UNIVERSITÄT DUISBURG ESSEN

Offen im Denken

Bachelor Thesis

Title Here

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Computational Methods in Modeling and Analysis of Learning Processes
Month, Year

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Chapter 1

Introduction

In academic and research settings, posters serve as a key medium for presenting work, fostering dialogue, and sparking collaboration. While effective in their simplicity, traditional paper posters often rely heavily on the physical presence of the researcher to guide discussions, answer questions, and provide context. This dependency limits their utility, particularly in contexts where accessibility, interactivity, or remote engagement are prioritized. The proposed thesis topic, "Implementation of an interactive poster using Raspberry Pi and traditional crafting materials," addresses this gap by exploring how modern technological tools can enhance the traditional research poster, transforming it into an interactive and self-explanatory artifact.

This project tries to bridge the fields of technology, design, and communication. By integrating microcontrollers such as Raspberry Pi with traditional crafting materials like paper and markers, the aim is to create a hybrid solution that maintains the familiarity of traditional posters while introducing elements of interactivity.

The thesis will adopt an iterative design-implementation-evaluation approach, ensuring that the final prototype meets the needs of its stakeholders and demonstrates usability in real-world scenarios. Initial phases will involve identifying the primary users and their requirements through stakeholder analysis. Based on this foundation, mockups and prototypes will be developed and refined through user feedback and usability evaluations. Each step will build toward delivering a functional and engaging interactive poster that leverages technology to improve the accessibility and communication of research.

This project aligns with the broader goal of advancing educational and presentation technologies by introducing creative, user-centered approaches to traditional formats. By focusing on the process of integrating hardware, software, and crafting techniques, this thesis will not only contribute to the field of interactive learning technologies but also inspire further exploration into how technology can enhance communication in academic and professional contexts.

Chapter 2

Related Works

2.1 Background and Limitations of Traditional Posters

(Citation on what are posters, maybe [1]?: "Posters are displayed on boards or stands and viewed from a distance. Posters are displayed simultaneously over the course of the conference and attendees are free to browse and study at their own convenience" Or put this in the introduction?)

Traditional paper posters have long been used as a tool for conveying information, whether it be in educational, professional, or public settings [1], [2]. "The 'traditional' poster presentation aims to present information in a succinct manner"[3]. However, despite their widespread use and popularity [2], simple paper posters suffer from significant limitations, particularly in their ability to actively engage the audience and their bandwidth for transferring knowledge [4]. It was shown that while most event participants agreed that posters were a good medium for knowledge transfer [5], [6], the knowledge retention of their viewers was often abysmal if they were read at all [6]. For example, at the Digestive Diseases Week (DDW) and British Society of Gastroenterology (BSG) meetings, only $<$1.5% and $<$0.3% read any of the posters respectively. "Delegates remembered very little when phoned about posters two weeks later" [6]. While it may be the case that "Publication rates of abstracts submitted to the BSG seem to be falling, implying that for more and more research, poster presentations are the only opportunity to share research findings" [6]. "Abstracts selected for presentation are usually collated as conference proceedings, but rarely found in the published literature." [1].

These findings highlight a key challenge with traditional paper posters: their ability to captivate and engage an audience effectively **(citation**

needed). Given the limited time and attention that viewers devote to posters, their aesthetic appeal becomes a crucial factor in attracting viewers and encouraging interaction[6]. A visually striking design can often be the deciding factor in whether a poster is noticed, read, or remembered, emphasizing that aesthetics are not merely decorative but integral to the effectiveness of paper posters[5], [7], [8]. “Studies that reported on the effectiveness of the poster presentation as a standalone intervention were unanimous in their conclusions that the poster was not effective at facilitating knowledge transfer be it through an increase in knowledge, change in attitude or behavior. his conclusion was supported by an evaluation study, in which participants identified that posters needed to be accompanied by another source of information to be effective – otherwise the only drawing point to the poster is the imagery.” [4] Factors like layout, format, readability, and even color schemes all influence how effectively key information can be conveyed to the reader [4], [7].

