hands in the future to make the projected screen interactive. This approach would eliminate the need to carry a computer or mobile device with you. Users could request a computer display just by using a specific gesture to an overhead camera which would display the projected image on a surface near the users' location [Pin01]. In [SPK+03] the Everywhere Display is used to create an interactive prototype in a retail environment where the product information are displayed in situation. Within this prototype user interaction is provided by gesture recognition whereby the system processes the video signals from an installed camera in combination with the projector of the Everywhere Display. In this case the installation was used to display further or detailed information of a specific product (e.g. a size chart for pants) but there are also other scenarios mentioned like using the projection as a guidance system through the retail store.

In a different approach for ubiquitous displays using projectors the researchers implemented two different features. Firstly an automatic scene modeling of a dynamically changing indoor environment. Secondly an automatic selection of the surface on which the content is displayed. The main advantage of this approach is that it can automatically cope with a dynamically changing environment. For the modeling of the scene a coarse-to-fine approach was chosen to achieve a good trade-off between efficiency and accuracy of the modeling process. First there is a core scanning of the scene with a range scanner. Second there is a fine scanning for projection areas through a combination of a projector and color camera. A projection surface is appropriate if it is planar, uniformly-colored with a diffuse surface, low saturation and high brightness [TIS+03].

An innovative approach of using ubiquitous displays in form of an interactive display robot is introduced in [CKL13]. Usually devices like projectors and especially sensors are set up in a specific place and are not mobile anymore. The wheeled interactive display robot is equipped with a small projector which is mounted on a pan/tilt system which enables the possibility to choose projection position freely. So the robot opens up the usage of new display concepts as for example the possibility to create projector based display installations which cover more than one room. Furthermore, users can choose the projection position of the interactive display robot on their own by using gestures recognized by a user interface based on sensors attached to the robot.

[CFH14] introduces the concept of smart wallpapers. Unfortunately no real wallpaper was developed but it was investigated how people would interact with smart wallpapers as well as how the wallpapers would enrich our everyday life. Therefore, a prototype was build which consists of large projectors which project the content on the wall and a web based application. The central web server stores all the information of the different walls and provides the information for every browser which registers with the server. Gesture based interaction as well as integration into smart home system where proposed as interaction techniques.

However, those approaches are missing the opportunity of creating content for non technical experts and are often restricted to the attached sensors and actuators, so some of them could work together with the VEII toolkit in a mutually supportive way. The Everywhere Displays' feature of correcting distortion of displayed content by using a pan/tilt mirror on which the information is reflected [Pin01] can be replaced by the VEII toolkits' feature of correcting distortion. The toolkit provides the possibility to correct distortion by correcting the translation of the content itself and not the translation of the projected display. Furthermore, the toolkit enables users to utilize a mobile devices' accelerometer to correct distortion by tilting device accordingly. The feature to detect whether the displaying surface is blocked or not introduced in [TIS+03] would enhance the toolkits' possibilities to create interactive installations in dynamically changing environments. By now the system can cope with distortion but not with objects or persons standing in front of the projector. The sensors and actuators of the interactive display robot introduced in [CKL13] could be integrated in the toolkits' environment whereby developers and designer could access them by using behavior rules. Furthermore, the mobility of the content display robot together with the VEII toolkit opens up new ways to display projected content. So non technical experts are enabled to create location-less dynamic interactive installations with gesture recognition. In [CFH14] it is especially mentioned that everyone's rooms are different and the system therefore needs to automatically layout its content on the smart wallpaper. They proposed a mix of algorithm and manual content positioning. The VEII toolkit could easily support the user to position and modify the displayed content on the wallpaper especially because both approaches are using the same web technologies.

3.2 Interactivity through sensors and actuators

In [BAM14] a toolkit for creation of smart objects and environments is introduced. By using a wearable device (bracelet) enhanced with RFID technology to detect the object or surface which is touched, users are enabled to integrate every day objects into their smart environment through RFID tag stickers. After first registering an RFID tag the user has to define a rule within a mobile application about the behavior of the bracelet if it detects this specific RFID tag. Then the defined rules get executed by interacting with the object in his environment.

[KPDS13] targets with the problem that existing hardware (especially smartphones and tablet devices) is hard to extend with additional sensors and actuators. A method is proposed where external hardware can be connected to the devices by clipping a WebClip to its touch screen. The bi-directional communication between the WebClip and the device is managed by a webpage displayed on the device. On the one hand the communication from WebClip to the device is realized using simulated touch gestures on the other hand the communication from the device to WebClip uses light sensors which receive light sequences generated by the webpage.

The first approach introduced in [BAM14] is some how similar to the purpose of the VEII toolkit. Regular users are enabled to create smart environments and interact with tangible object without technical expertise. Users can also create interactive behavior on their own. The second approach introduced in [KPDS13] could enhance the VEII toolkit and could support user to save costs by being able to enhance existing hardware with new sensors.

3.3 Content delivery

In [Sty07] a framework supporting a web-based multimedia presentation of a museum is introduced. With this framework curators can generate multimedia presentations on fixed information stations or web sites without any technical expertise. The developers of the framework want to minor the gap between traditional and interactive information media so the systems provides an installation wizard-like procedure which curators just need to follow to generate a new presentation. The framework separates the created content from each specific presentation to make content reusable for other installations. Therefore the framework provides a content management system for multilingual content where curators can create, organize and administer multimedia content as well as prepare the execution of the presentation application by using predefined application templates. Content creators however need to use external programs to create and adapt multimedia content like Microsoft Word or Adobe Photoshop. After finishing the content creation process curators need to export the presentation from the system and deploy it manually on the target information station. There are two types of information stations: Firstly a basic information station which is a simple touch screen monitor integrated in a bookstand. Secondly a basic information station extended

by an active projection area which provides interactivity by recognizing touch gestures via a camera. Curators need to create presentations for both information stations by using the predefined application templates provided.

[AKB+11] proposes an approach to use mobile devices to transfer and get content from public displays. The "Digified"-system consists of four main components. Firstly the Digifieds Server which is the main component for the data management and storage. Furthermore, it provides an RESTful API to provide access for the different clients of the system. Secondly the Digified Display Client is running on the public displays and shows the content delivered via responses on AJAX requests. Thirdly the Digified Mobile Phone client enables users to create content directly on their mobile phone and afterwards simply deploy it by using a 5-digit code or a QR-code. Last the Digified Web Client is for people without a smartphone or prefer desktop computers. The client has two main purposes which are firstly to provide detailed information about the Digifieds platform and secondly to enable users the same features as using their mobile phone.

[CMG+14] introduces the approach of using an App-Store for interactive public displays. Therefore the public displays are within a display network and therefore connected to the Mercury App-Store. Developers are able to create and register applications at Mercury so display owners can deploy them on their devices. Furthermore, display owners are able to manage and control their devices via Mercury. Display owners and developers are therefore enabled to deliver dynamic or static content to the displays in form of simple media slideshows with images or videos as well as web-based applications.

All approaches indeed enable the user to deliver content on an interactive public display. However the VEII toolkit is more versatile and can be used in a variety of different fields while the introduced approaches in [Sty07], [AKB+11] and [CMG+14] are limited to a specific use case.

4 Concept

This thesis engages with the process of creating interactive installations on ubiquitous displays especially on the creation and mobile adaption of its displaying content. Observations within the meSch EU project show that the current practice of cultural heritage professionals (CHPs) is to create and adjust content mostly on desktop computers and then deploy it remotely on a specific target display. Authors do often use multiple software combined to create simple content which makes it complex and costly. But content which seems well prepared on desktop computers may look completely incorrect on the target display. There are many different factors which influence the visual representation such as screen resolution, density, projection surface or viewing angle. Authors do therefore need to go through several time-inefficient cycles to get an acceptable but not a high quality result on the target display. Another difficult part of creating and deploying such installations is providing interactivity. The main question and barrier is how end-users such as CHPs can combine digital content to physical interaction. To achieve interactivity authors have to put in big cost and time effort because they do not have the needed expertise in programming or technical understanding by themselves and need to hire specialists.

So the current content creation, adaption and deployment process is not well adapted to its purpose (e.g prepare content different screen resolution) and misses some necessary features (e.g. providing interactivity in a simple and cost-efficient way). This thesis explores ways in which one single system is usable by authors without a higher technical understanding and not only by technical specialists to fill the missing gaps within the current approaches. Therefore, the first part is to minimize the technical boundaries for users. The goal is an approach which supports optimizing the process of creating and deploying content on a specific target device. Secondly the approach should enable on-site editing of content with immediate feedback of the changes and their representation on the target display. Thirdly there should be a way to combine physical interaction with digital interaction without big effort and technical expertise. This means, the approach should provide the possibility to modify content on the target display by using physical objects or sensors. In the following the requirements which were defined for the approach are explained in detail.

4.1 Reducing technological complexity

The approach should minimize the technical boundaries for an author to create an interactive installation. Therefore, a blackbox-system which, once installed, provides all the functionality to create interactive installations in an appealing and fast way should be provided. Additionally, the system must not need non-standard technical requirements which need massive adaptions or costly investments. Furthermore, creators should not need to have a technical understanding of the system. Content management systems in the field of web development seemed to be a good model where users do not need to know how the underlying technical part of the system and the technology works but they can create websites and content quick and easily. Using web technology for the toolkit colludes with the existing meSchup platform described in [KS15]. Developing the toolkit as a plugin for the meSchup platform supports the blackbox-approach and provides further possibilities for the communication between the two systems. The communication enables the interactivity between physical objects and digital content. Furthermore, through this plugin architecture an easy way to let authors create rules for interactive digital content should be provided.

4.2 Content Creation

The process of the content creation is an important step while establishing an interactive installation. Authors spend a lot of time searching and collecting content. The approach should therefore support authors while preparing these contents by providing one single system combining all the features needed to create appealing presentations. The approach should support the necessary media types which are used in interactive installations like text, images, audio and video as well as more complex content like content feeds or whole websites. Furthermorem, it should support managing added media in a way known by many content management system in the field of web development. Microsoft Powerpoint seems to be a good model where users create and present information in an appealing and structured way. Most creators know this system and feel comfortable with the way it works. Leaning on this approach seems to be a good approach to improve the user experience and to reduce the complexity of the system as well as the time users need to learn how to use it. Assuming that viewers will be multilingual the toolkit should support translation of created content.

4.3 On-Site Editing

To reduce the time needed to adapt an existing installation to the target environment our approach should support on-site editing of content with a mobile device. Visiting the installation and correcting its deficits on place will bring a big efficiency improvement to the creation- and

adaption- as well as the deployment-process. Instead of constantly switching between desktop computer and deployment environment the author just needs to create the content once and adapt it on-site using a mobile device of its choice. A further advantage of the on-site editing is that the author can experience the deployed installation as a common visitor and therefore can adapt the presentation more appealing.

4.4 Interactivity Scripting

An interactive installation is way more interesting, improves user experience, draws interest and provides more possibilities than a display with static information. The approach should give the users the ability to create interactive content as easy as static content. To achieve this the toolkit will be connected to the meSchup platform. Through this connection sensors and actuators are provided as trigger for the interactive content. Furthermore, the technical part of the meSchup platform should be hidden to provide the users a simple solution to create rules for interactive content. There should be an easy editor with drag and drop functionality to create rules without the need of programming skills as well as predefined templates from which users can choose matching templates according to their usage scenario and hardware. In detail there should be the possibility to create advanced behavior scripts written in JavaScript which are overlaid with semantic textual stories that embed form elements at specific positions to represent configurable parameters of the actual implementation. Using the text-based story together with control elements for customizing the behavior are a concept that is supposed to be well understandable by users without technical expertise. Those behavior scripts are provided by programmers and will be integrated into the system as behavior rule templates. Users then can choose from different templates and configure the parameters visible within the story of the behavior rule.

4.5 Scenarios

In the following section three different scenarios which illustrate our concept are presented. Firstly it is described how installation with digital content or interactive installations are created and used. Secondly an explanation is given why the toolkit will improve the current approaches in the given scenario.

4.5.1 Scenario I - Cultural Heritage

The first scenario is set in the field of cultural heritage especially about how museums create and make use of interactive installations with digital content. At first it is shown how curators create exhibitions with digital content based on observations of the meSch EU project. Secondly

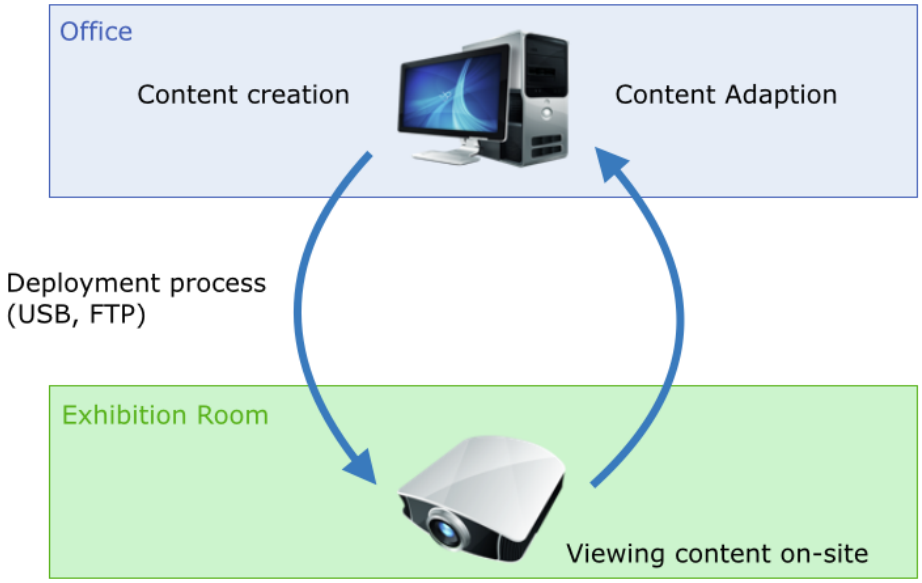


Figure 4.1: The content creation/adaption cycle of cultural heritage professionals

it will be explained how time-consuming and costly the creation of interactive installations for curators are at the current time. Afterwards an explanation of how exhibitions with digital content can be created within the VEII toolkit is given. Then it will be shown how the current creation and deployment process can be improved. At last it will be shown how the VEII toolkit will support curators to create interactive exhibitions easily and cost-efficient.

