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Guidance or No Guidance? A Decision Tree Can Help

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Abstract

Guidance methods have the potential of bringing considerable benefits to Visual Analytics (VA), alleviating the burden on the user and allowing a positive analysis outcome. However, the boundary between conventional VA approaches and guidance is not sharply defined. As a consequence, framing existing guidance methods is complicated and the development of new approaches is also compromised. In this paper, we try to bring these concepts in order, defining clearer boundaries between guidance and no-guidance. We summarize our findings in form of a decision tree that allows scientists and designers to easily frame their solutions. Finally, we demonstrate the usefulness of our findings by applying our guideline to a set of published approaches.

CCS Concepts

•***Human-centered computing*** → ***Visual analytics;*** *Visualization theory, concepts and paradigms;* •***Information systems*** → ***Decision support systems;***

1. Introduction

Thomas and Cook [TC05] define Visual Analytics (VA) as a process supporting the information discovery through a combination of automated analysis methods, interactive visual interfaces, human perception, and reasoning. Although VA is effective in its goal, users are not always able to complete an analysis successfully due to complex tasks and tools. In order to strengthen the synergy between humans and machines and foster a good outcome, in the past years scientists and practitioners focused their efforts on creating approaches and tools to actively support the users during the analysis. These approaches are generally referred to by the term *guidance*. The problem is, however, that the meaning of the term is overloaded and used in contexts that do not meet the definition of guidance [CMG*16]. In the last decade, the developments in the field of VA led to the emergence of methods incorporating knowledge bases, common expert practices, advanced interaction means and visualizations, so that the boundary between VA and guidance is blurred. Moreover, other research fields such as Information Visualization (InfoVis) and Human-Computer Interaction (HCI), also frequently integrate concepts of guidance [DFAB04, Mun09]. Therefore, it is not always easy to discern between guidance and no-guidance approaches. While the characterization of guidance [CMG*16] gives an initial idea and definition of this concept, it can be hard to map it to practical approaches. As a consequence of this fuzziness, the development of new guidance techniques might be hampered. Also, the evaluation and the framing of existing approaches becomes more difficult and ambiguous.

Explicit instructions how to bridge between theory and practice [LTM18, KK17, RAW*16] have been a successful strategy in the past to better understand theoretic concepts and make them applicable. In the same way, we present a decision tree containing a set of essential questions that (1) help scientists and practitioners to correctly frame their work with respect to guidance, and (2) better understand the concept of guidance as well as the different guidance degrees, which is essential for concept formation, make them better applicable, and advance the research in this field.

2. Guidance

Previous work defines guidance as a "computer-assisted *process* that aims to actively resolve a *knowledge gap* encountered by users during an *interactive* visual analytics session" [CMG*16, p.2]. Three words, highlighted in the definition, are particularly helpful in delineating the nature of guidance. It is a dynamic process that should accommodate the needs of an analyst during the analysis. The aim is to fill a so-called knowledge gap, meaning a possible lack of operational and/or domain-related knowledge that may hinder users to fulfill the analysis. This knowledge gap may be re-

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lated to different aspects of the analysis (or domains). Users may, in fact, have issues with identifying relevant data subsets, parametrize the visualization, or choose the proper analytical methods. More generically, users may have difficulties identifying the target, or goal, of the analysis, and the way (i.e., the steps necessary) to reach it. Hence, once identified, a guidance system should propose solutions (i.e., suggest alternative actions, parameters, etc.) to overcome these issues, so that the user is able to progress. The definition further stresses that guidance should be applied in interactive contexts, in which a user must take decisions to progress. However, this definition is a theoretic construct which makes it susceptible to misinterpretation. As most VA, InfoVis, and HCI approaches are aimed at supporting users in completing certain tasks, it might be difficult to discern which of these systems classify as guidance. This leads us to the formulation of our first research question:

> ***Q1*** *- How can we clearly separate guidance from no-guidance approaches?*

Further uncertainties come from a deeper inspection of the guidance degrees. Three such degrees have been characterized in previous work [CMG*16]. *Orienting guidance* aims at providing orientation by supporting the users' mental map. *Directing guidance* focuses on providing alternative analysis options to the users. Finally, *prescribing guidance* chooses one possible analysis path—among many—and leads users along this path. However, also in this case, it is not possible to identify a definite and easy to follow strategy to map a given approach to one of these degrees. Besides, the term 'orienting' seems overloaded. In fact, while directing and prescribing point users to *future* analysis steps, orienting comprises also elements of the *present* state of the analysis. Hence, our second research question is:

> ***Q2*** *- How can we improve the comparison and discern the degree of different guidance approaches?*

To answer these questions, we investigated the key differences between guidance and no-guidance approaches. We asked ourselves, which questions need to be asked in order to be able to characterize guidance properly according to the definition. We then structured them in a decision tree diagram to allow a step-by-step characterization and an easy comparison based on the guidance degree.