“Given its passive nature; if not accompanied by an active intervention (e.g. oral presentation, physical interaction), which can help with aural and verbal learning exchange, the ‘traditional’ poster may only reach a limited proportion of its intended audience .” [4] This nature also makes them badly equipped to accommodate alternative learning styles.[3]

“By embedding knowledge in interactions that involve people, it is possible to achieve reciprocal dialogue, which is the most effective method of transferring tacit knowledge.” [4]

2.2 Evolution Toward Interactive Posters

2.2.1 Paper Posters

These interactions don’t need to be exclusively based on dialogue only; Posters that ask the viewer to interact with them in some way help to attract attention and might even instigate thoughtful debate among attendees [9]. When asked for participation, participants spent longer at the poster, as it required them to think about the given questions/topic more thoroughly and deal with it in more detail [8], [9]. This increased engagement also causes participants to return to the poster more frequently, even if it is just to compare their results with those of their peers [8], [9]. This not only helps the participants to obtain more knowledge about a given topic but also the authors, as it identifies improved ways to communicate complex information [9]. However, it is important to note that “Simplicity is vital so that attendees are not waiting for directions”[9], “one engaged viewer will attract others”[7].

2.2.2 Digital Posters

Digital posters, sometimes called E-Posters, are a form of digital media, used to present information, just like "traditional" posters **(citation needed)**. “Reported advantages of the digital format include lower production costs, ease of preparation and transport, dissemination to a larger audience, and large archival capabilities”[10]. This also opens up the possibility of maneuvering the presented content in a 3D space as well as embedding multimedia elements, creating new ways of presenting information to an audience [11]. Technologies like DIPP (digital interactive poster presentation)[12], MediaPoster[13], as well as ePoster, emerged, trying to make use of the flexibility digital media has to offer **(citation needed or reformulate)**.

- DIPP (digital interactive poster presentation) “is a pdf version of a traditional poster that can be projected on a wall or screen at allotted times” [14], which is mostly used to briefly summarize the research, giving the audience the chance to decide which presentations to attend during the actual poster sessions [14].
- MediaPoster expands on this, adding the ability to embed external sources into an area of interest. Unlike normal hyperlinks, which would open a website or similar, a MediaPoster has a Media Display Area to the right, which would show the requested documents to the viewer, keeping them within the same environment with the poster always in full view. [13]
- ePoster by Conventus takes a slightly different approach, offering posters in digital format on dedicated hardware. Presentations are held on specialized screens, controlled by a device similar to a smartphone. The control device mirrors the large display but enables manipulation of the viewing area, as well as selecting different presentations, with its touchscreen. **(What to do here????)**

(removed the pictures here, i probably need the rights to use them?)

This innovative approach to posters not only enhances the flexibility and interactivity of the presentation but also significantly improves the audience’s ability to grasp and retain the material **(citation needed or reform)**. The integration of multimedia elements such as pictures and videos captures attention more effectively than traditional posters [15], serving as powerful tools for explaining complex concepts **(citation needed or reform)**. By embedding visual aids and interactive content, digital posters make the material more accessible and easier to understand, while also highlighting and clarifying essential parts of the presentation[15].

2.3 Technological Foundations for Enhanced Interactivity

2.3.1 Electric Circuits and Other Responsive Media

(redo this section? its mostly claims...)

Thanks to modern production and fabrication capabilities, building and integrating electric circuits has become more accessible. With the advent of tools like printed circuit boards (PCBs), conductive inks, and modular components, creating responsive and interactive systems is no longer limited to specialists. These advances have enabled the seamless integration of electric circuits into a variety of materials and media, opening the door to innovative applications in design, art, and engineering.

Among these innovations, responsive media such as Thermochromic ink, thin-film displays and a plethora of sensors have gained significant attention. Thermochromic inks, for example, can change color in response to temperature fluctuations, providing a visually dynamic way to convey information or interact with users. When paired with electric circuits, these materials create systems that are both functional and expressive, blending technology with creativity. Projects like PaperPixels [16] even go as far as to create Paper-based Displays with thermochromic ink by creating a circuit that powers piezoelectric elements according to an animation specified in their custom software, heating the ink at specific times. Due to the thermochromic ink's nature, they then change colors based on the temperature of the piezoelectric element. Depending on the "color scheme" chosen, images could appear "out of thin air" if the background color matches the unheated color of the ink.

Another notable project is IllumiPaper [17], which makes use of thin-film (TF) displays with electroluminescent or electrochromic properties, to light up predefined regions or change color based on user interactions. These displays are printed on the paper itself, creating a seamless integration of digital and physical media. Users can then interact with the media via a pen, using the Anoto technology to track the pen's movement pattern and capture input. This works by printing an "invisible" dot pattern on the paper which encodes specific coordinates, allowing the pen to determine its exact position on the paper.

