Study Setup Optimization - Providing Solutions with Patterns

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***Abstract*—This paper proposes the use of the contextual user experience (cUX) pattern approach for refining a study concept involving biometric image data. While the concept of a study may be clear from the beginning, external influences can not always be predicted beforehand. While designing a study concept for a thesis about the acquisition, inspection, and evaluation of Near Infrared (NIR) iris biometry images, certain problems arose, e.g., how to deal with the environmental light, which material to use for 3D printing or the problem of picking the right questionnaire. We used the cUX pattern approach to provide solutions in the form of patterns for the occurred problems during the refinement process of the study setup.**

***Keywords*–design patterns; pattern reuse.**

I. Introduction & Related Work

In this paper, we will present three patterns, created to provide solutions for problems encountered during the improvement of a study setup. Patterns, in general, are a well acknowledged method in Human-Computer Interaction (HCI), providing reliable solutions for specific problems. They can be advantageously used to ease the communication between experts with different levels of expertise or even alternate disciplines. This is particularly useful in interdisciplinary areas, such as HCI research and design. Patterns were first introduced by Christopher Alexander [1][2] as a means to capture working solutions for reoccurring problems in the field of architecture. His methodology was adopted by Gamma et al. [3] for Software Engineering and related disciplines, and has been used as a tool in these domains since. Patterns were adopted to supplement guidelines and other general means of guidance, because such approaches are often either too simplistic or high level [5][4]. Pattern solutions are firmly embedded in the context their problems occur in. This makes a specific pattern less reapplicable, i.e., only when the problem contexts match to a sufficient degree. But it also makes the solutions they describe more specific, as well as practice relevant, and lends them to be used by novices and experts [6]. Patterns have been adopted by other domains as well, such as Web Design and HCI [7][8][9] and also suggested as a general, discipline-independent knowledge transfer tool [10].

In section 2, we will shortly describe the study setup we wanted to improve, followed by an overview of the approach we used for pattern creation. We will show how we discovered and summarized the problem statements for each pattern and give an insight to the pattern creation process.

Section 3 will illustrate three solution patterns with the following *Titles*:

1) Choosing the Right Light Sources to Examine NIR-Images Differences
2) Lens Holder Construction for a Mobile Phone
3) Finding and Adjusting the Right Usability Questionnaire

Apart from the *Title*, each pattern is divided into six sections. The *Intent* provides a short description and is followed by the *Problem* statement, which is, in our case, a question. After stating the problem, a *Scenario* is presented that is used as an example, for which a *Solution* is provided. The solution is backed up by *Examples*, usually illustrated with images. The pattern ends by providing *Keywords*, matching the subject of the pattern. Last, we will discuss our findings in Section 4 and conclude this work in Section 5.

II. Approach

We wanted to improve and optimize an existing study setup, dealing with biometric images. These biometric images had to be analyzed afterwards, with respect to image quality. The setup was divided into several steps. During the first step, test subjects have to capture videos with a customized Nexus 5 mobile phone. The IR-blocking filter was removed from the rear camera image sensor, to enable NIR image capturing. The built-in rear camera image sensor is a Sony Exmor R IMX 179. The sensor offers an Red-Green-Blue (RGB) sub pixel layout with $3264x2448$ (8 MegaPixel) pixels and a sensor size of $5.68mm$ ($1/3.2$"), leading to an effective pixel size of $1.4\mu m$. The pixel size is decent for a mobile phone released in 2013. Therefore, taking images or videos in twilight conditions is possible. However, a brighter environment is preferred due to less image noise. Each test subject had to record at least three frontal face videos using two different filters / lenses, mounted on the mobile phone, which takes a lot of time. Afterwards, the test subjects had to fill in a questionnaire. Due to the time consuming video capturing process, the questionnaire needed to be short, while still maintaining a decent reliability. We proposed patterns to refine the study concept using an approach similar to the pattern generation process for car user experience patterns described in detail by Mirnig et al. [11], with some minor changes. The first mandatory step in our approach was to analyze the study concept and the associated setup to extract the problem statements. This was done by organizing a workshop with the person responsible for the study concept and a group of HCI researchers accustomed with the pattern generation process. During the workshop, the study setup was explained as follows: Study participants have to capture three frontal face videos: one without any lens, for NIR and visible light images, one with the IR-blocking filter / lens and one with the NIR-only lens. As it is possible to extract high quality images from high resolution videos, it was decided, to capture only videos instead of pure frontal face images. The two different lenses forced the researcher responsible for the study, to change them after every recording, due to the current lens mounting method. To ensure a variety of captured videos, the test subjects had to record the videos in different light environments, which where not yet defined. The final step was the acquisition of data, relating to the usability of the video recording process. As the video capturing procedure was time consuming, the data acquisition had to be fast, whilst still reliable. This workshop brought up the following three main problems:

1) Which light sources and ambient environments need to be considered, to ensure a diversity of captured image or video data usually acquired during real life usage?
2) How can the lens / filter changing process be improved?
3) What questionnaire should be used to provide reliable results while not using much time to fill out?

For each of the three problems, a draft pattern was created. The draft pattern initially did not provide any final solutions. Thus, the draft pattern was iterated for the first time, in a second workshop. The original draft pattern was reworked, with respect to the feedback from the first iteration. This iteration resulted in a refined version of the pattern. Each iteration improved the pattern to a certain degree. After the second iteration and rework phase, the pattern was finalized. It is noted that, depending on the experience of the involved experts, more iterations are necessary to create a good pattern. The final pattern should provide an adequate solution for the predefined problem statement. In our case, two iterations were sufficient.

In the next section, we will present the three solution patterns we generated. Each pattern provides a solution for a certain problem statement, previously mentioned in this section.

III. SOLUTION PATTERNS

A. Choosing the Right Light Sources to Examine NIR-Images Differences

Intent: There are several variables one needs to take into account when taking pictures or videos with a mobile phone. Due to the usually small built-in image sensor in mobile phones, sufficient environmental light is a crucial point. Insufficient light leads to higher image noise, which is generally not preferred. However, to analyze a wide area of possible real life conditions, selecting different environments for image capturing is important. This pattern presents three possible scenarios covering the most important lighting conditions. The scenarios were selected to provide images with a quality sufficient for subsequent analysis in mind.

Problem: Which scenarios are needed in order to acquire analyzable data, covering indoor, as well as outdoor, lighting conditions that enable NIR image acquisition?

Scenario: The study needed special image acquisition scenarios to reflect actual real life scenarios as closely as possible. Additionally, the ambient light in at least one of the scenarios had to cover the NIR wavelength ($>= 700nm$) spectrum to enable NIR imaging.

Solution: To cover most real life scenarios of possible image capturing conditions, we proposed three scenarios: one outdoor scenario using passive sunlight to enable NIR imaging and two indoor scenarios, using different light environments to challenge the imaging sensor of the mobile phone.

- **Outdoor (variable ambient light conditions)** - The outdoor scenario is and should be variable. In this condition, the sun is providing the ambient light. Therefore, the image quality is depending on time, weather, and location. To ensure the best possible conditions for NIR image acquisition, daylight is necessary. Therefore, image acquisition in this scenario should be done during daytime. An example of the outside condition is shown in Figure 2.
- **Indoor (dim light)** - The indoor scenario using a dim light source is intended to challenge the image sensor. The passive artificial light provides sufficient luminosity for images to be taken, as pictured in Figure 3. Nevertheless, the provided light is dark enough to force the image sensor to use a higher sensitivity setting (this is also referred to as ISO, which is derived from the International Organization for Standardization standard describing camera sensitivity settings), thus, resulting in more image noise. Note, that image noise is not desirable in general, but, if the main concept of the study is to analyze the whole range of possible image qualities, it is mandatory to include this unfavorable condition.
- **Indoor (bright light)** - In contrast to the dim light indoor scenario, the bright light indoor scenario uses a very bright artificial white light source to illuminate the frontal face area. This scenario complements the previously mentioned scenarios. The bright artificial light, covers the spectrum visible to the human eye (from about 390 to $700nm$), and provides a decent environment needed to capture regular frontal face images and can be observed in Figure 4. However, conventional light sources are usually not suitable for NIR imaging, as they do not cover the spectrum above $700nm$ (see Figure 1).