Observations within the meSch EU project showed that curators who want to create content for new exhibitions with digital content start at their desktop computer collecting and composing text and multimedia. Then they use software like Microsoft Word or Adobe Photoshop to prepare and arrange the content according to the installations purpose. After finishing the content creation and composing part at the desktop computer curators often need to export their content to a specific format (e.g. PDF) and deploy this file manually on the target computer (e.g by using a USB-stick or using a FTP-client) which is connected to the display device. If curators find content which is not well adopted for the target environment while examining the actual exhibition they need to go back to their desktop computer to adapt this specific content and repeat the whole deployment process. Often content creation/adaption-cycles (Figure 4.1) with many iterations arise in this occasion which are neither time-efficient nor produce a high content quality.

Curators are often limited in the creation of interactive exhibitions. They do not have the technical expertise as well as the needed hard- and software. So to deploy exhibitions with interactive digital content they need to hire specialists and/or buy particular software. Curators do therefor have to put big time- and cost-effort in those exhibitions for which reason they have

to weigh up the cost and benefit for every new project. Furthermore, curators often cannot reuse most of the components used during the exhibition after it ended.

With VEII realizing our on-site content editing approach as well as our interactivity scripting approach, the toolkit supports curators in creating interactive exhibitions with digital content in a more pleasant and effective way. By using the toolkit curators can compose content on their desktop computer as they are used to using the VEII web-based user interface. There they can create and adapt multimedia content and organize it on different slides in different projects (one project for one exhibition). To deploy the content to the target device they just need to select the device from a list and the toolkit will automatically display the project on the target display. Afterwards curators can visit the exhibition with a mobile device. Standing in front of the exhibition brings the curator into the visitors view. The user is now able to adapt the content according to the exhibitions' environment by using a mobile device. While adapting the content, the user gets immediate feedback on the target display, whereby the toolkit eliminates the need to go back to the desktop computer to correct maladjusted content. Furthermore, the on-site content editing supports playful experimentation during the creation of the exhibition because curators are now saving creation-time and get immediate feedback on the changes. An assumption of this thesis is that this will result in more creative and appealing exhibitions. To turn static exhibitions into interactive exhibitions the curator can add behavior rules either using his desktop computer or using the mobile device. The following scenario will illustrate the use of the VEII toolkit to create interactive installations with digital content in the field of cultural heritage.

John is a curator in the famous Linden-Museum, a museum for ethnology, in Stuttgart Germany. He is responsible for creating new exhibitions what comprises the content collection as well as the deployment of hardware and software. In collaboration with the University of Stuttgart the meSchup platform, containing the VEII toolkit, was integrated into the existing museum environment a few weeks ago. Thereby multiple hardware devices were configured within the meSchup platform like Bluetooth Low Energy Beacons, NFC-Reader, Distance Sensors and Raspberry Pies as display components. Furthermore, experts of the University of Stuttgart prepared a collection of behavior rule templates for the configured hardware John wants to use in his museum. John now wants to create two new interactive installations containing different content about the life of Neanderthal men and Neanderthal women. Each installation should provide one big image to draw the visitors interest and if the visitor comes closer the installation should change its content and show detailed information about the specific topic. He wants to realize this by using distance sensors to detect whether a visitor is standing in front of the installation or not. Therefore, he starts collecting images from the internet and saves them in a local folder on his desktop computer. Afterwards he opens up the web-based graphical user interface of the VEII toolkit in his Google Chrome browser. There he starts uploading the collected images by using the content management part of the VEII toolkit. Furthermore, he gathers texts from the internet and different books and adds them to the VEII toolkit as well. Thereby he is changing the font size and font family of the texts directly within the rich text editor. After John has finished collecting and adapting content, he switches into the project management view of VEII. There he creates a folder for the

Neanderthaler exhibition. In this folder he creates a project for each single installation and names them "Neanderthaler men" and "Neanderthaler women". Then he enters the Slide Editor for the first project. On the first slide he wants to show the image to attract the visitors interest, so he adds it by choosing it from the list of already uploaded images. The image appears on the slide and he scales and positions it until it corresponds to his concept of the slide. Afterwards John creates a new slide by using the slide sidebar. On this slide he wants to present the detailed information about the life of the Neanderthaler men. He chooses the images and texts he already created and adds them to the slide. After positioning all his media, he recognizes he missed uploading one image that he wanted to present on this slide. Therefore, he directly uploads the missing image within the Slide Editor and positions it accordingly to the other content. John now wants to provide interactivity by creating the necessary behavior rules in the Rule Editor. He opens up the rule overview and creates a new rule by choosing the template "Switch slide by distance sensor". John automatically gets forwarded to the Rule Editor where he can define three different parameters of the rule by using UI components in the story view. The first parameter is a select box where he has to choose the concerning distance sensor for the exhibition which he selects. The second parameter is a number slider where he can adapt the threshold value of the distance sensor to define at what distance the slide change should be triggered. John is not sure what distance is correct, so he does not change the default value of the slider by now. The last parameter is a select box of the available projects slides where he selects slide number two. Afterwards he duplicates this rule and adapts the threshold value and the displayed slide in the second rule so the first slide will be displayed again if the visitor is leaving the exhibition. John now closes the Rule Editor and opens up the settings-sidebar. There he chooses "RaspberryPi One" which is the RaspberryPi on which he wants to display the current project. Then John switches to the second project and creates the necessary slides and rules in the same way he did within the first project. Afterwards John takes its Nexus 9 tablet and visits the "Neanderthaler men"-project on-site. He opens up the project in the Google Chrome browser on his tablet and switches through the different slides to view the created content on-site. John is totally pleased with the result, so he opens up the settings-sidebar and changes the project mode from "Live-Edit" to "Deployment". The big picture he positioned on the first slide appears. As he comes closer, nothing happens. Therefore, John adapts the threshold values of the projects rules accordingly by testing them on-site using his mobile device. After optimizing the threshold value John visits the second exhibition and navigates to the "Neanderthaler-women"-project on his tablet. Firstly he recognizes that nothing is displayed, so he notices that he forgot to select the display device of this project. John opens up the settings-sidebar and chooses "RaspberryPi Two" whereby the content of this project immediately appears on the wall. Then John recognizes the content components of the second slide are not well positioned. He positions them again using the tablet device and scales an image by using a pinch gesture. Afterwards he changes the mode of this project to "Deployment" and tests the interactivity. After adapting the threshold values of the behavior rules of this project as before, John has finished creating interactive installations for his Neanderthaler exhibition.

4.5.2 Scenario II - Retail Store

The second scenario is set in the daily live of every normal person. Nowadays in every retail store you can find public displays which gives you further information about current special offers or background information about specific products. At first an explanation of how the content for those displays is created and how it is deployed is given. Secondly an explanation of how the VEII toolkit will improve the content creation and deployment process as well as the customer experience and the variety of information displayed is given. Thirdly a system for the customer to get further information about a specific product by using NFC-Tags as well as NFC-Readers created with the VEII toolkit in a real life example of a shoe retail store is introduced.

Currently content and hardware for public display gets created and deployed by professionals on behalf of the retail stores. Those displays are showing static content which is not adaptable by the retail store owners after the installation. Furthermore, once the content is not relevant anymore, retail store owners often have to replace the whole software and sometimes the hardware as well. This is often attached to high acquisition costs and big time-effort. That is why those displays and its content are often not interactive. A rare example of interactive displays or interactive products is the barcode scanner in big furniture stores which shows you the price of a specific product after scanning its barcode.

With the VEII toolkit retail store owners have no need to hire specialist to create the content for their public displays anymore. After setting up the system, they can create their installation by their own without any technical expertise. So store owners for example could update their special offers on a daily basis reacting on the currently changing market prices of their products. The content created could thereby be adapted on-site for each specific display using a mobile device. Furthermore, they can start develop interactive displays which draws interest and improves the customers experience. In the following an example scenario of an interactive installation with digital content for a shoe retail store is given.

Frank owns a show retail store in downtown of Stuttgart in Germany. Frank considers it as very important that the products he sells are fairly traded, are produced in factories with good working conditions and without the exploitation of the factory workers. He therefore collects all the information about his products and the factories where they were produced. Lately more and more customers want to know more about the products and the conditions in which they were produced. So Frank decides to enable his customers to get this information by using an interactive display within his retail store. In cooperation with the University of Stuttgart he deploys the meSchup platform containing the VEII toolkit within his store. Thereby the experts of the University recommend him to use Near Field Communication (NFC) because his old Android tablet can be used as NFC-Reader and NFC-Tags which he can mount on the shoes are not expensive. So his tablet gets configured as a NFC-Reader and hidden in a box under the big 50 inch screen he bought. The big screen is connected to a RaspberryPi which was configured as displaying component. Meanwhile, Frank orders 50 NFC-Tags for little money in the internet. After the NFC-Tags arrived,

Frank sticks the NFC-tags on the soles of the specific shows he wants to use. Afterwards he opens up the VEII web-based user interface in the Google Chrome browser on the desktop computer in his back office. There he adds a new project to the default Veii-folder which he calls "Shoe Origin". His big screen in the showroom has a resolution of 1920x1080 and therefore he selects the same resolution in the settings side-menu of the project. For each shoe, for which Frank wants to provide further information, he creates a slide in the project. Then he directly creates texts and uploads images to the concerning slides. Afterwards he creates a new rule and chooses the template "Change slide on registering NFC-Tag" which was provided by the programmers of the University of Stuttgart. Frank now sees a story looks as follows: "If the NFC-Reader [Select-Box] registers the NFC-Tag with the id [Text-Input-Field] then show the following slide [Select-Box]". Within the rule he can adapt the three parameters by using his mouse and keyboard. Firstly he needs to select his old Android tablet as NFC-Reader within a select box whereby his tablet is the only selectable item because no other NFC-Reader is configured in the meSchup platform. Secondly he has to enter the NFC-Tags identifier which he want to use in this rule by entering it in a text input field. And at last he needs to select the slide he wants to show after the NFC-Tag gets registered by the selected NFC-Reader. After adding and adapting the content of each slide and creating all necessary rules he chooses the RaspberryPi which is connected to the big screen in the settings side-menu to deploy the project to the big screen. As Frank goes in his retail stores showroom with his new iPad Air tablet, the big screen already displays the first slide with content of the first shoe. Frank now realizes he needs an information slide which informs his customers how to interact with this installation. With his tablet he opens up the Slide Editor of the project and creates a new slide. Via drag and drop he puts the new created slide at the first place. The big screen immediately switches to the empty slide. Frank then creates a new text "Put shoe on box below to get more information!" and changes its font size according to the feedback he gets from the screen. After checking the content of each slide by using the slide overview side-panel Frank opens up the settings side-panel and changes the mode from "Live-Edit" to "Deployment". To test his interactive installation Frank puts one shoe after the other on his presentation box. The content on the display changes according to the NFC-Tag mounted on the shoe soles.

4.5.3 Scenario III - Home

The third scenario describes a way to use the toolkit in normal people's home especially in the living room. It is not common practice to have a bigger display set up besides one or multiple televisions and the display of the personal computer. In this case displays are not mobile devices like smart phones or tablet computers. Within this scenario an assumption is that in the future displays will be ubiquitous in ways the non technical experts can not imagine by now. For example in Section 3.1 a smart wallpaper was introduced. This scenario explains how the VEII toolkit could be used if the smart wallpaper is mounted onto one or multiple walls within the living room. Therefore, the wall should be enriched with information which is useful for an inhabitant in its everyday life.

With the VEII toolkit every person would be enabled to create and adapt content on their own displays at their own homes. In this scenario so called widgets will be used which currently are not implemented but which will be an essential part in the future of the toolkit. Widgets can contain all kind of dynamic content from the internet e.g. the weather forecast or a simple website. By using the VEII Slide editor the creators are enabled to enrich the projection surface, in this case the smart wallpaper, with all kind of static and dynamic content.