(Would love to put the picture here but i'd have to get the rights for that, right?)

(how to go about commercial solutions? hard to cite...)

Commercial solutions to this also exist, notably, Interactive Paper [18] by a company with the same name, Interactive Paper. Their approach is electric circuits made out of conductive ink printed on the inside of the paper, sending NFC signals to a smartphone in contact with the respective NFC pad on the paper to then perform an action. They also offer a version that uses augmented reality to display content on a smartphone, though they have not published any information on the inner workings of this process.

2.4 Interactive Media in Education

(citation needed for below claims) Active student engagement is a cornerstone of effective learning environments. When students are actively involved in their educational experience—through participation, interaction, and hands-on activities—they are more likely to retain knowledge, develop critical thinking skills, and cultivate a genuine enthusiasm for learning. Engagement transforms the classroom from a passive setting into a dynamic space where curiosity and creativity thrive.

Research consistently highlights the benefits of interactive and participatory learning methods **(citation needed)**. Students who feel connected to their learning materials and peers are more likely to exhibit improved academic performance[19]. This is particularly true when teaching methods leverage modern technologies, real-world applications, and collaborative activities that resonate with students' interests and experiences[20]. "Even students who do not talk in class are often stimulated by questions or problem-solving exercises as they think about what they would answer in a particular situation"[21], helping them become more actively involved with the material or content, teacher or even their peers [21]. Interactive media will be more effective when already associated with high learning motivation [22], resulting in students, who are already highly motivated to learn and study the material, receiving an even higher beneficial effect from this form of media [22]. Students with lower learning motivation, however, could suffer from this kind of learning, as they might require more intervention and more supervision from a teacher during the learning process [22]. Thus, it is important to choose an appropriate kind of media.

Chapter 3

Methodology

(Overall, i kept it similar to the Methodology from the proposal and removed parts that just weren't relevant as the proposal was intended for an entirely different purpose than this project ended up having. I changed some parts that were relevant to be more accurate. Though i feel like this is just too little?)

In this section, I will outline the iterative design-implementation-evaluation approach employed, to develop an interactive poster system using Raspberry Pi as the central microcontroller. The methodology is rooted in user-centered design principles, emphasizing collaboration with stakeholders, iterative refinement, and requirements-driven evaluation to ensure the system meets its intended purposes.

The primary goal is to create a system that presents the COLAPS group's research in a concise and engaging way. The system should balance technical functionality with usability, visual appeal, and ease of integration into various contexts, such as education, exhibitions, or public spaces.

My approach begins with identifying key stakeholders and eliciting requirements through interviews and contextual inquiries. These requirements guide the creation of initial design mockups, which visualize the interaction concepts and serve as a foundation for stakeholder feedback. Based on these designs, prototypes are developed incrementally, with each iteration refining the system's hardware, software, and user experience.

Each prototype undergoes systematic evaluation, combining qualitative and quantitative methods to assess its technical performance, usability, and alignment with stakeholder needs. The insights gained from these evaluations inform subsequent iterations, fostering continuous improvement and innovation.

By following this methodology, I aim to ensure the final system not only meets technical and aesthetic expectations but also achieves its intended impact, creating a versatile, interactive platform that bridges the gap between traditional and digital media.

3.1 Identifying Stakeholders

In the development of this project, it is crucial to identify and engage the right stakeholders to ensure the system meets their diverse needs and expectations. Depending on who they are, the course of the entire project might change, thus this should be done as the very first step.

- End Users (General Audience): The primary users of the interactive paper poster will be individuals who engage with the poster. These users could interact with the poster through buttons (capacitive or tactile) or sensors, triggering visual or mechanical responses (e.g. lighting, moving parts, screen display). Their experience with this system will be central to its success. As such, their feedback on usability, engagement, and overall experience is critical for shaping the design and functionality.

- Research group: On the other side of the poster presentations are the presenters themselves, the research group *colaps*. They will be the ones showcasing the poster and presenting their research using it. As such, the system needs to be reliable and easy to use.

