Using heuristic evaluation to foster Visualization analysis and design skills

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Abstract – This paper describes an approach used by the authors to develop visualization analysis and design skills in Information Visualization students, at MSc level. This approach uses a well-known analytical usability evaluation method, heuristic evaluation, with different sets of heuristics to analyze existing visualization applications. An example is presented to illustrate how to apply those heuristics and the type of discussion that may arise. The proposed approach, used for three consecutive years, has been very successful to motivate stimulating critical analysis and discussion sessions, raising students' awareness concerning the benefit of using systematic analysis methods, as well as strategies and guidelines that should be used to design Visualization applications.

Introduction

The words by Tamara Munzner [1] "analyzing existing systems is a good stepping stone to designing new ones" capture the main purpose of the work we have been doing in our Information Visualization course in the last three years, and provided motivation for this paper.

Design of Visualization applications, as any interactive application, should follow a User-Centered approach, an iterative process entailing particular attention to the needs and characteristics of the target users at each stage. It is characterized by several formative evaluation cycles allowing the progressive refinement of a solution. Critiques by other designers, implementers, and domain experts have been found important in this refinement [2]. However, Visualization design is particularly challenging; there are multiple possible ways of creating visual representations of data; even more if they are to be interactive, as it is typically the case at present. Becoming acquainted with design approaches, and enlarging the set of visualization methods known to the designer is a suitable strategy to increase the probability of finding a good solution, promoting the generation of differ-

ent alternative solutions and the refinement of an adequate one. Accordingly, broadening the "design space", as well as practicing analysis methods that may be used both as critical thinking, and to refine solutions is most important in the training of Visualization designers/developers. There are different ways to pursue this training, by exposing them to different Visualization methods; on one hand, systematically traversing the methods following some taxonomy; and on the other hand, through the analysis of a variety of existing systems, a "good stepping stone" as put by Tamara Munzner. We argue these are complementary strategies and both should be used in a Visualization course. Yet, the analysis of existing systems may also be done in various ways, ranging from using an *ad-hoc*, non-systematic approach, to more effective lines of action, adopting structured methods. Visualization criticism defined by Kosara [3] as "an organized and well-defined channel to discuss work in visualization" has been used in Visualization courses and may be used for this purpose. We have been following an approach frequent in Human-Computer Interaction courses, which corresponds to asking students to analyze existing interactive systems using heuristic evaluation, as preliminary training to design and implementation. Heuristic evaluation is a widespread analytical evaluation method, sometimes referred to as a discount inspection method. It is well-known for its capacity to help finding potential usability problems, even when used by less experienced analysts. Yet, notwithstanding being widely practiced in other circumstances, heuristic evaluation may not be trivial to apply to visualization applications. Even though a number of visualization-oriented heuristic sets do exist, assess which are better in a specific instance is a difficult task, and still an open research question [4]. In this context, we have been using heuristic evaluation not to its usual aim of formative evaluation in the process of design refinement of a specific solution by providing a list of potential usability problems, but since it provides an analysis structure.

We show how we have been using a multi-pass analysis of visualization applications based on performing heuristic evaluations with different sets of heuristics meant firstly to improve critical thinking, while fostering the visualization designing skills of Information Visualization students.

This approach has been applied for three consecutive years. The presentation and discussion of the analysis performed by each group of students has motivated interesting sessions as most students seem very committed to show the positive aspects of the applications, the problems they have found, as well as to suggest improvements to the visualization applications they analyzed. Moreover, students are also asked to reason about the understandability, advantages and limitations of the different sets of heuristics and the applicability of the method to visualization applica-

tions. To illustrate how to apply the heuristics and the type of considerations that may arise, we work through a simple example.

Heuristic evaluation as an analysis and design-assisting tool

Heuristic evaluation is a widely used evaluation method meant to find potential usability problems [5]. It is performed by inspecting the user interface taking into consideration a set of heuristics that should be complied with. It produces a list of problems corresponding to non-compliant aspects rated according to their severity. Usability problems are categorized according to their estimated impact on user performance or acceptance; this implies an effort to understand the users, the tasks and the context of use, all fundamental aspects to consider in design. The resulting list is supposed to be used as a prioritized formative evaluation to improve the user interface.

Tory and Moller[6] considered heuristic evaluation as a useful expert review method to evaluate visualization systems, and advised the usage of visualization-specific heuristics. Since then, it has been used by several authors to evaluate Visualization applications and actually a number of visualization-oriented heuristic sets do exist. Yet, these heuristics may not be easy to understand and apply by non-expert evaluators. Although the heuristics understandability may not be trivial, using them to analyze a visualization application entails an effort that fosters a better comprehension of the required characteristics of such applications, which in turn contributes to develop design skills. In this vein, as already mentioned, we have been using heuristic evaluation to first improve critical thinking and analysis, while fostering visualization designing skills as a further goal with small groups of Information Visualization students. For this purpose, the well-known Nielsen's Ten Usability heuristics[3], and the Visualization-oriented sets proposed by Zuk and Carpendale [7] and Forsell and Johanson [8] were selected.