3 weeks ago Mary's husband has installed a new system at their home. He brought a small computer where the meSchup server is running and plastered a smart wallpaper onto one wall in the living room. Then he configured the wallpaper as a displaying device within the meSchup server. With the VEII toolkit he created one slide on which he added dynamic content. Firstly he added a small widget where the current weather forecast is displayed and positioned it on the left side. Secondly he added a widget which displays the current ranking table of the german soccer Bundesliga. If it is match day the widget will automatically show the current matches and their current results. Mary does not like that, it is too much information she does not need. So Mary decides to generate her own content which helps her in her everyday life. She immediately thought about her plants and how they are dying all the time. Either they have too much or too little water. On the internet Mary found a bundle containing multiple moisture sensors which are compatible with the meSchup platform. Furthermore, the description of the package contained a link where Mary finds multiple behavior rule templates which can be used to modify content by using the moisture sensors. After receiving the package she puts the sensor into her different plants and turns them on. Within the meSchup platform's user interface she configures the moisture sensors. Then she switches to the VEII toolkits' web based user interface. There she creates a new project which she calls "No more dying plants". Furthermore, she creates two slides for each plant which has a moisture sensor. On each slides she adds text which contains either "The sunflower in the living room needs water" or "The sunflower in the living room has too much water". Within the behavior rule templates she got from the internet, she found a template which suits her needs. There she can configure two thresholds. The first threshold is for the maximum moisture value and the second threshold is for the minimum moisture value. From the internet she gets the thresholds of her different plants. Furthermore, she can choose which moisture sensor should be used for this behavior rule by choosing it from a drop down where all moisture sensors are listed. Last she has to define which slide should be shown if the moisture sensor's value is out of the range of the thresholds and which slide should be shown if the value is within the thresholds. Mary chooses her predefined slides and if everything is fine her husband's soccer project should be shown. After creating a behavior rule for all the plants she takes her Nexus tablet and walks to her smart wallpaper in the living room. She deploys her project to the wallpaper by using the side-panel of the project page within the VEII toolkit. There she has to choose the wallpaper from a list of all display devices. Now Mary sees her first slide displayed on the wallpaper. She switches through all slides and positions the text according to her furniture in the living room. Then she changes the mode of the project to "Deployment". Now every time a plant has too much or too low water the display changes accordingly. Even her husband waters the plants now, especially on match day.

5 Implementation

The VEII toolkit was implemented at University of Stuttgart in the context of the meSch EU project and this diploma thesis. The toolkit builds on top of the meSchup platform for which reason the same or corresponding technologies were used.

The vision of the system is to provide a set of tools for users who want to create, adapt and deploy content on public displays or public installations. The VEII toolkit provides two management components where users can firstly maintain multiple instances of projects and secondly manage multimedia content which can be reused in different projects. VEII users can compose content on personal computers or mobile devices by using a slide-based approach as well as visit the installation on-site to adapt maladjusted content with immediate feedback on the displaying device. The system also provides an editor for creating behavior rules to create interactive content. Furthermore, users can switch the displaying component for a project using VEII.

In the following, we will give an overview on the architecture and explain the graphical user interface of the VEII toolkit.

5.1 Architecture

The diagram in Figure 5.1 shows the architecture of the complete VEII toolkit with its connection to the meSchup components.

The backend is developed in JavaScript using Node.js[1] and the Express[2] framework. For persistent data storing SQLite[3] with Sequelize[4] as a promise-based object-relational mapper is used. Multimedia content is saved on the web-server via the File Transfer Protocol (FTP). In Appendix .1 the database model is visualized.

Based on the backend the frontend was developed which accesses the meSchup server component and the VEII backend via the REST APIs and via HTTP. The user interface is entirely build

[1]Official Node.js Website, https://nodejs.org/en/ (last accessed on November 3, 2015)
[2]Official Express Website, http://expressjs.com/ (last accessed on November 3, 2015)
[3]Official SQLite Website, https://www.sqlite.org/ (last accessed on November 3, 2015)
[4]Official Sequelize Website, http://docs.sequelizejs.com/en/latest/ (last accessed on November 3, 2015)

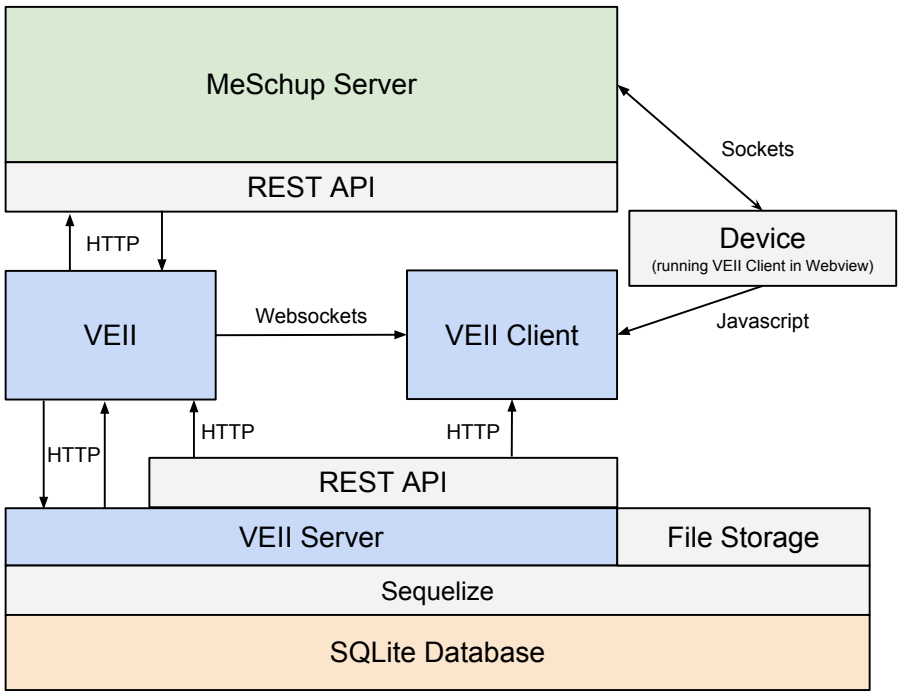


Figure 5.1: The architecture of the VEII toolkit and the connection to meSchup

in HTML5, CSS3 and JavaScript using the node template engine Jade[5]. Therefore, Twitter Bootstrap[6] in combination with Font Awesome[7] as frontend framework was used. Additionally, a variety of JavaScript libraries like jQuery[8], jQueryUI[9], ACE Editor[10] and Smoke[11] was used to eliminate the need to reprogram basic functionality.

The flow chart in Figure 5.2 visualizes the process of a VEII user creating and deploying an interactive installation on a display device. A User can create, update and delete multimedia content and add them to one or multiple slides which are in turn assigned to a specific project. Furthermore, a user can create, update, copy or delete a behavior rule to define the

[5]Official Jade Website, `http://jade-lang.com/` (last accessed on November 3, 2015)
[6]Official Bootstrap Website, `http://getbootstrap.com/` (last accessed on November 3, 2015)
[7]Official Font Awesome Website, `http://fortawesome.github.io/Font-Awesome/` (last accessed on November 3, 2015)
[8]Official jQuery Website, `https://jquery.com/` (last accessed on November 3, 2015)
[9]Official jQueryUI Website, `http://jqueryui.com/` (last accessed on November 3, 2015)
[10]Official ACE Editor Website, `http://ace.c9.io/` (last accessed on November 3, 2015)
[11]Official Smoke Website, `http://alfredobarron.github.io/smoke/` (last accessed on November 3, 2015)

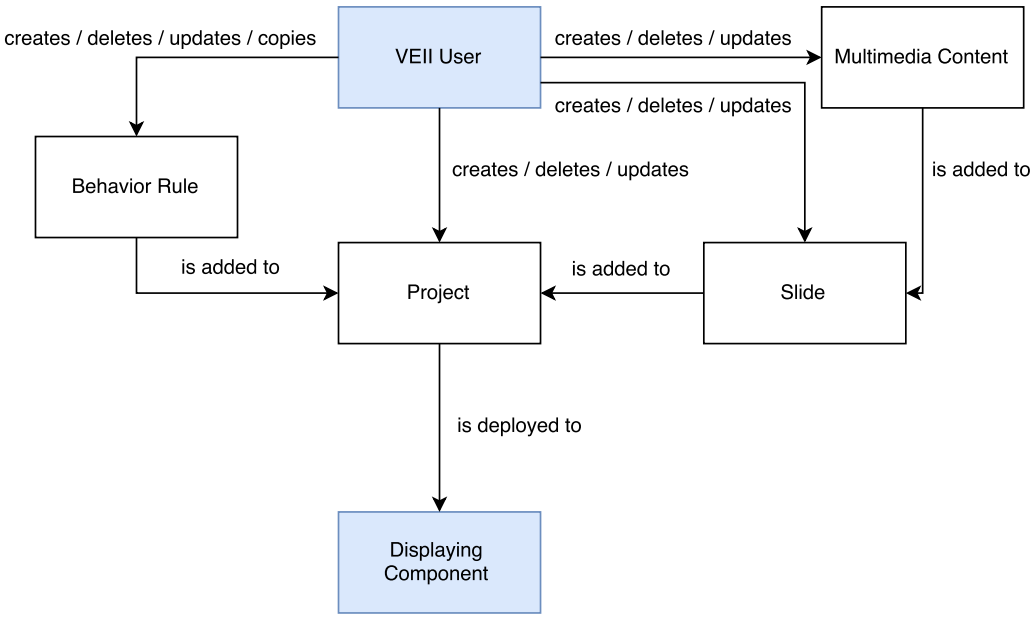


Figure 5.2: Flow chart explaining how a VEII user creates and deploys an interactive installation on a display device

interactive content within a project. Last the project needs to be deployed on the target display component.

5.2 User interface for creating interactive installations

As described in section 5.1 the frontend was developed entirely in HTML5, CSS3 and JavaScript using the template engine Jade. Furthermore, the user interface of VEII is designed for desktop computers as well as for mobile devices especially tablet devices. In the following, the main structure of the graphical user interface containing the navigation hierarchy as well as the most important pages will be presented providing screenshots for a better understanding. The main structure is shown in Figure 5.3. The basic graphical user interface (GUI) is structured in the following sections: At the top there is a menu bar called mainmenu with navigation items to switch between the different sections of the system. Often there is a submenu bar to provide additional options specific to the chosen section in the main menu bar. The content panel is always located in the center of the view where all relevant information is displayed. In some views there a one or multiple hideable side menus to provide specific content and to keep the

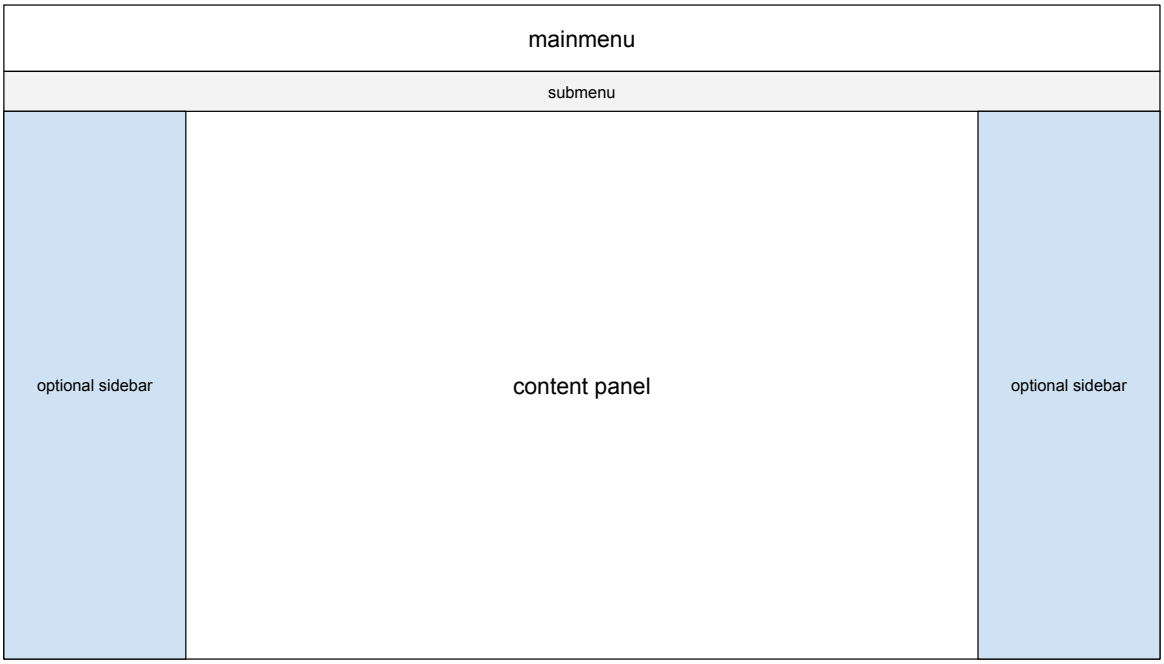


Figure 5.3: The main structure of the veii user-interface

user interface clean from too much information. All create, update and delete operations are performed within popover-dialogs. The VEII toolkit consists of four main sections:

Settings - Manage global settings

Content Management - Manage multimedia content

Project Management - Manage projects within a folder structure

Editor - Consists of two parts, firstly the slide editor for content and secondly the rule editor for behavior rules

In the following these different sections will be described and explained in detail.

5.2.1 Settings

The settings sections provides functionality to manage global settings which apply for the whole toolkit. At the top there is the main menu bar for navigation. In the content panel are three different containers. The first container displays all existing languages, the second displays all existing resolutions and the third contains the default template group for the VEII Rule Editor. By default, the toolkit creates one language (english) during the first start up.