3. Guidance, or No Guidance? That is the Question!

We applied a bottom-up analysis process to answer the aforementioned questions. Since guidance is a multidisciplinary topic, at first, we collected some works in the field of VA, InfoVis, and HCI [KMS*08, SSS*14, CMS99, DFAB04], including all the guidance approaches referenced by Ceneda et al. [CMG*16]. We then broadened the research including works that complied the definition of guidance, and finally inspected all of them with the aim of identifying the key differences. We choose a set of twenty candidate questions, to formalize the differences between approaches. These questions were structured as a decision tree to guide the characterization of a given technique. We tested the tree by matching its results to well-known approaches. We also tested the individual questions with regard to how much information they yield for the actual classification. Ultimately a set of six questions prevailed.

User-, System- and Mixed-Initiative In order to clearly separate guidance from other approaches, we should ask ourselves a simple question: is it the system or the user who makes decisions, takes actions and promotes the analysis? Although the majority of the existing VA, InfoVis, and HCI approaches are designed to facilitate specific user tasks, they do not readily qualify as guidance approaches. In case, they provide only *user-initiative* (see Figure 1) methods in which only the user advances the analysis process and generates ideas how to reach a target [AS03, Shn10]. They are not considered as guidance approaches. No matter how and how well the system may facilitate the analysis, in the end, it will always be up to the user to derive the necessary information and options to proceed towards his/her target, as they are not actively provided by the system in a reaction to the knowledge gap of the user. On the other extreme of the scale, we see *system-initiative* methods (see Figure 1). These methods comprise automated analysis processes that autonomously direct users to the completion of a task [PF91, FPSS96], taking over actions and making choices automatically [L*95, Mae94, HH98]. This also includes presentation-oriented approaches in which the system provides and presents results to users, without the need of external interventions, excluding initial setup [GLG*16, KM13, GP01]. System-initiative approaches do not comply with the definition of guidance either.

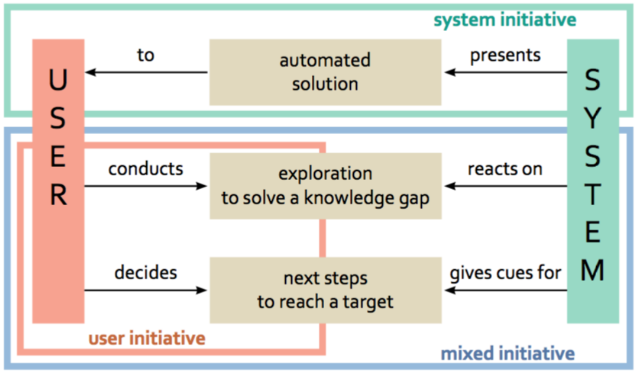

Figure 1: *Guidance is a mixed-initiative process. On the one hand, the user explicitly or implicitly expresses his/her analysis target and a possible knowledge gap that hinders progression, by interacting with the system. On the other hand, the system reacts to the user's actions and gives cues that help to decide which steps to take to reach the target.*

Instead, guidance is a *mixed-initiative* process (see Figure 1), like a dialogue between the human and the machine, in which users provide, implicitly or explicitly, their own needs and issues as input, and the system provides possible answers to alleviate problematic situations. Answers can be given at different levels of sophistication (or guidance degrees). The system may (1) provide suggestions, or change the way the information is arranged and presented to the user (orienting) [MSDK12], (2) suggest ordered and prioritized analysis options (directing) [GST13], or (3) prescribe the next steps/actions users should take (prescribing), in general the most appropriate one [MHS07]. In this context, it is important to note the iterative nature of this mixed-initiative process, which eventually may lead to a satisfactory completion of the analysis.