Nielsen´s heuristics are general and applicable to any kind of interactive system (available at http://www.nngroup.com/articles/ten-usability-heuristics/); yet, though they may have value in finding problems also in Information Visualization, as usability issues are often associated to visualization problems, using Visualization-specific heuristic sets is important. After analyzing several sets of Visualization specific heuristics, the two sets proposed by Zuk and Carpendale[7], and by Forsell and Johanson[8] seemed to have potential practical value and be manageable by inexperienced evaluators (as it is the case of our Information Visualization students and likely of many Visualization applications developers).

The former set is based on the works of Bertin, Tufte, and Ware, and was assembled to address visual and cognitive aspects[7]. The later set was empirically developed using heuristics of previously published sets to analyze a number of problems derived from earlier evaluations, and the 10 heuristics providing highest explanatory coverage were selected.

The method

The procedure we have been using involves several practical sessions throughout the course semester, starting after making an introduction to Visualization and addressing the main issues in Information Visualization. We ask the students to select a simple visualization application, as the applications featured in demo galleries of visual analytics tools, or any other example they might find interesting, and analyze it using what we have called a "naïve critique". This implies exploring the application, based on educated guesses concerning the target users, supported tasks, and usage context. We ask the students to point out possible problems, as well as positive aspects, using only their good judgement and previous experience acquired while using applications, web sites, etc. The work is partially done during a lab class so that some discussion and clarification is possible, then students finish the analysis at home, and prepare a presentation with their findings. In a subsequent session, students present the example they have analyzed and show their main findings.

In a second phase, later in the semester, heuristic evaluation is introduced, as well as several sets of usability heuristics: more general (Nielsen´s), and more specific to evaluate Visualization applications (Zuk and Carpendale´s, Forsell and Johanson´s). The students are then asked to evaluate the same example they have analyzed before using the Nielsen's and one of two of the Visualization specific sets of heuristics (at their discretion), present their findings, and discuss them with the class.

We noticed that some heuristics were not easy to understand hindering their applicability by our students, who do not have much experience. This provided the opportunity to also study the comprehensibility and applicability of visualization-specific heuristics.

Illustrative case

In order to illustrate the usage of heuristic evaluation with the selected heuristic sets, as well as the type of discussion it may trigger, we show some examples based on a visualization web-

application developed at our University (http://www.portugal-migration.info). This application is aimed at visualizing data from the nationwide annual application process of students to Portuguese Higher Education institutions, and currently allows the visual exploration of data concerning approximately 116,000 submissions, corresponding to the years from 2012 until 2014. The data set, provided by the Portuguese Directorate General for Higher Education (Direcção Geral do Ensino Superior), includes candidates' demographic data (as age, gender, district of residence), and application data (as final high school grades, establishment where the candidate was accepted, and its geographic location). The web-application was developed to be understandable by any person interested in analyzing the data, and features three coordinated visualizations: an adjacency matrix-based visualization, a map, and a chorded visualization of the student flow between any two Portuguese districts. These visualizations are meant to support different tasks and provide filtering capabilities, as well as details on demand through tooltips.

In the remaining of this section we will go through the visualization application example and present positive and negative aspects found to illustrate the usage of some heuristics of the selected sets. The analysis performed was used by the development team to produce a new version of the web-application.

For the first coordinate visualization (adjacency matrix), among the positive aspects noticed, were Zuk & Carpendale's heuristics number 3 "*Color perception varies with size of colored item*" and number 12 "*Provide multiple levels of detail*". In this visualization the color perception of the main elements does not vary with the size of the item as all matrix colored cells having the same size prevents this. Moreover, three levels of detail are provided: the first when we look at the matrix colored cells, the second pops up on mouse over one cell showing a summary of the migration between the two districts, and the third level when we click on a cell and the list of institutions where the students applied appears next to the matrix. These aspects are shown in Figure 1.