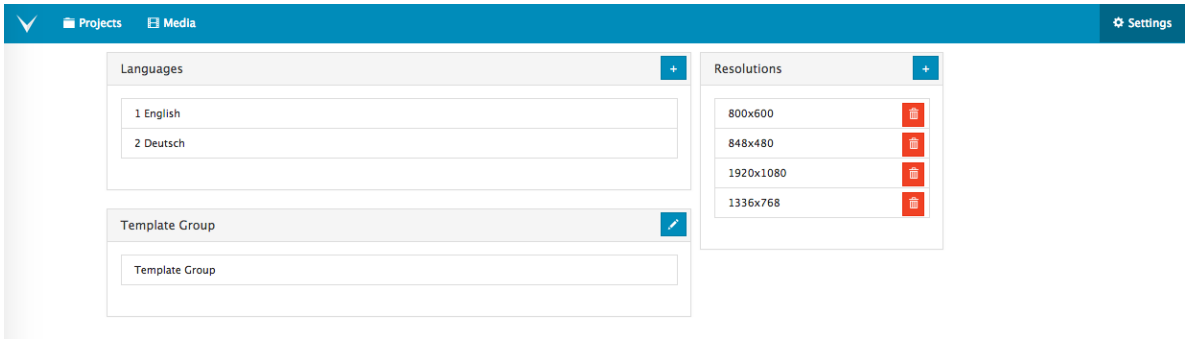


Figure 5.4: The settings view of the VEII toolkit

Then the user can add as many languages as needed. Every content created in the content management part of the toolkit can be translated in every language created in the settings section. Furthermore, the user can add resolutions to the system. A resolution consists of a width and a height and can be assigned to a project in the project editor. By default, the toolkit creates three different resolutions (800x600, 848x480, 1920x1080) during the first start up. In the template group panel the template group used by the VEII Rule Editor can be set. All rule groups of the meSchup system can be selected but setting a template group is not mandatory. An example view of the settings page is shown in Figure 5.4.

5.2.2 Content Management

The Content Management part of the VEII toolkit supports the user during the collecting process of content. It provides functionality to easily create or add content to the system. Content can be one of five different media types:

Text - text content editable via a WYSIWYG-Editor

Image - image file supporting .png, .jpeg, .gif

Audio - audio file supporting .mp3

Video - video file supporting .mp4

Widgets - content in HTML, CSS and Javascript

Each media type has his own view where all entities are listed. A submenu at the top of the list offers the ability to sort, filter and search within the existing content entities. Each media entity can have multiple tags. A tag is one word describing an attribute of one or more entities. Via tags entities can be grouped. Within this view the user also can translate existing content. An example view of the Content Management page for images is shown in Figure 5.5.

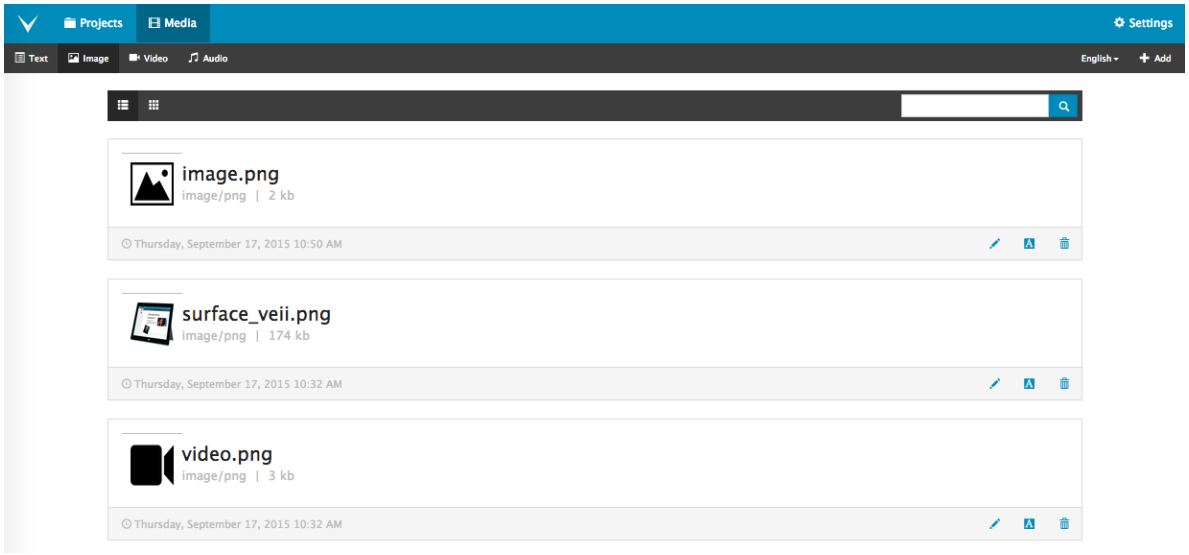


Figure 5.5: The Conent Management view for images within VEII

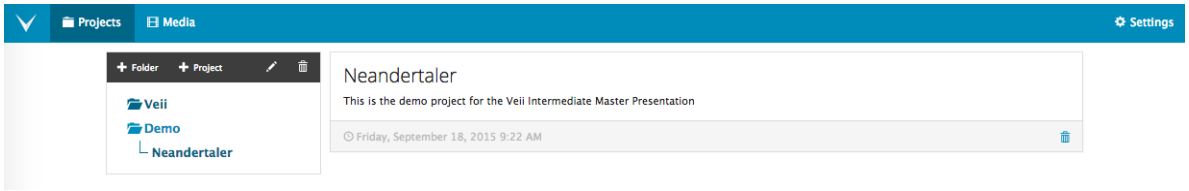


Figure 5.6: The Project Management view in the VEII toolkit

5.2.3 Project Management

Creating and managing existing projects is possible in the Project Management section of VEII. On the left side of the content area is a sidebar containing a tree-structure with folders and projects and on the right side is the content view of a selected folder. Each folder can consist of multiple folders and projects. The system creates one default folder called "VEII" on the first system start up. On top of the sidebar there are options to create, update and delete projects. After selecting a folder in the tree-structure, the content view shows the content of this specific folder. By selecting a project the user gets redirected to the Slide Editor of the specific project. An example view of the Project Management page is shown in Figure 5.6.

Listing 5.1 Example JavaScript code for showing a specific Slide after triggering an NFC-Reader

```
if (!isTriggeredByModule("NFCReaderOne"))
   return;

var data = {"projectId":"neanderthaler", "data":{ "method":"showSlide", "params":{param1:"1"}}};

api.device.RaspberryPi.WebDisplayOne.sendData = data;
```

5.2.4 Slide Editor

The VEII Slide Editor is based on a slide-based approach similar to Microsoft Powerpoint where a user can compose content on multiple slides. As known from Powerpoint features like adding text, images and other media are set at the top in a menu bar. An overview about composed slides is provided in a sidemenu on the left. There the user can create, copy and delete slides as well as switch between them. On the right side there is another sidemenu where the user can set the global settings of a project like the name, the description, the displaying device or the current display-mode. The slide editor is optimized for mobile devices so users are able to compose and adapt content using a mobile device as well.

5.2.5 Rule Editor

The VEII Rule Editor is an approach to easily create behavior rules to enable interactive digital content. The editor consists of 3 main parts. Firstly the story-view where rule creators can write text which explains what the code of the rule implements. This story-text can be enriched by predefined story-components which can be different input types like text-input, number-input or select-boxes. The story-components are representing a variety of sensors and actuators from all possible hardware devices as well as simple text. A story-component can also represent a content-entity from the projects slides created within the VEII Slide Editor. So every content created can be integrated in the rules to provide interactive digital content. The second part of the Rule Editor is a side-panel where the predefined story-components where listed. Story-components can be added to the story-view by using drag and drop. By default, the side-panel contains only the sensors and actuators which are configured within the local meSchup platform. The third part of the Rule Editor is the actual code editor. Here the rule gets implemented using JavaScript. For instance sensor events can be translated into a transition of a certain HTML element. A simple example script can look as seen in Listing

The code editor is hidden by default so non-programmers do not get confused while just configuring templates. In Figure 5.7 an example story is shown. A detailed explanation of the interactivity scripting approach and the story-view is given in Section 5.7.

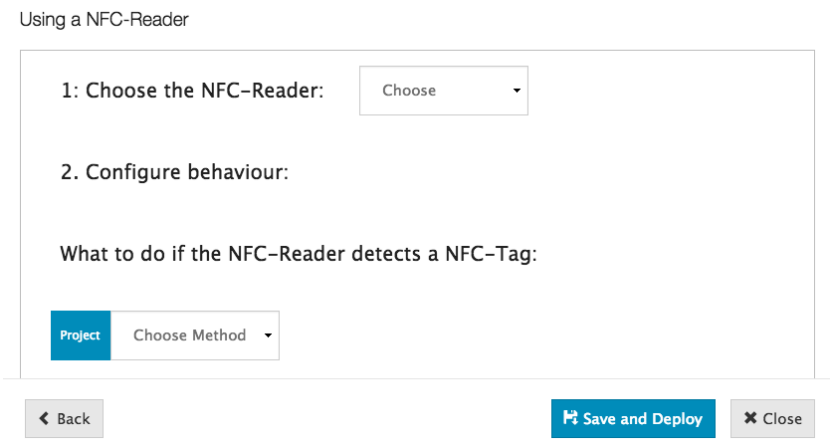


Figure 5.7: Example story for configuring a behavior rule using a NFC-Reader 5.3

5.3 Display client running on target device

The VEII Client is the displaying component of the VEII toolkit. It can be opened on any device with a web view (e.g. browser running in fullscreen-mode on target device). First the VEII Client gets the current projects content by using HTTP and then it established a WebSocket connection to the VEII Slide Editor to receive the updates during the on-site editing with a mobile device. Are more detailed description of the client and its use in the on-site editing approach is given in Section 5.6.

5.4 Deployment

The deployment of a project on a target device is done using the VEII Slide Editor. The VEII Slide editor provides a list of all possible target devices (loaded from the meSchup platform via Ajax) that have capabilities for displaying web content. After choosing one device, the toolkit sends a HTTP-Ajax-Request containing a specific URL to the VEII Client to the meSchup-platform which internally forwards the message to the target device. After receiving the message, the target device will configure its' WebView to show the URL received from the server which is the VEII Display Client of the current project and slide.

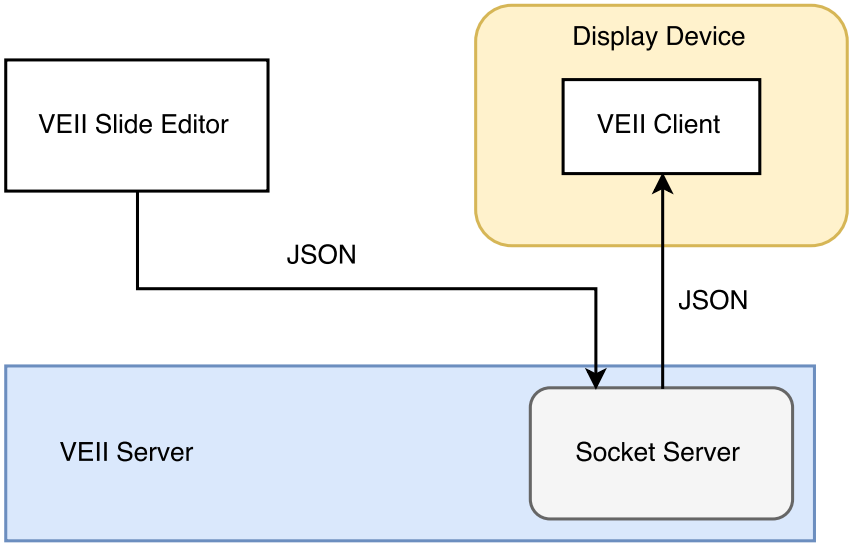


Figure 5.8: Technical implementation of the on-site editing approach

5.5 Project Modes

A project can be in one of two different modes. Each project is in the Live-Edit mode by default. Within the Live-Edit mode the changes within the VEII Slide Editor are instantly mirrored on the target display. Creators are therefore able to adapt the installations content on-site with immediate feedback. While a project is in Live-Edit-mode, behavior rule will have no effect on it. The second mode is the Deplyoment-mode. While a project is in Deployment-mode, it will not receive any updates currently made in the VEII Slide Editor but the behavior rules will be triggered based on sensor events. By using these to modes complications between creating or adapting content and the execution of behavior rules can be avoided.

5.6 On-Site Editing Approach

The on-site editing approach of the VEII toolkit simplifies the creation-, adaption- and deployment-process of interactive installations with digital content. Users can create and adapt content visiting the installation with a mobile device by using typical touch screen gestures for scale, rotate and move. Furthermore, users get immediate feedback of their changes without the need to redeploy the content on the target display. In the following the technical background of the on-site editing approach will be explained. Figure 5.8 shows the technical implementation of the on-site editing approach.

Listing 5.2 An example JSON-object for on-site editing send while moving a content entity

```
var _map = {
      "data":{
            "data":{
                  "projectId":"4",
                  "id":"entity-180",
                  "position":{
                        "offsetLeftPercent":38.81,
                        "offsetTopPercent":16.46
                  },
                  "size":{
                        "widthPercent":29.83,
                        "heightPercent":46.59
                  },
                  "angle":""
            },
      "action":"update_entity"
      }
}
```

The VEII Slide Editor and the VEII client are connected to a socket server which the VEII server is running. Each change within the VEII Slide Editor is sent to the socket server in JSON-format. The socket server then forwards the message to all connected clients. Each client then decides if it has to process the message by comparing the project identifier from the message to the identifier of the project it currently displays. An example JSON-message is shown in Listing 5.2. Additionally, all messages are only processed while the project is in the Live-Edit mode described in Section 5.5.