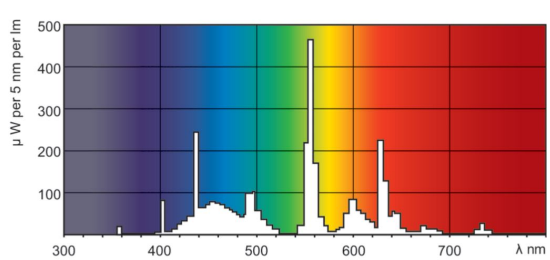

Figure 1. Philips TL5 HO 49W 865 Lamp [12] - Photometric Data.

Examples: This section shows nine sample images. They are grouped by the three proposed scenarios. Each group

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consists of three images: NIR only, NIR & visible light, and visible light only.

Figure 2. Outdoor - NIR only, NIR & visible light, visible light only (from left to right).

As mentioned in the solution section, the outdoor scenario provides sufficient light. This scenario provides the best NIR image quality, as the sunlight covers a wider spectrum compared to conventional light sources.

Figure 3. Indoor (dim light) - NIR only, NIR & visible light, visible light only (from left to right).

The indoor scenario with a dim passive light source tends to induce image noise and is not optimal for NIR imaging.

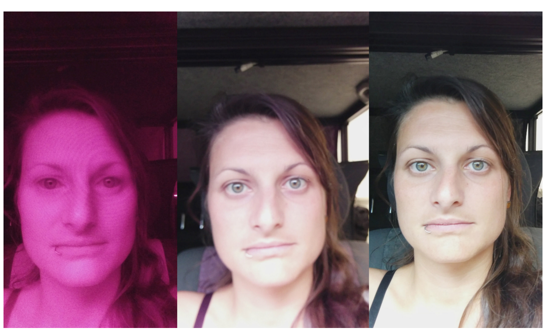

Figure 4. Indoor (bright light) - NIR only, NIR & visible light, visible light only (from left to right).

The last scenario provides a direct illumination of the facial area. It is very favorable for images captured in the visible spectrum, e.g., due to reduced image noise.

Keywords: NIR, visible light, wavelength, spectrum, image acquisition, illumination

B. *Lens Holder Construction for a Mobile Phone*

Intent: This pattern describes steps-by-step the construction of a lens holder for the Nexus 5 mobile phone.

Problem: Is it possible to create a method or item to reduced the lens change time and make the whole process more comfortable?

Scenario: Two different filters / lenses are each to be mounted on the mobile phone using a clip. This is very time consuming and elaborate. To ease the transition from one lens to another, they had to be mounted on a movable holder, with the possibility to be mounted on the mobile phone.

Solution: A custom made movable lens holder, mounted on a hard shell mobile phone case. The following points are describing a step-by-step guide to construct a lens holder for a mobile phone case:

- First, get a hard shell mobile phone case to work with. The case should be made of a robust material, e.g., polycarbonate. The easiest way to obtain a good mobile phone case is either by buying it or by printing one using a 3D printer. Note, that the camera lens of the mobile phone should not stick out of the case, when it is mounted on the phone, as it will be tough or impossible to rotate the custom made lens changer afterwards.
- Measure the phone case and the lens width, length, and depth. Measurements should be taken as precisely as possible.
- Sketch the available items (i.e., lenses and phone case), with the measurements from the previous step.
- The sketch is then used to figure out, how to arrange the lenses in a way, that allows them to cover the camera lens of the phone when the lens changer is being rotated.
- With the lenses arranged, pick a focus point between them. This is the pivot point of the lens changer. In our case, its the small circle in between the two bigger ones, as illustrated in Figure 6.
- Craft a paper prototype of the lens holder. Sketch the lens changer with the exact measurements and cut it out. This prototype can be used to simulate the finished product. Try it out, and see if it fits your expectations, as depicted in Figure 5.
- Digitize the sketch and construct a 3D model. Note that it may be beneficial to add some room to move, especially if using a 3D printer that is not 100% accurate. An example of the digitized model is pictured in Figures 6 and 7 (left).
- Print the 3D model with a material that allows editing with tools (i.e., a file or a multifunction rotary tool) later on. In this case, PVC was used.
- Deburr the edges whilst occasionally trying to fit in the lenses. When everything fits accordingly, proceed with the next step. If anything is odd or needs refinement, redo the 3D modeling and print the item again.
- Drill the pivot point holes into the 3D printed item, as well as in the phone case, to combine them later on.
- Temporarily mount the printed lens holder to the phone with a screw, as shown in Figure 7 (right).