3.2 Eliciting Requirements

The process of eliciting requirements will be carried out to ensure that the interactive paper poster meets the needs of its primary stakeholders. This phase will involve gathering information about the expectations, preferences, technical constraints, and contextual constraints, that would shape the design and functionality of the poster. This could be done by interviewing the team of the research group to get a grasp on the factors mentioned, as well as collecting and surveying the necessary research material that is desired to be presented. When starting the prototyping process, designing mockups, and implementing various features, a strong feedback loop with the research group should be established to guarantee that no unnecessary features will be implemented or important features will be left out.

3.3 Prototyping and Evaluating

In the process of prototyping, mockups of the poster will be made, to test certain features and to obtain feedback on their implementation. Each prototype will then be evaluated according to the abovementioned fundamental requirements, the functionality of the feature(s) implemented, and the impressions and feedback of the research group.

3.4 Materials

At the most fundamental level, a Raspberry Pi SBC or similar will be required for this project. For this, I propose using a Raspberry Pi 4 2GB. The reason for this is that, compared to the Pi 3 B+ for example, the Pi 4 offers two Micro HDMI and USB 3 ports, offering great expansion capabilities in terms of screens and IO. Its more powerful processor and ample RAM provide a more reliable basis for computing without the risk of running into any potential bottlenecks. Additionally, materials need to be researched that fulfill the requirements set by the stakeholders. **(Maybe elaborate more on the material research here? There wasn't *a lot* but i think it's worth mentioning on how i went about this? Or is this more implementation?)**

(I'd like to keep this in to then refer to in the results. Could be interesting to see how risks were actively handled once/after they occurred)

3.5 Risk Assessment Plan

The development of the interactive paper poster system may involve several risks that need to be identified and managed to ensure the project stays on track. The table below outlines the primary risks that can be identified at this point in time, as well as mitigation strategies.

Table 3.1: Risk Assessment Plan

Risk	Mitigation Strategy
Stakeholder Miscommunication	Establish clear communication channels (e.g., regular meetings, documented feedback) and maintain a feedback loop with stakeholders throughout the project.
Hardware Failures or Delays	Maintain spare components for critical hardware (e.g., Raspberry Pi, sensors, and peripherals) and plan for alternatives in case of supply chain issues.
Technical Integration Challenges	Adopt a modular design approach to minimize dependencies between components, allowing easier troubleshooting and replacement of individual parts.
Time Overruns Due to Feature Creep	Strictly prioritize features based on stakeholder requirements and time constraints; establish a clear Minimum Viable Product (MVP).
Insufficient Usability Feedback	Conduct frequent usability testing with diverse stakeholders at every iteration to ensure feedback is gathered systematically.
Software Bugs or System Instability	Implement version control (e.g., Git) and perform continuous integration and testing to catch and resolve bugs early.
Power or Portability Issues	Test power requirements early in the prototyping phase and optimize for efficient power consumption. Use battery packs or alternative power sources as backups.
Unfamiliarity with Certain Technologies	Allocate time for researching and experimenting with new technologies (e.g., advanced sensors or peripherals) during the early phases of the project. Seek guidance from experts if needed.

Chapter 4

Results

4.1 Stakeholders and Requirements

To ensure that the interactive poster would address the actual needs of its intended audience, the first step in the implementation process was to identify the relevant stakeholders and elicit concrete requirements. This process provided the foundation for the design decisions described in the subsequent sections.

4.1.1 Identify stakeholders

The stakeholders in this project were defined as all individuals or groups with a direct interest in the functionality, presentation, or long-term use of the poster. As such, the following groups were identified:

- The head of the COLAPS research group, Irene-Angelica Chounta, who initiated the project and acted as the primary source of requirements regarding content and functionality.
- The other members of the COLAPS research group, whose publications and research topics constitute the content of the poster and who have a stake in how their work is represented.
- End-users such as external researchers or students, who are expected to interact with the poster and whose needs for clarity, usability, and engagement shaped the design choices.

4.1.2 Elicitation Method

To clarify the needs and constraints of the identified stakeholders, I prepared a set of guiding questions and conducted an interview with the supervising professor, who both initiated the project and represents its primary beneficiary. The questions were structured around themes such as physical constraints, intended goals and audience, content and structure, interaction design, accessibility, maintenance, and success criteria. At this stage, the interview was conducted exclusively with the supervising professor, as she holds the clearest vision of how the poster should represent the research group and how it should be used in practice.