5.7 Interactivity Scripting Approach

The goal of the interactivity scripting approach is to enable non-programmers to create interactive digital content without any technical expertise. Therefore, the so called story-writing approach was implemented. Programmers can create templates for behavior rules which provide different specific implementations of interaction between sensors and digital content (e.g. if NFC-Tag gets registered and NFC-Reader then change the current displayed slide). These template rules can be described within the story-view of the rule with text. Programmers can supplement this text semantically by adding UI input elements like input-fields or select-boxes which represent different technical components like a sensor or a digital content entity. The VEII Rule Editor provides a side-panel where all possible sensors, actuators, components and content-entities are listed. Programmers can add those predefined components into the story-view. Those UI elements are linked to the code via a mapper-object. The mapper-object manages all entities of UI elements in the story-view as well as the current displaying device, the current project for which the rules apply and it is part of the actual implementation of the rule. An example for a mapper-object is shown in Listing 5.3 and the resulting story view is shown in Figure 5.7.

Non-programmers are now able to adapt the rule by using the UI elements without the need to touch or even see the code. Figure 5.10 visualizes the technical implementation of the interactivity scripting approach. The VEII Rule Editor gets all possible sensors and actuators in JSON-format by using the REST API from the meSchup server via HTTP. After a behavior rule is created, the VEII Rule Editor saves the rule via the same REST API to the meSchup server. Any sensor configured within the meSchup server triggers its rule engine and all rules are executed. The server then sends the data to the specific target device by using the sendData-method which forwards the message to its displaying component (e.g. a WebDisplay).

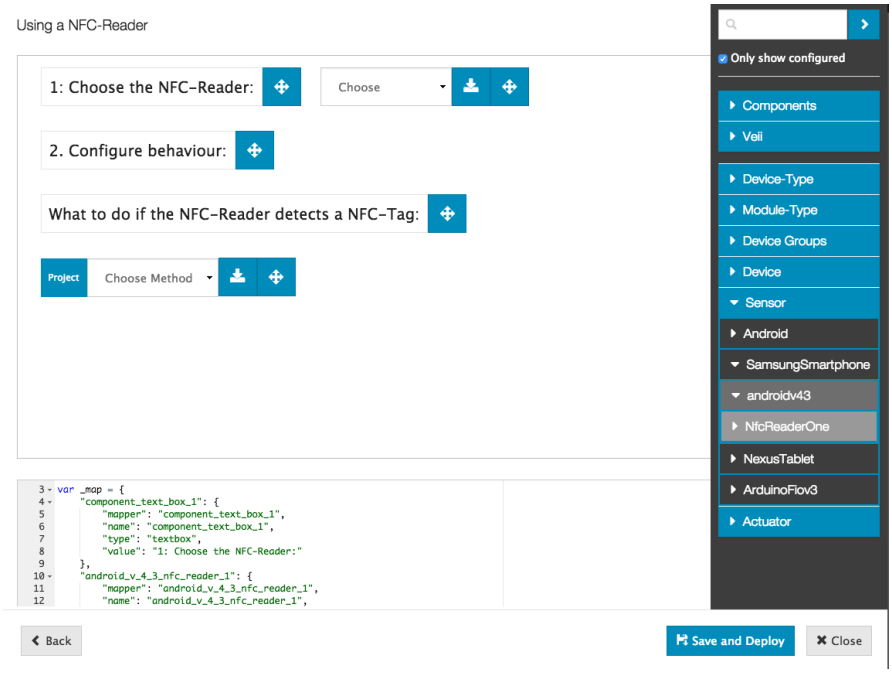


Figure 5.9: The VEII Rule Editor with code shown and opened side panel

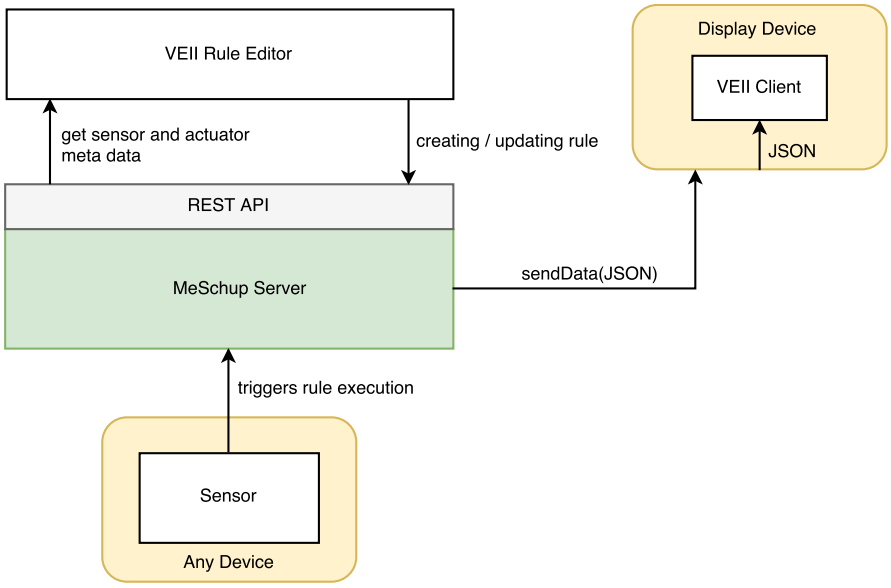


Figure 5.10: Technical implementation of the interactivity scripting approach

Listing 5.3 An example mapper-object of a behavior rule with a text box and a NFC-Reader defined.

```
{
   "component_text_box_1": {
      "mapper": "component_text_box_1",
      "name": "component_text_box_1",
      "type": "textbox",
      "value": "1: Choose the one NFC-Reader:"
   },
   "android_v_4_3_nfc_reader_1": {
      "mapper": "android_v_4_3_nfc_reader_1",
      "name": "android_v_4_3_nfc_reader_1",
      "type": "select",
      "module": "android.v.4.3",
      "component": "android.v.4.3.nfc.reader",
      "value": "",
      "varType": "action"
   },
   "displayDevice": "ProjectorOne",
   "project": "DemoProject"
}
```

5.8 Summary and Discussion

In this chapter, the implementation of the backend and the frontend of the system was explained. Furthermore, an overview of the graphical user interface as well as a detailed impression of the technical background of the on-site editing and interactivity scripting approach was given. The toolkit solves the challenges described in chapter 4. Creators are able to create and adapt content for interactive installations with digital content on-site by using a mobile device without the need of technical expertise. Furthermore, we assume that the VEII toolkit will improve the content quality as well as time needed to create and deploy interactive installations. We will prove these assumptions in Chapter 6.

6 Evaluation

The Visual Editor for Interactive Installations was evaluated in two different studies. The first study was aiming at pre-testing the usability of the system especially the content creation and the creation of interactivity using the story-telling approach with focus on the qualitative feedback from the participants at the end. For the second study the VEII toolkit was deployed in a genuine museum environment whereby cultural heritage professionals were invited as participants. The goal of this study was to collect qualitative feedback on the usability, usefulness and opportunities of the approach assessed by professionals in the targeted domain of cultural heritage. In the following the different studies and their results are explained and discussed in detail.

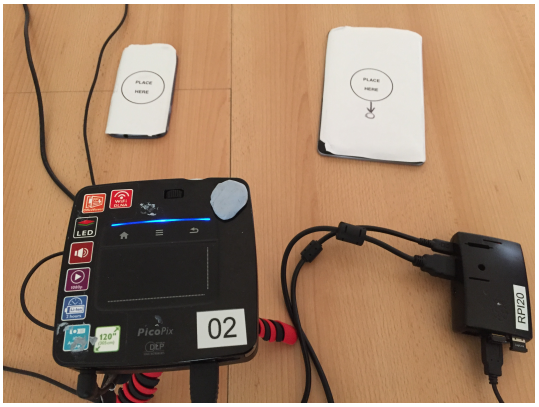
6.1 Case Study I - Pre Study

The purpose of the pre study was to evaluate the usability of the toolkit with users who do not know the system. The evaluation goal was to see if a predefined task can be solved by the participants using the system without any introduction. A further goals was to uncover and solve usability issues before running the main study with CHPs in Amsterdam. Therefore, a study with 9 participants was conducted and performed at one day. There was no baseline condition like a control group included into the pre study because on the one hand the goal of the pre study was to evaluate the usability of the system and on the other hand there is hardly a system to compare to.

6.1.1 Participants and Setup

For the study 9 participants (3 female, 6 male) with an average age of 25 years and a different level of technical expertise (from "I know how to code" to "I only use my computer to browse the internet") where recruited. The participants where not required to have any technical expertise and were selected randomly. Four of them used software like Adobe Photoshop and Microsoft Powerpoint quite often, the others did not hear of it or only used it once. Two of the participants were also familiar with the content management system Wordpress. The participants did not get any reward for participating at the study.

(a) The desktop set up in one room



(b) The hardware for the installation set up in the other room

Figure 6.1: The general setup of the pre-study

The test-environment was set up in two different rooms. In the first room there was a desktop computer where the participants had to create the content which they wanted to display in their installation as well as the rules which would provide the interactivity. Therefore, a server instance of the meSchup platform was running on the desktop computer. In the second room there was set up a RaspberryPi connected to a projector serving as the displaying device and two Android devices which were used as NFC-Readers. All devices were connected to the local network. Before the participants started testing the Android devices were configured as NFC-Readers in the meSchup platform and one template which provided the needed behavior functionality to solve the given tasks was implemented. The reason for this was the assumption that non-professionals will also use rule templates for creating interactivity and will not program the code on their own.

6.1.2 Procedure and Tasks

Every participant got a short introduction to the test environment but not to the VEII toolkit. They all had to accomplish the same task: Create an interactive installation using the toolkit which provides multiple slides featuring different content and which uses NFC-Tags registering on a NFC-Reader to switch between them. This task was divided into the following steps:

Step 1: Content creation
The participant should create two slides with different content on the desktop computer.

Step 2: Creating interactivity
The participant should use a template to create rules which provide the NFC functionality.

Step 3: Deploy content
The participant should deploy the created content on the display device in the second room

Step 4: Adapt content on-site
The participant should visit the installation with a mobile device and adapt to content according to the environment.

Step 5. Switch to deployment mode:
The participant should use the mobile device two switch the installation from the "Live-Edit" mode to the "Deployment" mode.

Step 6: Test the interactivity
The participant should use a NFC tag on the different NFC-Reader two switch between the created slides.

The participants were allowed to ask questions during the whole process, most of them did not need to make use of this possibility. After finishing the task, every participant had to answer a System Usability Scale (SUS) questionnaire with 10 questions. Afterwards each participant took place in a semi-structured interview which lasted about 15 minutes. The questionnaire and the questions of the interview are shown in Appendix.4. On average, the total duration of a study per participant lasted 45 minutes.

6.1.3 Study results and discussion

In this section the observations about participants' creation strategies as well as the results of the System Usability Scale (SUS) questionnaire, the participants qualitative feedback and consequences derived from these insights are discussed.

6.1.3.1 Creation strategies

All participants successfully created, adapted and tested an interactive installation with digital content and therefore fulfilled the given task in the study. The average time of completing the task was 28 minutes. One observation was that the participants had a similar creation strategy: after about 30 seconds of just viewing at the user interface to get a general overview, most of the participants started by trying out all different UI buttons to see what happens. Afterwards they started adding and adapting content, mostly more than needed. Some of them got so engrossed in optimizing their content and using the various transform options that they forgot to go on with the next step of the task: P6 said, "*I really liked the possibility to adapt the content as I needed it like rotating and scaling images without the need of using external programs*". Then the participants switched to the Rule Editor where they created two behavior rules by using templates. P4 noted: "*It was great that I did not have to program the rules on my own. Through the description I knew which template to use*". The participants where

(a) A participant creating content on a desktop computer.

(b) A participant using a mobile device to tweak content on-site

Figure 6.2: A participant during the pre-study

surprised how simple it is to provide interactivity and make use of complex hardware. P1 commented: "*I created something with technology I didn't even heard about within 20 minutes*". Every participant created a rule and configured it within no time. Last the participants went to the installation and adapted the content on-site where all participants used the mobile device to adapt the content in the target environment.

6.1.3.2 Working with the system

The participants were very positive about working with the VEII toolkit. They found it intuitive and easy to learn which is confirmed by the average score of 3.7 (SD = 0.63, 0.0 - lowest, 4.0 - highest) of the question "I would imagine that most people would learn to use this system very quickly" of the SUS. Every participant learned to use the system within 10 minutes without the need of any assistance. Nevertheless, the participants also mentioned aspects of the system which should be improved. This is shown by the score of 2.8 (SD = 0.75) in the SUS of the question "I thought there was too much inconsistency in this system". In this case most participants were confused about the placing or the meaning of specific UI elements. For example there was a "Done"- and a "Close"-Button in the rule creation view which often got mixed up. The VEII toolkit ended up with a total score of 82.5 in the SUS. As visible in Figure 6.3, every question got a score above the standard average score of 68 which is the threshold of a usable system. Any software with a lower score as 68 is considered to be not usable.