- Double check if everything is according to your needs.
- Finally, install the lenses into the lens holder and mount it to the phone case. See Figure 8 for the final result.

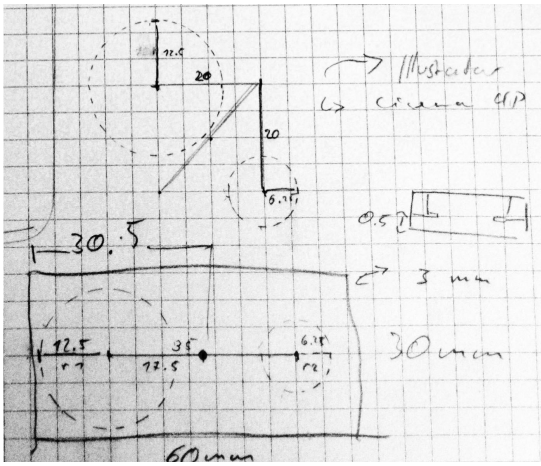

Figure 5. Sketch of the lens holder with exact measurements and radius.

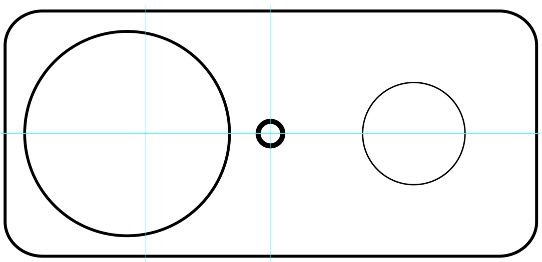

Figure 6. Digitized 2D model of the sketched lens holder.

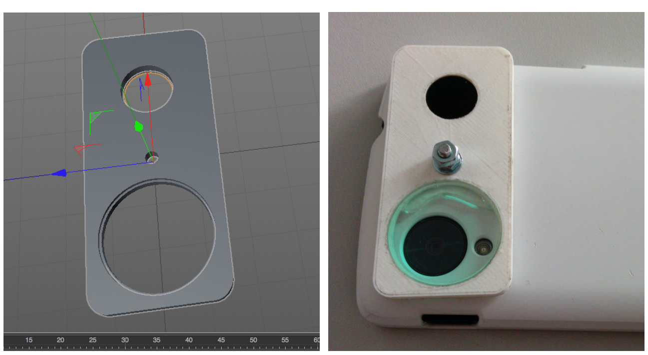

Figure 7. 3D model of the lens holder (left), already printed lens holder with installed lenses/filters (right).

Figure 8. Final lens holder mounted on the phone case.

Examples: Figure 9 holds a QR Code that is linked to a video showing the lens holder in action, whereas Figure 10 is picturing the effect of the different lenses on image acquisition.

Figure 9. YouTube Video - Nexus 5 Lens Holder Case [13].

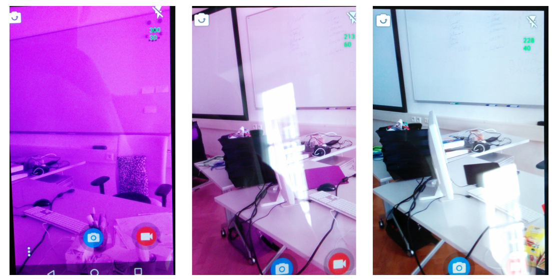

Figure 10. NIR, NIR and visible light, visible light only by using IR-blocking lens (from left to right).

Keywords: NIR, lens holder, phone case, PVC, polycarbonate, 3D modeling, 3D printing

C. Finding and Adjusting the Right Usability Questionnaire

Intent: This pattern tries to guide you how to find the right usability questionnaire for your needs and how to adjust it to your certain needs.