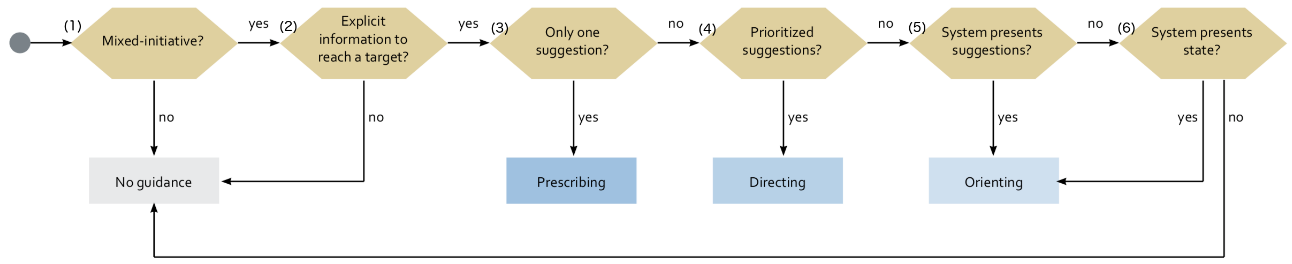

Figure 2: *A decision tree illustrates the key differences between guidance and plain visual approaches. By answering the questions it is possible to determine the exact guidance degree. The nodes are numbered, see Section 4 for a detailed description.*

4. Decision Tree

To facilitate the decision whether an approach qualifies as guidance (Q1), and if so, which degree of guidance (Q2), we constructed a binary decision tree, composed of simple but essential questions. The individual questions can be answered more easily than simply trying to decide if a specific approach matches the definition of guidance, and in sequence they provide a step-wise approach toward decision finding. The tree illustrated in Figure 2 is composed of six hexagonal nodes containing binary yes/no questions. There are four rectangular nodes representing final states, three for the different guidance degrees and one representing the cases that are not guidance. Due to restricted space, the questions can only be sketched in the tree graph, but will be explained in detail in the following.

Node 1: Mixed-initiative? In an initial step, we check the nature of the system at hand. The decision tree discriminates interactive approaches with respect to who is in charge of the analysis. Hence, the decision tree first asks whether the analysis work-flow follows a mixed-initiative approach. The exact question that should be answered here is:

> *Does the system provide information or suggestions of next steps in reaction to the user's interactions?*

If this is not the case, then the system cannot be classified as a guidance system. A guidance system is a system that provides information that is actively produced in a response to the behavior of the user, with the aim of helping the user to reach his/her analysis target.

Node 2: Explicit information to reach a target? If the previous question was answered with yes, another question that is decisive for a guidance system is:

> *Does the system provide the user with explicit information to help the user to reach his/her target?*

The information provided by the guidance mechanism should be *explicit* and aimed at helping the user to reach the target of the analysis. This might also comprise to define a target in the first place. Simple information such as zoom level or history of actions is not explicitly provided to help the user reach his/her analysis target, and thus, it is not considered as guidance.

There are three degrees of guidance, which are characterized by the the way the system reacts to the user's needs. If the question above is answered with yes, we proceed to identify exactly which degree of guidance is provided.

Node 3: Only one suggestion? Once it has been determined that we are dealing with a mixed-initiative process that provides explicit information to reach the analysis target, and thus, probably with guidance, we need to determine which degree of guidance is provided. To this end, the first question to answer in this respect is:

> *Does the system decide what should be the next step or sequence of steps, i.e., does it provide just one suggestion to the user how to proceed with the analysis?*

If this question is answered with yes, we are dealing with a system that provides prescribing guidance. It directly prescribes a set of actions to proceed. In other words, the system may choose a precise analysis path or a defined solution and subsequently prescribe the necessary set of actions the user should take to continue the analysis. Since the system decides autonomously about the analysis strategy and the way the actions are selected, the resulting freedom of the users is limited. However, as we have determined in a previous step that we are dealing with a mixed-initiative approach, the system provides these suggestions in reaction to the user, and it is also up to the user to actually execute these actions. Pure system initiative approaches, which autonomously conduct analysis methods and only present the results to the user, are not considered to be guidance.

Node 4: Prioritized suggestions? In case we are dealing with a mixed-initiative approach, but the system cannot be classified as prescribing guidance, we ask the following question:

> *Does the system provide the user with a number of alternative suggestions, with an explicit prioritization of these suggestions?*

If if this question can be answered with yes, we are dealing with directing guidance. Directing guidance may provide users a set of ordered alternatives, where a certain priority is assigned by the system. It could be based on (inferred) user preferences, interests, or based on some metrics. Although the suggestions are given a priority, the choice is still up to the user.