Working with the VEII Slide Editor
The participants thought the Slide Editor is intuitive and easy to use which is based on struc-

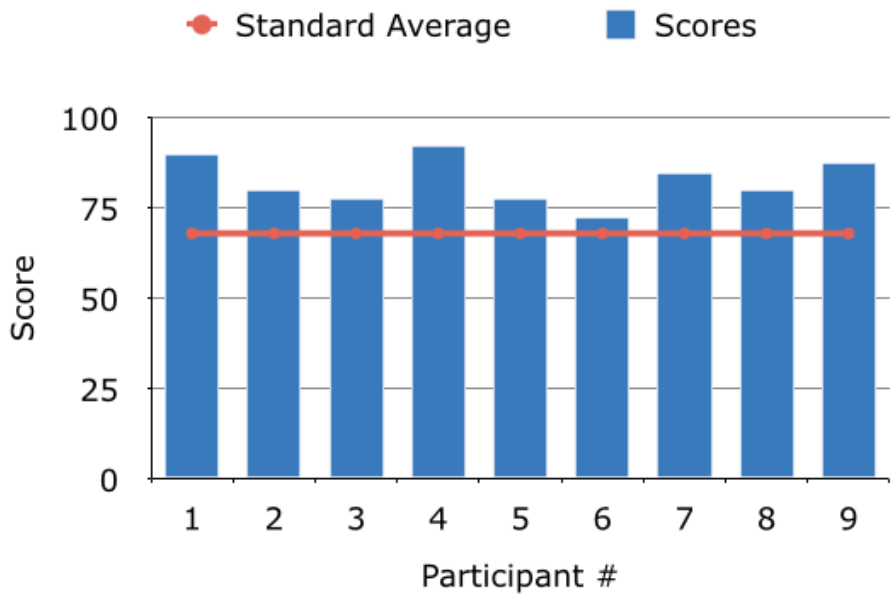


Figure 6.3: The results of the pre-study SUS questionnaire by participants

tural similarities to existing software. P4 said, "*The structure of the editor remembered me of Powerpoint which definitely helped me understand it more quickly*". P2 commented: "*The image management view felt like using Wordpress, which I often use*". But also participants who did not have any technical background or knowledge of existing software got used to the VEII Slide Editor fast. P1 mentioned: "*It is very convenient that I can compose the desired content by only using the mouse. If something did not fit, I could easily modify it*". Furthermore, the participants were convinced of the variety of transform options of content like scale, moving and rotating which were available within the VEII Slide Editor. P6 said, "*Adapting the position or the size of content is very easy. I really liked that I could adapt content on the mobile device as easy as on the desktop computer*".

Working with the VEII Rule Editor

First the participants needed to create a behavior rule by choosing a template and defining a name and an optional description. In this case the UI seemed to be confusing. P4 mentioned: "*Firstly I was not sure if I need to set a name and description for the chosen template or if I would create a new one with it*". Nevertheless, all participants were convinced of the story-approach especially because the complex code was hidden. P9 said, "*Through the story I knew what to do but I did not have to know how it technically works*". P8 confirmed: "*I read the text so I could choose accordingly. Code would be confusing*". Furthermore, the participants liked that they could configure the rule by using simple UI elements like select boxes. "*I found it easy to select from the drop down, which NFC-Reader I want to use. It was very clear*" added P3. Some of the

participants found that the labels of the UI elements within the story were unnecessary. P2 said, "*I was a bit confused of some of the labels within the story, they sounded very technical, but at least I realized that I do not need them*". In this part the two buttons "Done" and "Save" often got mixed up. Some participants pressed the "Done"-Button after configuring the rule and wondered why nothing changed. All in all the participants described working with the system as "*simple and clear*" (P8).

On-site editing
All participants found that the on-site editing approach is very convenient and easy. Almost everyone said that he had particularly liked that part. P5 noted: "*One can see how it looks finished and then easily customize it*". P8 said, "*I liked the combination of preparation and alignment in the live-edit mode. I could easily modify my content without big effort*". P1 and P5 mentioned that using a mobile device this way was very new for them but they were excited about the immediate feedback. Not every participant tested the correction of distortion by tilting the mobile device because it was not part of the task. But those who tried this option were very enthusiastic about it. P6 said, "*This was something special that I did not know before. It would be great to correct the content if the projector is not positioned even to the wall*". Furthermore, the participants were convinced about separating the content creation and adaptation from presenting content and triggering behavior rules by using two different modes.

6.1.3.3 Feedback

However, the participants in general desired more feedback from the system. Because of missing feedback or explanation of UI elements some participants did get stuck for a few minutes. P6 noted: "*Sometimes it was not entirely clear on what button I have to click next*". The participants proposed to realize feedback in the form of tooltips to get further information about UI elements. P3 said, "*It would be great if the symbols would be explained if I position the mouse over them*". P4 and P6 had some problems with the structure of the menu within the rule creation views. P4 mentioned: "*The menu was a bit difficult to use, sometimes the button I needed was not where it used to be in similar software*". In this case P4 meant the "Save"-Button of the rule which was placed in the upper right corner and he expected it to be in the lower right corner where the "Done"-Button was placed. P1, P3, P4, P6 and P9 also mentioned that they would like to have a short introduction to the system in form of a guided tour which introduces the most important features as well as a short tutorial or example video of how to create an interactive installation. P9 said, "*A short tour at the beginning which highlights the most important features and explains them would make it easier to start with the system*". P3 added: "*In some software I was using, there were short introduction videos to show the user what to do, I could imagine using an introduction video for this software as well*".

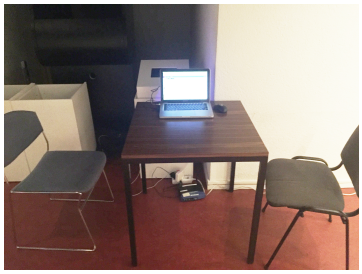
The participants also mentioned different areas where they could imagine using this system. Some of them had more basic ideas like P2, P3 and P6 mainly mentioned all kinds of public display in cities, at train and bus stations as well as at the airport. Especially the participants wished to get further information while interacting with the public display. For example they want to use their digital ticket at the airport to get direction instruction to find their terminal just by getting close to the display. Another example was to get more information about the punctuality of the train they want to take by using their online ticket. P1 and P5 where looking beyond the box and thought about supermarkets and car dealers where it is currently not common practice to use interactive displays. P5 said, "*I could imagine car dealers to give visitors car keys which have some kind of sensor attached or integrated. This would enable visitors to get further information at specific places in the store*". P1 added: "*If there would be displays in supermarkets I could use them to get more information about the products*". In this case P1 did not think about which sensors to use but it is conceivable that manufacturers could integrate for example NFC-Technology within their packing of products. P7 is professionally often at fairs and sometimes he has to set up exhibitions stands for his company as well. P7 noted: "*I really would like to use this system at one of our presentations at a fair. We would often like to change some small details but do not know how to change the content of the displays because external companies prepared them for us*".

6.1.3.4 Improvements

Mostly the participants mentioned to improve the feedback of the system. The lack of information somehow resulted in participants misunderstanding the system and therefore they needed more time to solve the task. The Participants proposed multiple ways to improve the systems' feedback to the user.

1. Integrating tooltips for UI elements
2. Provide a guided tour at first usage
3. Prepare tutorials or video-tutorials

Before doing the second study at Allard Pierson Museum in Amsterdam one of the proposed approaches was implemented. Using tooltips to give the user more information about specific UI elements seemed to be the most useful way to provide a permanent assistance while using the system. Furthermore, the other approaches could be implemented as well to provide further assistance to the user. Conceivable are not only tutorials for using the basic functionality of the system but also for implementing behavior rules using the story approach and the side panel with predefined sensor and actuator components as seen in Figure 5.9.



(a) The participants desktop computer.

(b) A projector augments a plinth with an artefact on it.

(c) The tangible cup and the two NFC-Reader

Figure 6.4: The general setup of the study

6.2 Case Study II - Cultural Heritage

The purpose of the study at Allard Pierson Museum in Amsterdam was to evaluate the VEII toolkit with Cultural Heritage Professionals in the context of a real exhibition space. One evaluation goal was to find out if the implemented approaches within the VEII toolkit are suitable for users who are not technical experts. Another goal was to collect the feedback of the CHPs and their suggestion on how the system can be improved and in what way they would integrate it in their professional environment. Therefore, a study with 5 participants was conducted performed over two days at Allard Pierson Museum in Amsterdam.

6.2.1 Participants and Setup

For the study 5 participants (all) with an average age of 38 years (50+ highest, 22 lowest) and a different level of technical expertise were recruited. Every participant had to fill in a short questionnaire (see Appendix .3) about their general background which includes questions about their gender, age, profession and experience in designing interactive and non-interactive exhibitions (1 - No experience, 5 - A lot experience). The general background questionnaire showed that the participants were working in a variety of different professions. There was a media manager who is responsible for the collection of media and information for exhibitions in her museum as well as a student of museology, a filmmaker who develops interactive systems for a living museum, a museum professional/historian and a phd student of museology. Therefore, the experience in creating exhibitions was very low, only one participant had a score of 4 in creating exhibitions at all. In total the participants had a score of 2 in experience on creating exhibitions and a score of 1 in experience on creating interactive installations. Only one participant had some experience with creating interactive exhibitions. The participants where not required to have any technical expertise and were selected randomly. Three of five participants were actually working in a museum, one of them wants to work in the museums

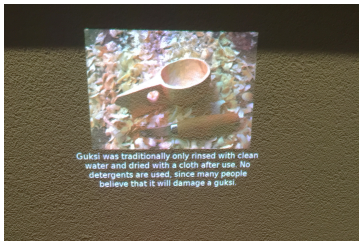
field after her study and one is supporting curators creating installations once in a while. The participants did not get any reward for participating at the study.

The study-environment was set up in one exhibition room of the museum. On one side there was a table with a desktop computer which represented the participants' office. There the participants had to create and compose content and configure behavior rules for their interactive installation. Furthermore, a server instance of the meSchup platform was running on the desktop computer. On the opposite side a projector connected to a RaspberryPi was set up to be used as displaying component for the interactive installation. In front of the projector there was a one meter high wooden box on which two NFC-Readers where placed as well as a replica of a traditional Finnish drinking cup "Kuksa" which should be used as tangible object to execute the interaction. The NFC-Readers where two Android devices which where hidden by using paper to hide the technology from the participant. On the bottom of the drinking cup a NFC-Tag was posted. Besides, there was set up a second RaspberryPi connected to a second projector as a demo installation. This setup was used to demonstrate the participants how the system works and gave them one example of what can be done. Therefore, an interactive installation in form of an info point was realized. First a big info sign and the text "Come closer to get more information" was shown. If a participant comes closer the content changes and shows directional instructions. Furthermore, a Wifi Access Point was set up to create a wireless local area network to which all devices where connected. All RaspberryPies, the distance sensor and the two Android devices which where used as NFC-Readers where configured within the meSchup platform in advance. One assumption was that the participants would not take part in setting up the technical part in their working environment so they do not have to in the study as well. Additionally, two behavior rules where implemented. One for the Distance Sensor used in the demo and one for the task the participants should handle. A further assumption was that cultural heritage professional will not be able to code the behavior rules on their own, so these templates which they should configure were provided. Furthermore, an iPad Air was prepared as mobile device which should be used to adapt content on-site.

6.2.2 Procedure and Tasks

Every participant was welcomed at the reception of the museum and accompanied to the study set up. There the participant needed to sign a consent form (see Appendix .2) and fill out a short questionnaire about their general background. Afterwards they got a detailed introduction into the system and a demonstration by using the demo project. Then the participants where introduced into the task they should solve. Therefore, a short story was told. The participant should imagine being a curator who wants to create an interactive exhibition about the traditional Finnish drinking cup "Kuksa". The participant should create three slides, create a behavior rule by using a template and configure it using the VEII Rule Editor. Last they should test the created exhibition by moving the cup. The task was divided into the following steps:

(a) Participant composes content on desktop computer



(b) Example content of a participant

(c) Cup augmented with projected text

Figure 6.5: Participant during the study

Step 1: Content creation
The participant should create three slides with different content on the desktop computer. With the first slide the Finnish drinking cup should be augmented with a projected text like "Move Me".

Step 2: Creating interactivity
The participant should use a template to create a rule which provides the NFC functionality. There the participant had to choose the two NFC-Readers as well as the slides which should be displayed.

Step 3: Deploy Content
The participant should deploy the created content on the display device by using either the desktop computer or the mobile device.

Step 4: Adapt content on-site
The participant should visit the installation with a mobile device and adapt content according to the environment.

Step 5. Switch to deployment mode:
The participant should use the mobile device to switch the installation from the "Live-Edit" mode to the "Deployment" mode.

Step 6: Test the interactivity
The participant should move the Finnish drinking cup and place it on the different NFC-Reader to test the interactivity.

The participants were allowed to ask questions during the whole study. After finishing the task, every participant had to answer a System Usability Scale (SUS) questionnaire with 10 questions. Afterwards each participant took place in a semi-structured interview which lasted about 15 to 30 minutes. The questionnaire is shown in Appendix.4. On average, the total duration of a study with one participant lasted 45-60 minutes.

6.2.3 Study results and discussion

In this section the observations about participants' creation strategies as well as the results of the System Usability Scale (SUS) questionnaire, the participants qualitative feedback is discussed.