On the negative side, the adjacency matrix visualization does not comply with Nilesen's heuristic number 4 "*Consistency*". Specifically, in the filtering options it is possible to select both genders and all institutions types; however, such option is not available for filtering the year. Also, the values of the color scale vary according to the chosen filter, thus the same color may represent a different number of students when we change the filters applied to the visualization. Moreover, gender selection is made through symbols while all other selections are presented as lists that expand when we click on them.
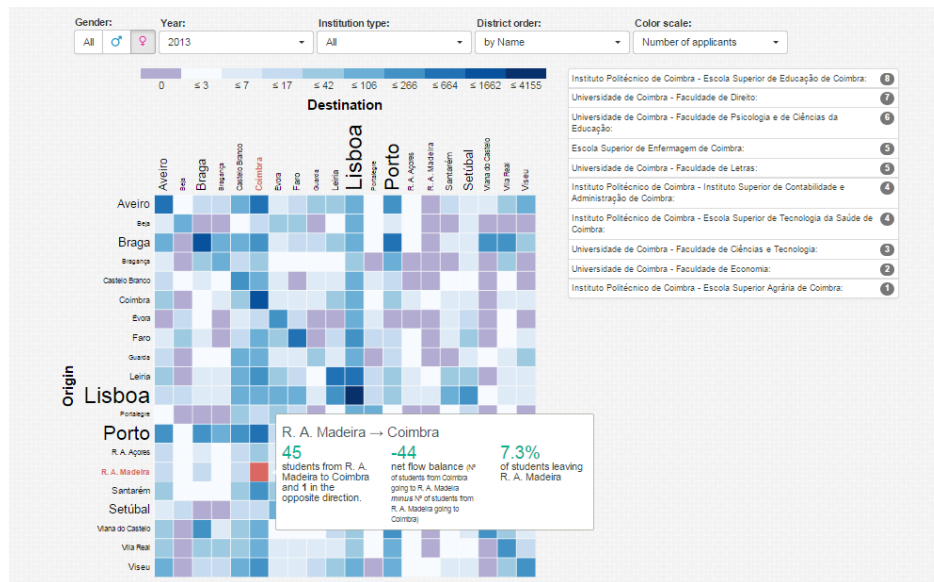
Figure 1 – Adjacency matrix visualization. This visualization is compliant with Zuk and Carpendale' heuristics number 3 and 12, "*Color perception varies with size of colored item*" and "*Provide multiple levels of detail*", respectively. Nielsen´s heuristic number 4 "Consistency" is not complied with, as there are different types of filter selection and the color scale varies depending on the filters applied.

Another visualization provided by the web application is a chord diagram, depicted in Figure 2. In this case, Zuk and Carpendale's heuristic number 11 "Consider Gestalt Laws" is satisfied. In particular, the association of the flows with the respective city is done by placing the name of the city near the visual representation of the flow and using color, orientation and size.

Yet, two problems classified as severe were identified in this visualization. The first was that some chords are so thin that they were extremely hard to see and select, which does not comply with Zuk and Carpendale's heuristic number 1 "Ensure visual variable has sufficient length". The second problem corresponds to the existence of only one chord between each pair of cities attempting to represent a bidirectional flow. As a consequence, only the information relative to one direction of the flow is shown. As an example, the chord connecting Porto and Aveiro will only show information regarding the students leaving Porto to go to Aveiro, thus it is impossible to find out the percentage of students that leave Aveiro to go to Porto. This does not comply neither with Forsell and Johansson's heuristic number 1 "Information Coding", nor with Nielsen's heuristic number 2 "Match between system and the real world", as the visualization does not encode all the relevant data.
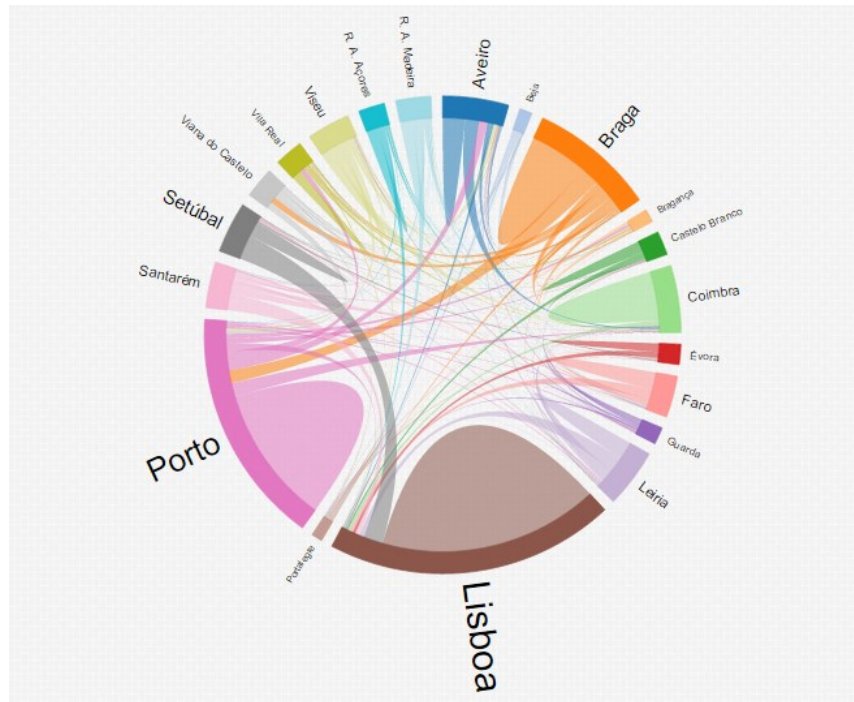
Figure 2 – Chord diagram visualization. Zuk and Carpendale's heuristic number 11 "Consider Gestalt Laws" is complied with, whereas heuristic number 1 "Ensure visual variable has sufficient length" is not satisfied. Also, Nielsen´s heuristic number 2 "Match between system and the real world", and Forsell and Johansson's heuristic number 1 "Information Coding" are not satisfied.