Node 5: System presents suggestions? If the previous question was answered with no, it might still be the case that the system provides suggestions how to proceed:

> *Does the system provide the user with suggestions for next steps to reach his/her target?*

If this question can be answered with yes, we are dealing with orienting guidance. A system might provide a list of suggestions *without* a clear prioritization of the next step to take. Since there is no priority, users are left the freedom to choose among them.

Node 6: System presents state? Finally, in this last question we consider the case of a system presenting information related to the analysis process:

> *Does the system provide the user with information related to the current or past state of the analysis?*

We consider an approach to be orienting guidance, not only if the system provides suggestions how to proceed, but also if the system provides users with information about their past or current status in reaction to the user's actions. This may include results of intermediate calculations or provenance information. The central point is that this information should be tailored towards helping the user to overcome his/her knowledge gap and to better understand how to proceed to reach the target. However, systems that merely provide information fitting in an existing information schema of the users should be treated carefully, and not considered as guidance. In fact, the information provided, although appropriate for the users' mental map, may not constitute a mean to foster the analysis.

5. Practical Application of the Decision Tree

In this section, we discuss the application of the decision tree to well-known techniques. We discuss positive and negative examples to prove that our decision tree has the potential to help the classification of approaches, that otherwise, could have been not clearly and precisely characterized.

May et al. [MSDK12] present an approach using using signposts for graph navigation. These signposts present navigation options to graph regions outside the visible area and they are derived from the user's navigation history. According to our classification schema, this approach is mixed-initiative, it does not decide or prioritize suggestions, but presents suggestions to define and reach targets, which warrants an orienting approach. Similarly, Gladisch et al. [GST13] support the navigation to targets in a hierarchical graph. They utilize flexible degree-of-interest (DoI) functions according to which the system prioritizes suggestions. The visual cues incorporated into the visualization not only indicate where interesting targets are located, but also why the system considers them relevant. The ranking of targets and the corresponding prioritization of visual cues clearly categorizes this approach as a directing one. Schwärzler et al. [SKMW17] provide suggestions for the reconstruction of 3D objects from sequences of 2D photos. The proposed visual approach is mixed-initiative, according to our classification. The user can freely draw sketches on 2D photos and adjust the parameters affecting the resulting 3D model, while the system supports the user in this task by suggesting proper mappings and matching similar elements in different images. Further visual cues inform the user about the current state of the reconstruction. The combination of both, suggestions of next steps and feedback on the current analysis, classify this approach as orienting guidance.

As negative example, Lieberman et al. [L*95] present an *agent*, i.e., a system that senses user's activity and takes in reaction automated actions. The system leads the progress of the analysis by automatically listing and changing the order of the results displayed to the user. Although this approach may seem to provide some assistance, the user is not directly involved in the decision process, and therefore does not comply with the definition of guidance. Similarly, approaches that are usually classified as *storytelling* [KM13, GP01] are not considered guidance, either. The aim of storytelling is to present some results to users, arranging already discovered information into a convincing story. Although at first sight we may think of them as guidance, actually the user is not involved at all into the process and has no means to modify the results of the analysis as these are predefined.

6. Conclusions

Guidance is an emerging research topic with the potential of bringing several benefits to the analysis process. However, practice showed that it can be difficult to decide if a given approach complies with the definition of guidance. As a consequence, the lack of a crisp and definite way to recognize guidance impedes a correct design and development of such approaches. The work presented in this paper is tackling exactly this problem. While previous work focused on the characterization of guidance as *the answer* to users' knowledge gap, our work elaborates on *the questions* to be asked in order to arrive at that answer. We identified and isolated the key aspects that characterize guidance, so to allow an easier design and evaluation of both existing and new guidance methods. To this end, we set up a decision tree to be used to distinguish guidance from no-guidance approaches, categorize the degree of guidance approaches and advance the formation of the concept *guidance*. We demonstrated the applicability of our decision tree to well-known approaches. In particular, we argue that it helps to differentiate and characterize approaches that, without further constraints, could not be readily classified. In further extensions of this work, we plan to provide another decision tree that helps to understand in which cases guidance methods should be used, to foster understanding *if* and *when* guidance is really needed. In conclusion, our step-wise solution makes the concept of guidance understandable and directly applicable, which is decisive to advance well-defined research in this field.

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