6.2.3.1 Creation strategies

During the study all participants created their own interactive installations with digital content using NFC technology and a tangible cup as trigger. The average completion time was 22 (12 lowest, 43 highest) minutes. An observation was that the participants had different creation strategies. P1 started designing her exhibition on a piece of paper and tried to rebuild it within the VEII Slide Editor. P3 and P5 where more respectful towards the system and thus slowly started to gain an overview of the system before actually creating content. In the opposite P2 and P4 where very fast in creating the needed slides. P1 said, "*It's very easy to use, I'm used to this kind of system*" and P2 thought it was "*very easy and super handy*". After creating and composing the content on different slides the participants added behavior rules. Firstly it was hard for the participants to understand what "rule" actually means. P1 mentioned: "*My first impression was, what kind of rules?*". After explaining it in detail and calling the rules "behavior rules" the participants got used to it. P1 and P5 exceeded the task and were trying to create way more complex interactivity than expected which was not possible because only the specific template for the planned interactivity were provided. On the one hand P1 and P5 discovered a bottleneck of the current system. If there is no suitable template for the desired interactivity, creators have to call an expert who implements a new template. On the other hand it shows how the system promotes playful experimentation. P1 and P5 got excited using the system and therefore wanted to create advanced interactivity in the same way they would do it in their professional environment. After creating the behavior rules, the participants went on deploying the project on the display device and using the mobile device to adapt content on-site. P4 mentioned: "*The fast change between desktop and mobile is very good and practical*". All participants modified the created content to match the position of the wooden box. Furthermore, the participants did not know where the cup is standing while they created the content on the desktop computer so they needed to position the "Move me" text on to the cup using the mobile device. P5 added: "*I really liked it that I could augment the cup, I did not think about using projectors this way by now*". Next the participants had to set the project to deployment mode. Some participants had some issues with the different modes for example P2 said, "*I was a bit confused by the live-edit and deployment-mode. You have to get used to it, but it makes sense to work in a live- and an edit-mode*". Last the participants tested their installation by moving the cup to the different NFC-Readers.

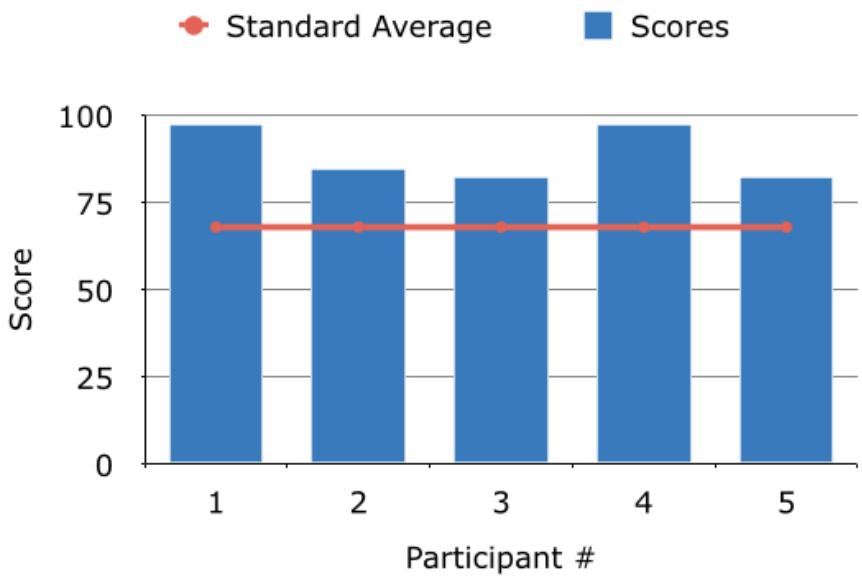


Figure 6.6: The results of the SUS questionnaire by participants

6.2.3.2 Working with the system

The participants found the VEII toolkit was intuitive to use and easy to learn which is reflected by the average score of 4.0 (SD = 0, 0.0 - lowest, 4.0 - highest) of the question "*I would imagine that most people would learn to use this system very quickly*" in the SUS. One assumption was that the system is very usable for users who do not have any technical background. This is confirmed by the average score of 3.8 (SD = 0.4) of the question "*I think that I would need the support of technical person to be able to use this system*". Despite the positive review on the ease of use of the system, participants felt less confident while creating an interactive installation. The question "*I felt very confident using the system*" only got an average score of 3.0 (SD = 0.63). A reason for this could be the short usage time. Participants where using the system for the first time and only about 30 minutes. The VEII toolkit ended up with a total score of 89.0 in the SUS. In Figure 6.6 the results of the SUS are shown ordered by participant. Every question got a score above the standard average score of 68 which is the threshold of a usable system.

Working with the VEII Slide Editor
The participants where fast in learning how to use the VEII Slide Editor and called it "*very easy to use*" (P4). Some of the participants where learning the system faster because of structural similarities to existing software. P2 mentioned: "*Parts of the system reminded me a bit of how you edit information in Wordpress*". But also participants without any technical background got

used to the VEII Slide Editor fast. P5 said, "*First I was not sure how to create content and how to use the slides, but after a few minutes it was easy*". In opposite to the first study the participants in Amsterdam where missing some additional features within the editor. They were asking for a possibility to add basic shapes like rectangles, circles or arrows to highlight specific elements of the view. Therefore, P1 said, "*The possibilities for designing slides seemed a bit limited*". Furthermore, P1, P2 and P4 wished for a method to provide slide templates. A slide template would contain multiple fixed empty content entities which then can be replaced by the creator. So creators can secure that all of the slides will be structured the same way and do not have to position the elements for each slide over and over again. P2 mentioned: "*It would be nice to have a template which already contains positioned images and texts*". Additionally, P2 suggested adding vertical and horizontal anchors to improve the alignment of content entities among themselves.

Working with the VEII Rule Editor

As already mentioned, the participants had some issues with the term "rule" itself. It was not entirely clear what is meant and what is regulated by those rules. Furthermore, the term "rule" cannot directly be connected to the interactive behavior which should result from creating rules in the VEII toolkit, therefore it is understandable that the participants were confused. Thus, it was easy for all participants to add a rule by using a template and then configure it according to the task. P5 said:"I really liked the configuration of the behavior. Just choosing the right device or slide was simple". P4 did not remember in which order she created the slides and therefore could not select the specific slide during the rule configuration without getting back to the VEII Slide Editor. Afterwards P4 suggested selecting the slides in the rule editor by a predefined name and not by a number. An alternative approach would be to show a slide preview within the rule editor. P1 suggested a new feature which enables to switch slides automatically after a specific time period. Furthermore, P1 proposed to implement the creation of interactivity in a way which is more similar to creating animation in Microsoft Powerpoint. Therefore, using multiple states of content entities and define the transition between them by choosing from a predefined list of animations. All in all the participants had a positive impression of the VEII Rule Editor and the rule templates. P1 noted: "*I would need to get used to the rules, but I could imagine using them to define behavior*".

On-site editing

The participants were impressed of the possibility to compose and adapt content using the mobile device and getting immediate feedback from the system. P4 said, "*Seeing how the adaptation I did on the iPad directly on the projection surface was great. It is really useful*". P2 added, "*I could easily take my iPad and go on site and see how it looks and then adjust content*". P1 noted: "*It is easy to edit on the spot especially wrong positioned content or spelling mistakes*". However, all participants met with a difficulty which affects the mobile device and rich text. All text within the VEII Slide Editor is written and modified in a rich text editor. Within this rich text editor it is very difficult to change the font size of the selected text. P2 said, "*Unfortunately*

I could not change the font size using the iPad". P1 added: "*There should be provided an improved way to modify the font size on the iPad*" and P2 mentioned: "*It was really hard to change the font size on the mobile device*". Furthermore, P2 was a bit worried of older curators and the VEII toolkit. P2 said, "*All the curators are men who are like 60, so for them it would be a little bit harder to start using it but it is so simple, I think they will not have lots of problems with it either*". Despite of the adaptation of the font size, the participants where excited about the on-site editing approach.

Feedback
Furthermore, the participants where asked if and how they would use the VEII toolkit in their professional environment. P2 took up the approach of using a tangible object for the interactivity. P2 said, "*If I would make an exhibition and I would have something interactive like a 3D scan of an actual object, then it would be really great to have someone interact with the object and then get the according information.*". P3 however thought about deploying the system in a living museum. P3 wanted to create multiple interactive exhibitions within the living museum and combining them with the living exhibits. P3 said, "*Creating interactivity not only by using objects but by using the exhibits themselves would be a great idea*". P4 mentioned: "*The system is a great solution for especially highlight one or two items in an exhibition which is overall more traditional*". Therefore, P4 thought about enhancing traditional exhibitions by adding interactive components. P5 was particularly excited about the possibility to change content fast. P5 thought about changing exhibition content on a daily basis to adapt the information according to requirements of the visiting group of people. For example P5 mentioned adapting the content for a group of children on the first day and on the next day receiving a group of older guests and show different content. This kind of changing content or the presentation of content on a daily basis is not possible the way P5 is creating exhibitions by now. Furthermore, P5 was thinking about connecting the VEII Slide Editor to the internet. In particular P5 imagined school children to create their own interactive exhibition at home one day before they are visiting the museum. Curators would now be able to deploy those exhibitions in different places of their museum, so children could visit their own exhibitions the next day. P5 added: "*School kids would remember the things they need to present better because they have to prepare it in a new way and further have the possibility to present it to their classmates in a real museum. I imagine them saying: 'Hey, look what I did!'* ". All in all the participants where excited about the possibilities of the system especially because it is providing flexibility for the location and the content of an exhibition. P4 mentioned: "*As far as I know such a system is not available yet, a system that uses the more advanced sensors and that is so easy to adapt and to use and configure it by yourself*".

6.3 Summary

The VEII toolkit was evaluated within two studies. The first study was a pre study to test the usability of the toolkit with focus on the qualitative feedback from the participants. With a

score of 82.5 the toolkit reached a high usability and especially stands out in its simplicity for new users to learn to use the system. The qualitative feedback nevertheless opened up some consistency gaps within the system which could be closed afterwards but also showed new perspectives and new usage scenarios like using VEII to create appealing exhibitions on fairs. The second study was focused on the qualitative feedback of the cultural heritage professionals, furthermore the usability was tested as well. With a score of 89.0 in the SUS the improvements implemented (e.g. using tooltips to give more feedback to the user) after the first study took effect. The qualitative feedback of the cultural heritage professionals opened up new ways to look at the system. They put the emphasis on things that were not previously considered like the importance of aligning content or the different usage possibilities.

7 Discussion

In this chapter the advantages of the system are highlighted and supported by observations and feedback of the studies. Furthermore, the weaknesses of the system are discussed and possibilities how they can be eliminated are introduced. Last the requirements for an optimal system are described, based on the observations and experiences gained within the creation of this thesis.

One of the major advantages of the VEII toolkit is its ability to enable users to create and manage content in one system. Users do not need multiple software like Adobe Photoshop for images or Microsoft Word for texts to create and compose different types of content. Participants where enthusiastic about having all media in one place. They mentioned that preparing and composing exhibitions is much easier with a central system where content is collected and managed as well as composed and adapted. Another advantage is the similarity of the user interface to existing software. Therefore, many users get used to the system very quick and feel more confident while using it. Although, the similarity to existing software causes higher expectations on the system. Participants associated the toolkit with software like Microsoft Powerpoint and therefore compared them subconscious. As a result many participants wished for a higher variety of features for creating content like shapes or circles. Furthermore, they wished for a Powerpoint-like creation of animation where multiple states of content entities and the transition between them can be defined. The key feature of the VEII toolkit is the mobile on-site content editing. Users are able to visit the installation on-site with a mobile device and tweak the content created on the desktop computer while getting immediate feedback from the target display device. Thereby the toolkit supports the user by automatically adapting the content on the chosen resolution. Furthermore, the system takes over the task of deploying content to the display device, users only need to choose the required target. Thus, the toolkit reduces the time which was needed to create, deploy and adapt interactive installations and supports the user while adapting the content according to the environment on-site. The participants where very excited about the on-site content editing because until now they mostly where not able to adapt the content of the interactive installations by themselves or it was very complex and cumbersome. Additionally, the participants emphasized on the opportunities that arise from the on-site editing approach like adapting content according to the expected audience on a daily basis. In particular there was one aspect which came up within the studies. Changing the font-size in a rich-text editor on a mobile device is ponderous and therefore lowers the advantages of the on-site editing approach. Because of this a prototype in form of a slider for changing the font-size of on a mobile device was implemented however the changes

apply on all parts of the given text. So if a user sets different font-sizes in different parts of the text, they would be all set to the new font-size while using the slider. Nevertheless, the VEII toolkit supports texts with different font-sizes by using multiple text entities or by not using the prototype. The next advantage of the VEII toolkit is its connection to the meSchup platform. Users are enabled to create interactivity by using external sensors without technical expertise of the hard- or software needed to configure them. The meSchup platform is handling the communication between the devices and systems as well as the execution of the behavior rules. Additionally, the VEII toolkit provides an easy and understandable way for users to adapt parameters of rules which define the interactivity behavior. Therefore, developers can write a text-based story and supplement it with predefined UI elements which users can adapt to their needs. The complex implementation behind the behavior rules is hidden from the user so they do not get confused or lose self-esteem while using the toolkit. In the future an online-platform could be created where developers can upload and share their created behavior rules as well as users can search rules according to their hardware. Thus, the users have to find out what values are best for the parameters of a specific behavior rule and therefore have to go trough several try and change cycles. The VEII toolkit on the one hand supports the user by enabling him to do this changes on-site but on the other hand it would be a great improvement if the user could change parameters by demonstrating the value using the actual sensor. The meSchup platform already supports programming by demonstration so it is conceivable that this feature will be integrated into the VEII toolkit. Nevertheless, the VEII toolkit does not eliminate the need for technical experts by now. Users are not enabled to create the implementation of the behavior rules by themselves. One approach to solve this problem could be a Snap[1]-like editor where users can create rules by dragging and dropping predefined elements while the code gets generated in the background automatically. The VEII toolkit only supports the creation of stories by using predefined UI elements which represent parameters of the rule implementation and not the actual implementation of interactive behavior.