4.1.3 Key Requirements

From this elicitation process, a set of functional and non-functional requirements emerged, which served as the foundation for subsequent design and implementation decisions.

The system shall...

Functional Requirements

- ... allow users to browse a wide range of content produced by the research group, including publications, seminars, lectures, projects, and thesis topics.
- ... provide a simple and straightforward interaction design.
- ... allow users to manually search for specific content.
- ... support the replacement and editing of data, even if such updates are expected to be infrequent.
- ... consider audio narration as an accessibility feature.
- ... support the scanning of QR codes and NFC tags (e.g., from business cards) for integration into a digital guestbook.
- ... allow the user to take a picture of themselves for the guestbook.

Non-Functional Requirements

- ... be lightweight yet sturdy, ensuring portability by no more than two people.
- ... feature a playful and engaging design that encourages exploration and interaction.

Constraints

- ... have a maximum size between A1 and A0 format.
- ... be developed within a reasonable budget.

4.2 Initial Proof-of-Concept

The initial proof-of-concept phase focused on transforming early design ideas into tangible prototypes, with particular emphasis on the ‘lucky wheel’ metaphor suggested during stakeholder discussions. This metaphor was selected as it provided a recognizable and intuitive interaction model, reducing the need for extensive instruction and encouraging playful engagement.

To quickly visualize the idea and make it into something tangible, a rough paper sketch was made, illustrating the key design points: A spinning wheel to select categories, a screen to browse the content for each category, and a keyboard for user inputs. Additionally, Camera placement for the QR-Code and Guestbook image was also illustrated.

Two alternative input devices were considered: an oversized trackball, intended to emphasize playfulness and accessibility, and a retro joystick, valued for its simplicity and iconic status. While the trackball offered unique interaction qualities, it would have required custom development. The joystick, by contrast, was commercially available, familiar to users, and limited in input complexity, making it the more practical choice. Ultimately, the Atari joystick was selected for its minimal design and robustness against both accidental and intentional misuse.

Comparing those two ideas, the joystick was ultimately decided to be the better choice. Joysticks were an already established platform/hardware, that could readily be bought at a reasonable price, while the trackball solution would've required extensive development from myself, which would put extra strain on my ability to complete this project in time. They're well known, and it's intuitive nature makes the system more inviting. Specifically, the Atari joystick was chosen as the input device, due to it originally only having one button and the joystick, thereby minimizing both accidental and intentional misuse.

Provide image of sketch

A WebApp was created based on the paper sketch to serve as a mockup and simulation for the interaction, as a way to "experience" the idea rather than seeing it just as a flat sketch. The original sketch already considered to use LED signs, which were designed in this step with the help of OpenAI's ChatGPT image generation.

Provide image of webapp

The accompanying design document detailed each feature and design choice, while also proposing alternative implementation paths, such as material options for the wheel and housing. By sketching out the workflow of the system at this stage, potential oversights could be identified early, ensuring alignment between interaction concept and technical feasibility.

provide design document

The Web App was subsequently presented to the professor, who offered additional feedback and requirements. In summary, the proof-of-concept validated the core interaction model of a spinning wheel controlled via joystick, confirmed its feasibility for playful yet robust user engagement, and highlighted specific areas (such as the guestbook feature) requiring refinement. This provided a clear foundation for subsequent CAD modeling and early prototyping.

4.3 CAD and Materials

Small section on the creation of the CAD model and material choices/tests

4.4 Early Prototyping

TODO: Add images for: 3D Printed Prototype fully assembled, CAD Model(?), magnet pole orientation, skewed image on display

A small-scale prototype was developed, drawing upon the CAD and the design specifications previously outlined. The objective of this prototype was not to serve as a functional miniature version of the final poster; rather, it was employed as a platform to validate the feasibility of using magnetic sensors for reliable input capture and to provide a tangible demonstration platform to communicate the concept and design to stakeholders.

4.4.1 Design Rationale

3D printing was selected as the manufacturing process due to its low cost and ability to rapidly produce customized parts with minimal waste. The selection of magnetic sensors/encoders over other technologies, such as rotary encoders, was driven by several factors. These sensors were chosen due to their small form factor, cost-effectiveness, and resistance to mechanical and electrical degradation over time, particularly in prolonged use scenarios. In this particular instance, the utilization of an MT6701 would have been the optimal selection. This is due to the fact that the computations necessary to convert the magnetic field into angular degrees had already been incorporated into the chip's architecture. However, given the unavailability of breakout boards during the developmental stage, an alternative solution was necessary. For this purpose, the TLV493D was selected, as it was readily available on breakout boards, inexpensive, and supported by existing Python libraries. Unlike the MT6701 however, the TLV493D outputs only raw three-axis magnetic field values, requiring additional software computation to derive angular positions.

