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Short Papers

Card Sorting Techniques for Domain Characterization in Problem-driven Visualization Research

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Abstract

In a problem-driven visualization research, the domain characterization is fundamental to the design process of a visualization solution to enable insight and discovery. Complex, fuzzy and exploratory analysis tasks in a specialized domain present considerable challenges to the designer, as well as the expert, to establish a shared understanding of the domain problem and analysis needs. In this paper, we provide a three-stage practical guideline for conducting card sorting exercise to address challenges in the domain characterization and a case study from the biological domain.

Categories and Subject Descriptors (according to ACM CCS): D.2.1 [Software]: Requirements/Specifications—Elicitation methods

1. Introduction

Establishing a shared understanding of the application domain and tasks presents considerable challenges for both a designer and a domain expert in problem-driven visualization research. The designer may struggle to build sufficient background knowledge in the domain to extract the expert's needs and to transform into more abstract low-level tasks. On the other hand, the expert may have difficulty articulating or introspecting about their needs because the domain tasks are complex and fuzzy due to the inherently exploratory nature of the analysis and additional meta data available [Mun14]. In addition, there may be other constraints, such as limited availability of the expert's time. We present a participatory design activity, namely card sorting techniques, to address challenges in the early stage of the design process.

Card sorting is a user centered design technique commonly used to elicit tacit grouping of items by asking respondents to sort a set of cards into meaningful groups [LD11,NS95,ZA02,WW08,Mai09]. For example, each card represents a component of a website, and these can be sorted by stakeholders to elicit categorizations as design implications and requirements for the website [NS95,URK01]. Each card or item can be an object, a picture, or a name of attribute [RM05,Mai09], which are grouped in either *open* or *closed* sorting. In an *open* sort, the respondent names each resulting group themselves, whereas in a *closed* sort, a set of categories is predetermined and provided to the respondent. The choice of either *open* or *closed* sorting depends on the goal of the activity, whether to elicit tacit categorization of items, or to evaluate the assignment of items to categories. Thus, card sorting activity can be either *generative* or *evaluative* [MMAM14].

As the field of visualization matures with theories and models of the design process [LD11,MSQM13,Mun09], we see a unique opportunity to narrow the focus to a specific stage in the process and provide practical guidance. We carefully analyze the existing guidelines and use cases of card sorting in literature from software engineering and human computer interaction [RM05, GD05, MR05, DAA05, FH05, Mai09] and reflect on our experience to provide a practical and flexible guideline to address challenges in the domain characterization. We describe one case study where we collaborated with computational biologists to develop an interactive visualization system to study structural variation of the human genome.

In this paper, we focus on card sorting techniques, rather than the design study as a whole. Although techniques themselves are not novel, we highlight the flexibility and applicability of card sorting to a wide range of domains, and its usage as both generative and evaluative methods in the early

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stage of the visualization design process. By breaking down the card sorting exercise into 3 stages (*preparation, execution* and *analysis*), we describe options at each stage and provide practical advice.

In summary, the main contributions of this paper are:

- a three-stage practical guideline for conducting card sorting activities for the domain characterization
- a discussion of exemplary case study from the biological domain

As other low-tech methods, such as "paper prototyping" or "wizard of Oz" [Mun14], have been successfully adopted from the fields of software engineering and human computer interaction by the visualization community, we anticipate that a wide range of readers from the visualization community would find the card sorting techniques useful and immediately applicable to address domain characterization challenges in their problem-driven projects, especially when the tasks are ill-defined and inherently exploratory. A card sorting activity helps to establish a shared understanding of the domain tasks and it takes us a step closer to reaching the "sweet spot" of gaining just enough domain knowledge and the tacit knowledge from the user to draw design implications and requirements [SMM12].

2. Related Work

[MMAM14] presents a design activity framework which consists of four overlapping key activities: "understand, ideate, make and deploy". This framework relates to the nested model [Mun09] and provides actionable guidance throughout the visualization design process. Their paper also provides an extensive list of methods drawn from both the visualization community and the design literature. Card sorting is one of hundred exemplary methods, and we elaborate on the application of this participatory design technique in the visualization design process.

[LD11] reports a successful use case of card sorting to categorize geovisualization domain tasks. Their exercise helped designers to gain an insight into varying spatial emphases in experts' approaches to tasks. Additionally, the comparison of sorting results between designers and experts allowed to check for the mutual understanding of the domain problem.

The special issue in Expert Systems (Volume 22, Issue 3, 2005) is a collection of papers describing the use of card sorting techniques and use cases in computer science. [RM05] gives a practical tutorial on sorting techniques. The collection also includes a wide range of analysis methods and case studies: a semantic analysis to investigate perception of women's office clothes [GD05], a method to derive co-occurrence matrices from card sorts to study perceived similarity of visual products [MR05], and statistical analysis techniques, such as the edit distance to measure similarity between two different sorts [DAA05] and the orthogonality (aggregate difference) between two sorting results [FH05].