So the VEII toolkit offers parts of the features an optimal system would need. It contains the on-site editing as well as easy access to sensors and actuators and enables users to create interactivity on their own. But to be an optimal system the VEII toolkit would need to provide a bigger variety of creating content for example basic shapes like circles or rectangles but also dynamic content in from of widgets which could contain HTML, CSS and JavaScript. Furthermore, an optimal system would offer the opportunity to create and implement behavior rules by using the graphical user interface without the need of any coding experience. Additionally, users should be enabled to use the actual sensors to define values for parameters within the behavior rule which is already implemented in the meSchup platform. Additionally, user should be able to target the actuators of devices within the behavior rules and not only the digital content displayed in web-views.

[1]Official Snap Website, http://snap.berkeley.edu/ (last accessed on November 3, 2015)

8 Conclusion and Future Work

Conclusion

This thesis proposed an approach for mobile on-site content editing for interactive installations in form of the VEII toolkit for creating and composing digital content as well as creating behavior rules to manipulate content on triggering different sensors. Furthermore, there is a mobile component which enables users to change content on-site while getting immediate feedback from the display device using a mobile device. Therefore, the VEII toolkit is connected to the meSch EU projects' meSchup platform which minimizes the technical boundaries for non technical experts to create smart environments and enables non technical experts to use all kind of sensors and actuators. Related work in the field of creating and deploying interactive installation never faces the task of enabling non technical experts to create interactive installation with digital content. Therefore, the VEII toolkit was implemented. The toolkit consists out of three main components which are accessible via a web-based graphical user interface. Firstly the content management part where users can create and manage content like text, images, audio and video. Secondly the VEII Slide Editor where users are enabled to add and compose media on different slides like known from Microsoft Powerpoint. Thirdly the VEII Rule Editor where users can choose behavior rules from different templates in which the complex implementation is hidden by using so called "stories". Furthermore, technical experts are enabled to create behavior rule templates and explain them using a "story". Within a "story" they can insert placeholders for different parameters of the code, so non technical experts are enabled to adapt the behavior rules without any technical expertise.

The evaluation within two different studies showed that the approach of using mobile devices to enable users to adapt content in situation lowers the boundaries of authors to create interactive installation. Furthermore, the participants were very positive about the system and were really interested in using it in their professional environment. Especially the on-site editing part as well as the possibility to adapt or change content very fast was highlighted by the participants.

Future Work

In the following ideas and possible features which came up during the development of the VEII toolkit or which where given as feedback at the studies will be introduced. They give a hint in which direction the system could go in the future.

Widgets
Implementing widgets will be a key feature in the further development of the system. A widget is a media type which can contain web-based content like HTML, CSS and JavaScript. It would enable users to create and display dynamic content. Therefore, it is conceivable to display whole website or snippets which are actually implemented for the VEII toolkit. Widgets could especially target the social media channels, for example a user could project his Facebook newsfeed on to the wall next to his television. By using widgets the system would reach a brighter audience and not only specific cases where static content should be displayed.

Slide Templates
Multiple participants wished for predefined slide templates. Enable users to create and use slide templates for on the one hand making the creation process even shorter and on the other hand guaranteeing the equality of multiple slides. Slide templates could furthermore promote the communication between different users of the system. The idea of adding anchors to improve the alignment of content entities somehow belongs to the approach of slide templates because it would support the creation process.

Adapting font-size
It is very cumbersome to edit the font-size of text within a rich-text editor. Therefore, a prototype for adapting the font-size of text with a slider-element was implemented. The prototype though is very restrictive and only allows to change font-size of the whole text within the rich-text editor. Creating and evaluating new ways to adapt the font-size within a rich-text editor would support the on-site editing approach as text is the most used media type within interactive installations.

Combining behavior rules
During the studies it became clear that using one rule for every part of the interactivity will become messy fast. In a short time the user would create a high amount of rules and would lose the overall view. Enabling the user to combine multiple rule templates in one single rule would improve the organization and the management of the interactivity.

Behavior Rule Collection
One of the most important features which should be implemented is a behavior rule collection. In the best case a web-based platform would be implemented to enable experts to upload

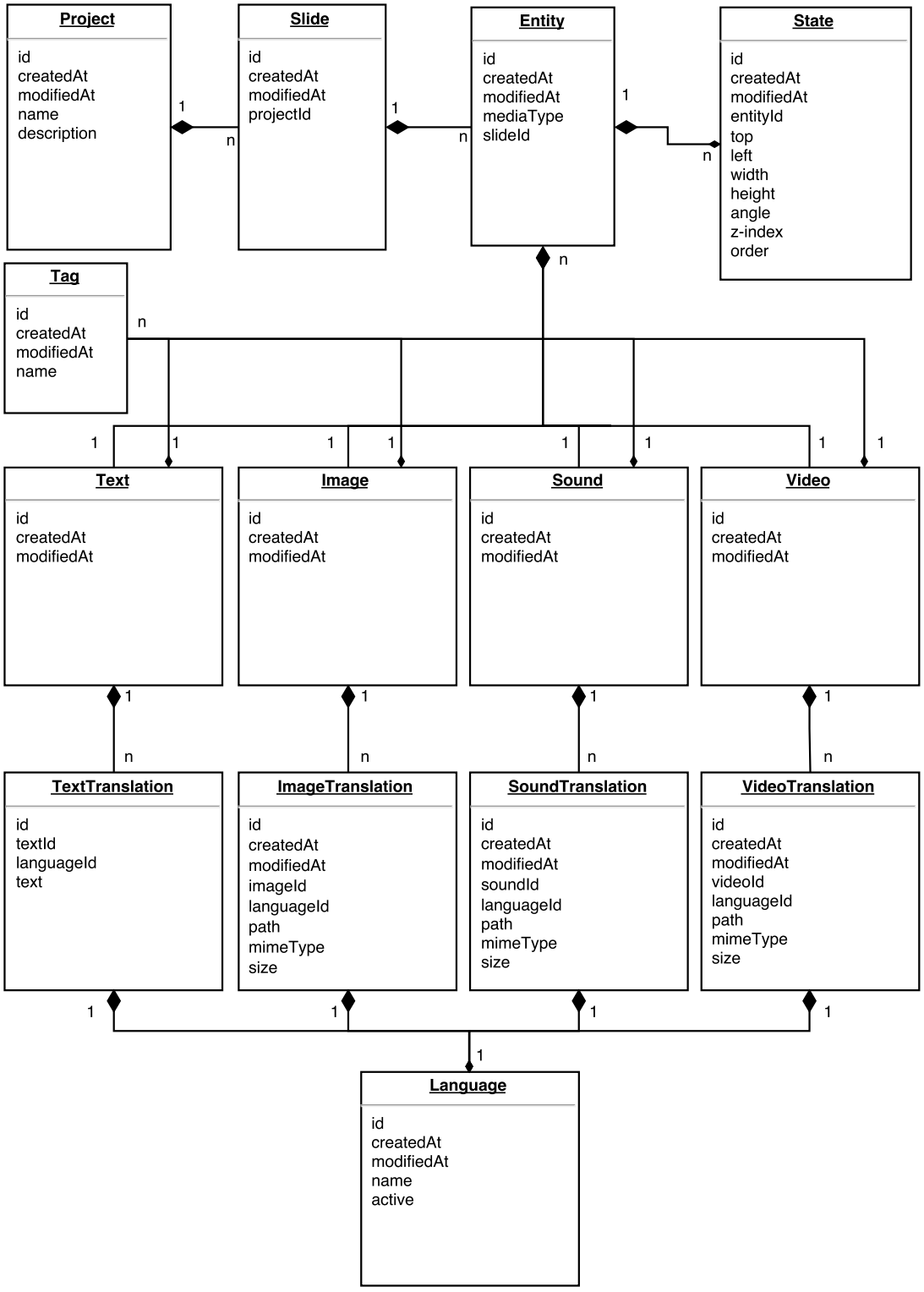
their created behavior rules. Non experts therefore could search for their templates on the platform according to their hardware specific needs. Furthermore, there could be added a request feature where non experts could describe the behavior rule they need and any expert could implement the code for them.

Behavior Rules for Devices

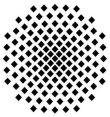
By now the VEII toolkit supports users to create and adapt behavior rules to establish interactive content. So users can for example move, scale and rotate content entities using rules. An improvement to the system would be to integrate the opportunity to create rules which aim at actuators of devices like vibration on a mobile phone. This would bring interactive installations to a higher level. A possible use case would be while walking through a museum and the own smartphone signals if there is something interesting nearby. This could be achieved by using Bluetooth to detect the phone and a rule which triggers the vibration actuator.

Appendix

.1 Database Model



.2 Consent Form



University of Stuttgart
Germany

Consent Form

DESCRIPTION: You are invited to participate in **a research study** on "**Programming Concepts for Interactive Devices**"

TIME INVOLVEMENT: Your participation will take approximately **30-60min.**

DATA COLLECTION: For this study, we will give multiple tasks to solve. We will make observation notes and ask you to fill out different surveys.

RISKS AND BENEFITS: No risk associated with this study. The collected data is securely stored. We do guarantee no data misuse and privacy is completely preserved. **We cannot and do not guarantee or promise that you will receive any benefits from this study.** Your decision whether or not to participate in this study will not affect your grade in school.

PARTICIPANT'S RIGHTS: If you have read this form and have decided to participate in this project, please understand your **participation is voluntary** and you have the **right to withdraw your consent or discontinue participation at any time without penalty or loss of benefits to which you are otherwise entitled**. **The alternative is not to participate.** You have the right to refuse to answer particular questions. The results of this research study may be presented at scientific or professional meetings or published in scientific journals. Your identity is not disclosed unless we directly inform and ask for your permission.

CONTACT INFORMATION: If you have any questions, concerns or complaints about this research, its procedures, risks and benefits, contact following persons:
Thomas Kubitza, MSc. (thomas.kubitza@vis.uni-stuttgart.de)

By signing this document I confirm that I agree to the terms and conditions.

Name: _____

Signature, Date: _____

.3 Gerneral Background Questionnaire

General Background

1. **Gender**
   Tick all that apply.

   - [ ] Female
   - [ ] Male

2. **Age**

   .....

3. **Profession**

   .....

4. **Do you have previous experience in the design of exhibitions?**
   Mark only one oval.

	1	2	3	4	5	
No experience	◯	◯	◯	◯	◯	A lot experience

5. **Do you have previous experience in the design of interactive exhibitions?**
   Mark only one oval.

	1	2	3	4	5	
No experience	◯	◯	◯	◯	◯	A lot experience

6. **Are you working in the museums sector? If yes, what kind of museum?**

   .....

   .....

   .....

   .....

   .....

7. **Did you design exhibition that involve projections before? How was this done practically?**

.....

.....

.....

.....

.....

.4 System Usablity Scale Questionnaire

Toolkit Usablity

*Required

Standard Usability Scale

1. **I think that I would like to use this system frequently.** *
   Mark only one oval.

	1	2	3	4	5	
Strongly Disagree	◯	◯	◯	◯	◯	Strongly Agree

2. **I found the system unnecessarily complex.** *
   Mark only one oval.

	1	2	3	4	5	
Strongly Disagree	◯	◯	◯	◯	◯	Strongly Agree

3. **I thought the system was easy to use.** *
   Mark only one oval.

	1	2	3	4	5	
Strongly Disagree	◯	◯	◯	◯	◯	Strongly Agree

4. **I think that I would need the support of a technical person to be able to use this system.** *
   Mark only one oval.

	1	2	3	4	5	
Strongly Disagree	◯	◯	◯	◯	◯	Strongly Agree

5. **I found the various functions in this system were well integrated.** *
   Mark only one oval.

	1	2	3	4	5	
Strongly Disagree	◯	◯	◯	◯	◯	Strongly Agree

6. **I thought there was too much inconsistency in this system.** *
Mark only one oval.

	1	2	3	4	5	
Strongly Disagree	◯	◯	◯	◯	◯	Strongly Agree

7. **I would imagine that most people would learn to use this system very quickly.** *
Mark only one oval.

	1	2	3	4	5	
Strongly Disagree	◯	◯	◯	◯	◯	Strongly Agree

8. **I found the system very cumbersome to use.** *
Mark only one oval.

	1	2	3	4	5	
Strongly Disagree	◯	◯	◯	◯	◯	Strongly Agree

9. **I felt very confident using the system** *
Mark only one oval.

	1	2	3	4	5	
Strongly Disagree	◯	◯	◯	◯	◯	Strongly Agree

10. **I needed to learn a lot of things before I could get going with this system.** *
Mark only one oval.

	1	2	3	4	5	
Strongly Disagree	◯	◯	◯	◯	◯	Strongly Agree

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All links were last followed on November 3, 2015.

Declaration

I hereby declare that the work presented in this thesis is entirely my own and that I did not use any other sources and references than the listed ones. I have marked all direct or indirect statements from other sources contained therein as quotations. Neither this work nor significant parts of it were part of another examination procedure. I have not published this work in whole or in part before. The electronic copy is consistent with all submitted copies.

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place, date, signature