Problem: There are a couple of usability and user experience questionnaires available. Which one should be picked and how is it possible to adjust them to your needs?

Scenario: Due to our study setup, we want a short questionnaire that can be filled out quickly on paper. Thus, it needs to have fewer items, while maintaining statistical reliability (reliability values of 0.70 or more).

Solution:

- **Define**
  The first step, before even choosing a questionnaire, is to define what you want to evaluate. Try to think, which aspects a questionnaire needs to fulfill in order to benefit your research. These aspects should come directly from the research questions which are investigated in the study. For example, if there is a research question regarding *intention to buy after using a system*, then a questionnaire on *intention to buy* or one with *intention* to buy as a subscale is needed. Define your research questions first, then look for the appropriate questionnaires. Include only those aspects or constructs which pertain to your research questions.
- **Consider**
  It takes longer to fill in a questionnaire with complex items, especially if there are a lot of items. It is

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usually difficult to hold a participant's attention for more than 15 minutes in most questionnaire situations (most important for online questionnaires). Thus, it is recommended to keep the complexity and number of items such that a comfortable amount of 10-15 minutes total for filling in the questionnaire is reached. Use open questions only when they can not be replaced by any other item, as they require more thought by the participant and take longer to fill in as a result.

- **Choose**
  After it is clear what to evaluate and how big the scope should be, before creating a questionnaire, try to search for common and reliable questionnaires fitting your needs.
  Here is a small example of reliable questionnaires used to evaluate, e.g., usability and technology acceptance:
  - Questionnaire for User Interface Satisfaction [14]
  - Perceived Usefulness and Ease of Use [15]
  - Nielsen's Attributes of Usability [17]
  - Computer System Usability Questionnaire [18]
  - Practical Heuristics for Usability Evaluation [19]
  - Pardue Usability Testing Questionnaire [20]
  - System Usability Scale (SUS) [21]
  - Technology Acceptance Model [16]

  If none of the common questionnaires fit your needs perfectly, either pick one that satisfies most of them or create your own. If you need to create your own questionnaire skip the next step and proceed to "Create".
- **Customize**
  After choosing a common questionnaire that fits your need, it may be necessary to customize it slightly. Customizing existing questionnaires, however, should be done with caution. If such a customization changes the meaning of a validated questionnaire's items, then the questionnaire requires revalidation. Customization most often happens to make a questionnaire easier to understand by the intended target audience or when they are translated to other languages. Here is an example extracted from the SUS questionnaire: "I found the system unnecessarily complex". Sometimes, e.g., when working with children, they might not know the word "complex" however they usually know the term "hard to understand". Thus, changing the question to "I found the system unnecessarily hard to understand" would be legitimate. However, changing the question or the meaning completely is not and would reduce the tests reliability. The same is true for translations, which should ideally be done or at least double-checked by a native speaker of the target language. Sometimes, which happens especially with larger multi-purpose questionnaires, such as the Unified Theory of Acceptance and Use of Technology (UTAUT) [23] or others, individual items might not make much sense for the study at hand. For example, the aforementioned *intention to buy* from an acceptance questionnaire would not make sense when applied to the evaluation of third party web interface, which can not be bought and is not intended to. Items, or even whole constructs, can and should be omitted in such cases. This also means, however, that not all calculations between constructs can be done like in the full questionnaire. Any omissions made should be kept to the necessary minimum and need to be explicitly stated when disseminating the results, in order to ensure comparability with other studies using the same questionnaire or subscale.

In general, the optimal questionnaire has to provide enough statements or items covering the most common shades of opinions about the to be evaluated subject.

Examples: An example of the translated SUS questionnaire (translated by David Wilfinger et al. [22]) that was used in the study setup, is presented in Figure 11.