4.4.2 Mechanical Integration

The TLV493D magnetic sensor was mounted on a breakout board (black PCB in the render) and integrated into the 3D-printed housing using a set of raised standoffs, with M2 socket head cap screws screwing directly into the plastic. The standoffs ensured both mechanical stability and correct orientation of the sensor relative to the rotating magnet. The circular plug, which was connected to the spinning wheel on the other side, served as the magnet holder. This allowed the sensor to be placed at a fixed distance above the plane of rotation. This configuration guaranteed that the sensor's sensitive area was continuously aligned with the movement trajectory of the magnet, thereby facilitating the reliable capture of angular displacement data. The magnet itself was positioned in parallel alignment to the sensor.

4.4.3 Electrical Integration

The breakout board simplified wiring by providing pre-routed connections and mounting holes. This modularity allowed easy replacement if the sensor failed or the design was modified. Electrically, the TLV493D was connected to the Raspberry Pi via I^2C, using pins 3 and 5 for communication and pins 1 (3.3 V) and 9 (ground) for power.

4.4.4 Software Integration

The initialization of the sensor was largely uncomplicated, primarily due to the presence of an usage example in the library documentation. However, the conversion of the sensor data to degrees and/or radians necessitated the calculation of the arc tangent for the y/x values from the sensor output, followed by the modulo operation with 360 to obtain values ranging from 0 to 360 instead of -180 to 180. The function responsible for reading and calculating the sensor data was delegated to a separate thread, enabling its execution in parallel with the application's other components.

During the testing phase of the implementation, it was noted that there was minimal change in the values reported by the sensor. These findings were independent of the proximity of the magnet to the sensor, as well as the velocity with which the magnet was rotated. A thorough investigation into the matter revealed that the magnet in question did not possess a magnetic field with the poles divided into two equal segments along the central axis (resulting in each pole representing half of the circular shape). Instead, the poles were positioned on the two opposing large faces of the magnet. Consequently, the magnetic field remained virtually unchanged, with only the pole rotating along its own axis on top of the sensor. Subsequent to orienting the magnet in a perpendicular position relative to the sensor, quantifiable values were obtained, and the calculations were confirmed to be operational.

The sensor output, however, was noisy. To address this, a moving average filter was implemented. Eight samples per window were found to offer a good compromise between latency and stability, smoothing out spurious fluctuations while maintaining responsiveness.

4.4.5 Display Integration and Limitations

The incorporation of a display was imperative for the subsequent visualization of the magnets' position in this prototype. The selection of a generic 1.8-inch ST7735 SPI TFT display was made on the basis of its wide availability, diminutive size, and reasonably high resolution for its size. An external Python library had already been developed for this display, which was also one of the primary concerns with this prototype. The display was wired to the Raspberry Pi via standard SPI pins (MOSI, SCLK, CE0) and GPIO pins 24 and 25 for reset and data control. The process of displaying images on the display interface was found to be somewhat challenging, though not overly intricate. The library documentation provided an ample array of examples for reference. However, it was not specified that the width and height values could not be interchanged to "simulate" a 90-degree rotation. In order to accomplish this, it is necessary to employ the rotation parameter.

The initial interface presented on the display was developed through the implementation of the Python Imaging Library (PIL). This software continuously generated and transmitted images to the display interface. The image in question consists of a green circle accompanied by a red line, which collectively serve to visualize a compass. Above the image, there is red text displaying the values of both degrees and radians, which are calculated from the sensor output. This was initially useful for visualization and evolved into early versions of the configuration tool as a console application, which was used for recording the angles for each slice.