3. Card Sorting

The core activity of card sorting is to engage the participant to sort a set of items into categories [RM05, Mai09]. The original concept stems from the Personal Construct Theory, which states that there is enough commonality to let us understand each other, but there are also enough differences to make us individual [Kel55,URK01]. Also, [FT05] points out that domain experts organize information based on abstraction of semantic characteristics, whereas novices organize information based on syntactic or non-domain specific characteristics.

In this paper, we target problem-driven visualization research, where "the goal is to work with real users to solve their real-world problem" [SMM12]. Typically, this type of project involves a few domain experts from a specialized field and the number of accessible real users is often limited, at least at the beginning. Thus, we take a qualitative and a small scale approach, where each exercise is conducted on a one-to-one basis.

The same open card sort exercise can be repeated to gather a number of criteria and categories from a single respondent in one session. Also, you can recruit respondents with different roles, for example a "front-line analyst", a "gatekeeper", or a "tool builder" [SMM12] to identify commonality or discrepancy in understanding of the domain problem. Depending on the design of the exercise, card sorting addresses different aspects of the domain problem.

In the following sections, we divide the process of card sorting activity into three stages (*preparation*, *execution*, and *analysis*) to discuss options and provide advice at each stage.

3.1. Preparation

The first task is to collect as much information as possible about the problem domain via conventional methods, such as contextual inquiry [Bey97], observation and literature review. Based on your initial understanding of the domain tasks, you distill a series of questions that the user may ask in analysis and put each question onto a card. We call these entities, *inquiry-based cards*. In case of a complex question, consider decomposing into discrete questions. For example, a question may be, "When the value of A is higher than that of B, what is the value of C?" This question can be split into two separate questions: "Is the value of A higher than that of B?" and "What is the value of C?" Each question should be typed, printed, and stuck to an index card to improve legibility [RM05].

Besides analysis questions, the content of cards can be anything pertinent to the domain, including things that do or do not exist yet. For example, a set of cards may consist of data attributes and some which may have not been derived or acquired. As long as it is relevant and plausible, these items can be included and they may even encourage creative thinking.

Another type of cards, particularly useful for the visualization research, is a set of *picture cards*. The picture cards may consist of figures from the relevant literature, images from existing tools, and new visual encoding ideas. By introducing new visual encoding ideas, you can evaluate if the encoding is intuitive to understand or if it is appropriate in the context. Also, consider making each representation abstract enough that the user would understand the encoding, but would not be distracted by the details of the image [RM05].

The last advice is to look for design studies that characterize the same or a similar problem domain. Such design study paper may include the domain characterization as one of its main contributions.

3.2. Execution

Before conducting the exercise with a domain expert, the facilitator should carry out a session by themselves for two reasons. First, it allows the facilitator to familiarize with items and to check if the collection of items is comprehensive to their knowledge. Second, the exercise will result in criteria and categories, which you can anticipate from the expert. The resulting categories can be the input for a closed sorting to identify commonality or difference.

Start a session by explaining about card sorting to the respondent. [RM05] provides sample instructions. Then, ask if the respondent understands each item and whether the set reflects domain tasks well. If some cards are deemed irrelevant to the task, those cards may be removed to be discussed afterwards.

We recommend a semi-structured format, where the respondent is guided, but allowed to deviate from the plan if necessary. For example, if the respondent remembers a relevant item in the middle of the exercise, allow them to add a new card to the set.

Once the respondent has grouped card into groups, ask to name each group and the overall criterion used for sorting. Then, discuss each group and criterion for clarification. Record the arrangement of cards by taking a picture with a smart-phone or a digital camera. We found it useful to index each item by numbering on the back, so that each card can be flipped in position and the number label is still legible in the photo. The same exercise can be repeated to elicit more groups and criteria.

3.3. Analysis

Given the scope of domain characterization and small-scale card sorting, we suggest semantic methods where interpretation of respondents' behavior and outputs relies on the facilitator's judgment [FT05]. A careful observation during the sorting exercise and analysis of resulting criteria and categories are critical to this approach. For instance, a respondent may struggle to sort an item. This item should be further investigated to understand the underlying source of difficulty. The semantic methods can provide rich insights, but requires the facilitator's time and scrutiny [FT05].

When analyzing criteria, categories and card assignment, it helps to compare commonality and difference between results from different respondents. Generally speaking, a high commonality suggests consistency, validity and usefulness of the categorization, while differences in categorization suggest inconsistency and variability. This process is instrumental to identify any potential discrepancy in understanding of the domain problem.

If there are a number of criteria obtained, each criterion can be further classified as either "subjective" or "objective" [RM05]. For example, "ones I like" is a subjective criterion, while "underlying data type" is an objective criterion. The card assignment is usually more consistent using an objective criterion than a subjective one.

4. Case Study

The case study is a collaborative project with computational biologists to develop an interactive visualization system to analyze structural variations of the human genome. The input data was preprocessed data from the whole genome sequencing of uterine cancer patients. Even after several interviews with the domain experts (the user), we (the designer) struggled to abstract the domain-specific tasks into system requirements.