Two positive and one negative aspects were discovered while analyzing the third coordinate visualization. The map was found to be compliant with Zuk and Carpendale's heuristics number 5 "Consider people with color blindness", and number 7 "Quantitative assessment requires position or size variation". Specifically, the different colors of the map are still distinguishable by people with deuteranopia and tritanopia, as shown in Figure 3. Also, the radii of the circles are proportional to the number of candidates of each district. Despite encoding a quantitative value through area, which does not provide the most accurate assessment (Spence, 2007) the map visualization still conforms with Zuk and Carpendale's heuristic number 7.

Although there is a link named "Help", unlike the previous visualizations, there is no help when we click on it. In fact, some orientation is given on the top of the page; however it should be complemented by the help. This can raise false expectations to the users and does not comply with Nielsen's heuristic number 10 "Help and documentation".
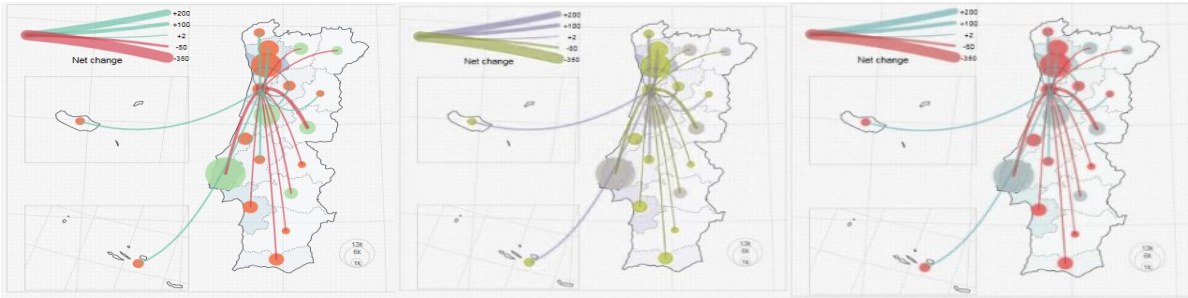
Figure 3 – Map Visualization. Zuk's heuristic number 5 "Consider people with color blindness" is complied with. From left to right: original image, and images as seen by people with deuteranopia (green blindness) and tritanopia (blue blindness). (simulation obtained uploading the original image to Coblis – Color Blindness web simulator available at http://www.color-blindness.com/coblis-color-blindness-simulator/)

Discussion and conclusion

After using the described approach for three years, involving more than forty students, we believe that besides learning how to apply a potentially useful method, which may be used throughout the development cycle of Visualization applications, students become more aware of the principles and guidelines that should guide such a process (as heuristics "crystalize" them), fine-tune their critical thinking, and consequently develop their design skills concerning this type of application. This is in line with the statement "They (the heuristics) often can act as instructional guides for the teaching of novices and can evolve into design patterns for construction such as those that exist for software engineering." [7]

As a side effect, the entire process helps realize that the use of systematic evaluation methods pays-off against *ad-hoc* approaches, and, more specific to Visualization, that there are methods that can be used to evaluate Visualization applications, even though they still offer room for improvement and research opportunities.

Results concerning understandability and applicability of the heuristics suggest that on one hand, heuristic evaluation (irrespective the heuristic set used) does help students to consider issues that they would have otherwise missed as it fosters a more systematic inspection of the user interface relevant aspects. On the other hand, students generally found Nielsen´s heuristics to be less finely tuned to Information Visualization examples, as expected, yet still useful. Concerning the heuristics specifically developed for Information Visualization evaluation, students felt some difficulties in interpreting and applying some of them (e.g. number 1, 2, 6 and 10 by Zuk and Carpendale). In

particular, we consider that part of the difficulties was due to some inconsistencies of the syntax of Zuk and Carpendale's heuristics, and rephrasing them might alleviate this problem.

In a nutshell, we have seen that performing heuristic evaluation using different sets of heuristics can be a very formative learning experience for Information Visualization students as it affords valuable insight for the design of visualization applications. Moreover, using this method produces interesting and useful results, even when performed by less experienced evaluators (as our students).

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