However, the eventual introduction of a front-end library to power the main application rendered the continued use of the SPI screen increasingly impractical. While the process of streaming single images (even when updated continuously) using the PIL module functioned adequately, there was no sufficient method for streaming Kivy applications without utilizing a display driver and employing the SPI screen as the primary interface. A preliminary investigation was conducted into the potential of employing PIL to capture a screenshot from a Kivy application and transmit it to the display. However, this endeavor was promptly discontinued due to the substantial technical complexity and throughput bottlenecks encountered. Despite the availability of publicly accessible display drivers for ST7735 SPI screens, it was observed that none of these drivers appeared to be compatible with the display utilized in the prototype. The technical intricacy and unpredictability of the endeavor, as well as the potential unavailability of viable outcomes, were not deemed justifiable at this stage of development. Consequently, the SPI screen was regarded as an unstable technological trajectory, leading to its eventual abandonment in the pursuit of a more viable interface.

4.4.6 Key Findings

This prototyping stage yielded two important outcomes. First, it validated the feasibility of using magnetic sensors for input capture, provided the magnet is oriented correctly and filtering is applied to stabilize noisy data. Second, it eliminated SPI-based displays as a viable option for further prototypes, thereby clarifying hardware requirements for subsequent prototyping.

4.5 GUI Design and Creation

I made *some* Layout drawings for the tools and the application. While those were based on nothing but what i thought would make sense and be usable, might be interesting to include them here while explaining why i did what i did. Also would include a short paragraph on the frontend framework choice as this one wasn't as straightforward.

4.6 Logic Implementation

Here i'd put **everthing** i did before refactoring the codebase. This includes everything from the documentation until half of 12.8., like:

- Initial Database design
- Making the prototype configuration tool on the 3D Prototype with all it's logic
- Later moving it to Kivy (with the problems that came with that)
- Creation of the first Application Window and it's expansions
- Implementation of the Content Manager tool
- Database Redesign (and outlining the risk of SQL Injections which was later fixed)

While this list is somewhat chronological, i'm not sure if it makes sense to keep it that way. While during this time, i was mostly focused on finishing one program before starting another, i'm sure there was *some* jumping around, which would make more sense to just keep in its "subcategory" (like Content Manager tool implementation).

4.7 Refactoring

This might be the most interesting section as the learning curve of application development really took it's toll on the program up until this point and things became quite the spaghetti code, which was just unmaintainable and impossible to work with at this point, even for me as the creator.

I'd outline what the issue was, give some explanations on why this was happening and propose the plan i drafted up (and implemented) to mitigate this.

Some POI would be the management layers for topics and categories, the expansion of the database wrapper, and object management in code.

Obviously this all caused some issues after implementation with things i couldn't test at the time, but they were rather minor, so if i include them, i'd probably do it briefly.

Here i also fixed the SQL Injections.

4.8 Expanding Capabilities

This would include...

- the implementation of the searchbar
- naming categories in the configuration tool
- expanding the configuration tool with the ability to rename recorded categories
- expanding the category management layer with the necessary functions to facilitate the above and then some (namely creation and deletion)

These, too would include thoughts behind certain decisions and problems that were encountered and are worth mentioning (if any).

4.9 HID Integration

Implementing the Joystick controls was also pretty interesting, as it required some reverse engineering (if you could call that) of the communication with the library i chose. There was also some special design choices i made that i'd like to outline (e.g. using ENUMs to assign inputs). There's also one problem that i'd like to explain because it also led to an unusual but necessary choice in behavior.

As you can tell, there might be things missing. Namely the NFC reader, LEDS, Feedback mechanism and Multimedia support. This is obviously dependent on whether or not there will be another (albeit short) phase of development, where i might be able to finish one of these features. Which is also dependent on how much of the exposé i can reuse, as rewriting this in it's entirety would take up all the time i have left for this thesis.

I have written a paragraph about this in my documentation, which i would later include in the limitations section.

Chapter 5

Conclusion

I'm not sure what to put here but some things that come to mind are the final feedback from you as the stakeholder, as well as the limitations.

5.1 Limitations

For one, i'd like to go over the risk assessment plan in general and outlined how some risks were mitigated from the beginning, and how others were mitigated while/after they were encountered.

Then, how and why the actual implementation differed rather greatly from what was proposed/planned in the methodology section.

Later on i'd like to go over why certain features were dropped, though this strongly ties in with the "feature creep" part of the risk assessment plan so i might put it there.

I'll probably find some other things when i go through my notes and materials in detail. This is just a rough sketch that awaits your input :)

5.2 Future Works

Talking about what could be improved or added to this project after me. For example implementing the features that didn't make it to the final version, optimizing certain processes or workflows, etc.

List of Figures

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