The domain problem was fuzzy because the analysis tasks were complex, open-ended and inherently exploratory. In addition, a conventional ethnographic observation was not feasible, because the user worked on multiple projects concurrently. Having been unable to characterize the domain problem fully, we decided to adapt card sorting techniques to actively engage the experts in the participatory design exercise of one-hour sessions.

For the sorting exercise, we prepared two sets of cards: inquiry-based and pictures based cards. Based on the information we gathered from previous interviews and studying relevant literature [MSB09, SGF*11], we generated ten inquiry-based cards and eight picture cards, three of which were our new visual encoding ideas. The questions and the collected figures are listed in the Supplementary Material 1.

Using these cards, we first practiced sorting exercise on our own, which resulted the criterion ("genomic size and resolution") with four categories ("genome", "chromosome", "segmentation" and "feature"). These categories were consistent with the domain characterization from a design study of a multi-scale synteny browser [MMP09]. We also prepared to use these categories for closed card sort exercise to validate a shared understanding of the domain.

Although we scheduled with two “front-line analysts”, only one respondent was available to participate in the activity. First, we asked the participant to examine the inquiry-based cards and see if the set represented questions asked during the analysis. At this point, the respondent added two questions to the set. Then, we asked to conduct open card sorting with this inquiry-based card set.

This exercise took about 20 minutes to complete, and the respondent named the categories as “primary analysis”, “in depth analysis”, and “impact / validation” and its criterion as “process”. Through the interview following sorting, it was confirmed that these categories reflected implicit stages in the analysis process. Neither the designer nor the respondent was aware of these stages, as also evident in the respondent’s comment, “*I have never thought of research questions this way, but it is interesting.*”

After recording the result of the open card sorting, we asked the respondent to perform closed card sorting. First, we used the same inquiry-based cards for closed sorting with the four categories based on the “genomic size and resolution”. This took less than 10 minutes to sort, perhaps because the respondent was already familiar with the questions. Besides the two new questions added, the assignment of cards into provided categories was comparable to our sorting result. In the expert’s result, some questions were placed between two categories, indicating that those questions could belong to either category.

Second, we asked the respondent to perform closed sorting with picture cards. The arrangement of inquiry-based cards from the preceding step remained on the table to link between questions and visual encodings. The result of this sorting session is shown in the Figure 1. Each card was flipped in position to show its unique label in order to record the arrangement (Supplementary Material 2).

There were two main outcomes of this card sorting activity. First, the categories of research questions based on the different stages in analysis informed us about the hierarchy and the order in which these questions were addressed in their exploratory analysis. Subsequently, we reflected this order in the interface design of a prototype (Supplementary Material 3). The experts found the prototype useful and intuitive to use, and based on the insights gained, they advanced on to other research question before the prototype was fully developed into a software.

Second, careful analysis of the picture sort outcome indicated a gap in existing visual representations of structural variations. Because there was no picture card assigned to address the functional impact of structural variation at the feature level, this finding subsequently encouraged [SMRA13] to develop a novel gene-centric encoding of structural variation.

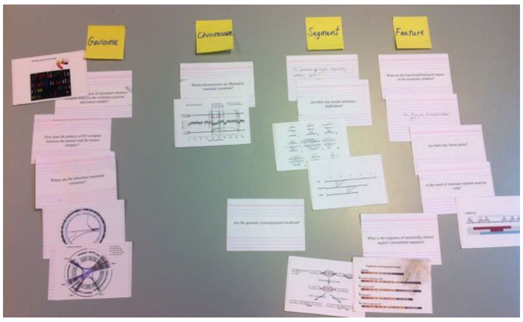

Figure 1: *Result of closed card sorting with inquiry-based and picture cards. Each category is shown on a sticky note.*

5. Discussion

Studying design processes in visualization design [LD11, MSQM13, Mun09] and design study pitfalls [SMM12] and reflecting on our experience, it becomes evident that establishing a solid understanding of the domain tasks and the problem is critical in the early stage of the visualization design process. We advocate the use of card sorting techniques because of their simplicity and adaptability to many specialized domains. The card sorting exercise actively engages the user in the design process, and this type of participatory design exercise has also been shown to help establishing a rapport between the designer and the user [SMM12, GDJ*13].

The advantage of card sorting is not only to elicit tacit categories, but also the distilling process in the card preparation. As complex tasks are decomposed into discrete items, it helps the designer understand the context as well as the relationships of tasks.

We found the use of inquiry-based cards and picture cards useful in our project, but these are not the only choice of entities or ways to run the exercise. In fact, the strength of the technique is that it is very adaptable to different purposes. In this paper, we do not discuss large scale card sorting and different analysis methods [ZA02, WW08, FT05]. Because card sorting techniques are very versatile, we encourage other visualization researchers to share examples and anecdotal evidence of card sorting on the following web forum (`http://goo.gl/IPFsXu`).

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