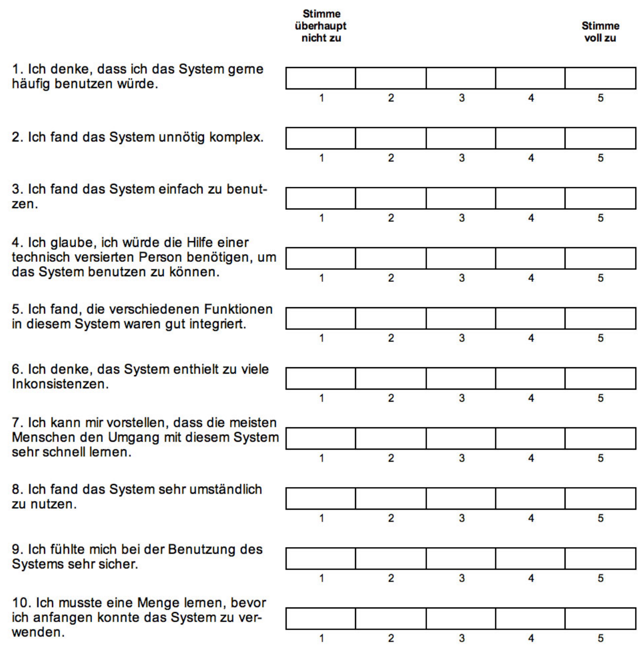

Figure 11. SUS questionnaire (German)

Keywords: questionnaire design, SUS, TAM, test theory, usability

IV. Discussion

Using the cUX pattern approach to create easy-to-use solutions, allowed us to adjust and improve the overall study concept and setup in several ways. Apart from that, we also acquired a deeper insight into the pattern creation process overall. This gave us a chance to notice certain weak points in the creation process, which, when improved, would help to generate better patterns. As mentioned at the end of Section 2, each iteration and the following rework phase, refines the pattern. The pattern is increasing in quality, with every feedback received during the iteration process. Bottom line, the more iterations processes a pattern runs through, the better it gets. In our case, we had a constant collaboration during the creation process of the patterns, which enabled us to get on demand feedback, if necessary. Due to active collaboration, we had the possibility of continuous iterations, allowing us to interplay between problem statements and solutions.

Usually, problem statements are defined in the beginning and changes can only be made during workshops. Solutions, however, are provided during the fist iteration, at the very earliest. Therefore, modifications can be made only after receiving feedback. Until then, the work on the pattern is on hold. The interplay showed us a huge advantage, due to the possibility to refine the problem statement, while at the same time, adjusting the solution. This induced the improvement of both the problem statement and the related solution leading to a higher quality pattern. The problem, however, was the recurring chance to rephrase the problem statement at any time. Thus, it was tempting to rephrase the problem statement to fit a certain solution, even when it was only covering a part of the statement. This behavior is not desired at all. Pattern are supposed to provide proven solutions. In the beginning, after describing the problem statements, we did not know if we could cover that criteria with our suggested solutions. However, we evaluated our patterns regarding that point, by trial and error. Each and every solution we provide in our patterns was tested before it was adopted into the patterns. This was, as well, only possible due to the interplay and instant feedback and, therefore, can not be applied in general. However, we found that this way of verification improved the provided solutions to a high degree.

The next point we want to discuss, is the use of a *Topics* section proposed by the cUX pattern approach. Topics, in this case, are predefined keywords, used to show scope of the problem and additionally, address one or more user experience factors. We willingly omitted that section, as we saw no need for them in our created patterns. Topics may be beneficial to organize a collection of patterns, providing a variety of solutions for a large main field. Each pattern can be assigned to at least one of the topics. However, in our case, we only had three problem statements that we wanted to address. Thus, creating a system in which we want to organize our patterns seemed unnecessary. Therefore, it was sufficient enough to provide keywords only at the end of the patterns. The keywords provide research topics and fields that may be related to the pattern and may be used to get more insight into certain areas covered or not sufficiently covered in the patterns.

V. CONCLUSION

This paper presents how patterns created by utilizing a slightly modified cUX patterns approach can be used to optimize a study setup for biometric image analysis. The pattern solutions were successfully used to optimize the study setup in question and document these for future applications. However, future work will have to focus on reapplying these patterns and refine them further, in order to provide more thorough solutions and to provide solutions, which have worked in more instances (i.e., as well-proven solutions, as should be the case for genuine patterns). The three patterns can be used to inform future study setups with solutions regarding (a) choice of the right lighting conditions, (b) construction of a custom lens holder, and (c) choice (and adaptation) of the right questionnaire for the study's purpose and research questions.

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