International Journal of Image and Graphics

Designing the Visualization of Information

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Received (Day Month Year)
Revised (Day Month Year)
Accepted (Day Month Year)

The construction of an artifact to visually represent information is usually required by *Information Visualization* research projects. The end product of design science research is also an artifact and therefore it can be argued that design science research is an appropriate research paradigm for conducting *Information Visualization* research. Design science research requires that, during the *Rigor Cycle*, the design of the artifacts should be based on a scientific knowledge base. This article provides a knowledge base in the form of design guidelines that can guide the design of the view for an *Information Visualization* solution. The design principles and guidelines presented in this article are identified by means of a literature review.

Keywords: Design Science Research, Design guidelines, Design Principles, Information Visualization, Visualization.

1. Introduction

Various perspectives on what *Information Visualization* is exist in the literature. Some of the descriptions for *Information Visualization* include the following:

- The visualisation of information extracted from input data set. [1]

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- Making data easier to understand using direct sensory experience. [2]
- The visualisation of data that is structurally more complex than scientific data.[2]
- "Visual representations of the semantics, or meaning, of information".[3]
- "A visual exploration tool that enables the user to interact with the visualized content and comprehend its meaning".[3]
- "Used for creating computer graphs or animations to present information, data, scientific results, or concepts to facilitate communications or decision making".[4]
- "The use of computer-supported, interactive, visual representations of abstract data to amplify cognition".[5]

Within the context of this article, it can follows from the preceding descriptions that a visualization design or tool which is associated with research in the field of Information Visualization, usually involves the creation of a specific and purposeful visualization artifact.

Design science as a research paradigm is proposed as being appropriate for *Information Visualization* research since a) *Information Visualization* research usually results in the creation of a visualization artifact and b) the result of Design Science Research (DSR) is the creation of a purposeful Information Systems (IS) artifact. This article originated as part of a larger *Information Visualization* research study, which employs design science as a research paradigm. The larger study requires the creation of a visualization artifact.

Gregor and Hevner [6] consider design science research to be a growing research paradigm in the field of Information Systems.

Furthermore, Hevner [7] postulates that conducting design science research consists of three research cycles. The three research cycles of design science research is depicted in Figure 1.

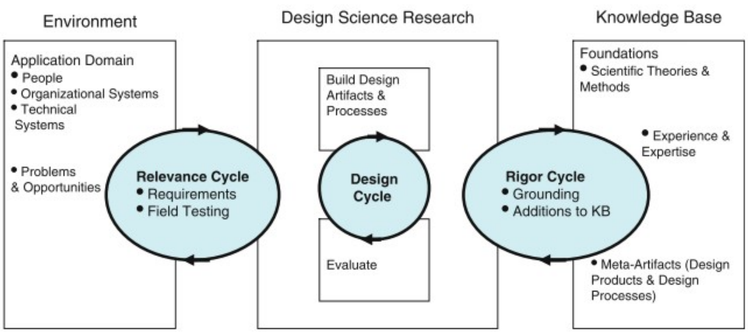

Fig. 1. Design science research cycles. [7]

The *Relevance cycle* provides the requirements for the research, as well as the criteria for evaluating the research results.[7] These requirements and evaluation criteria serve as input mechanisms to the research.

The *Design cycle* consists of the activities to build and evaluate the artifacts.[7]

The *Rigor cycle* provides a knowledge base to the research, which can consist of scientific theories, methods, experiences and expertise in the research domain. In addition, this research cycle adds the research results to the existing knowledge base to ensure that the built artifact is considered to be research and not just merely routine development.[7]

Various visualization solutions have been criticised for not adhering to design principles. [4]

This article aims to add to the existing knowledge base by providing design principles and guidelines during the *Rigor cycle* of a larger research study. The design principles and guidelines, provided by the *Rigor cycle* can be utilised to guide the design of a visual representation of information.

The remainder of this article is organised as follows. In section 2, *Information Visualization* and *Knowledge Visualization* are discussed. Literature, from which a summarising list of *Information Visualization* design principles and guidelines is presented, is discussed in section 3. Section 4 provides a discussion on how *Information Visualization* design principles and guidelines can be used for feedback during the demonstration of the built artifact. This article is concluded in section 5.

2. Information Visualization vs. Knowledge Visualization

The concepts of *Information Visualization* and *Knowledge Visualization* are discussed in this section of the article.

The discussion is structured as follows. The discussion starts with a consideration of what visualization is. Having outlined what visualization is, the difference between information and knowledge is then considered next. Having an understanding of what visualization, information and knowledge is, consequently allows for the articulation of working definitions for *Information Visualization* and *Knowledge Visualization.*

This section is concluded with proposed working definitions for *Information Visualization* and *Knowledge Visualization*, by sequentially considering the following:

- What is visualization (section 2.1)?
- What is information and knowledge (section 2.2)?
- What is the difference between *Information Visualization* and *Knowledge Visualization* (section 2.3)?

The aim of this article is to provide principles and guidelines for the design of an *Information Visualization* specific view; therefore a working definition for *Information Visualization* is presented by combining the preceding considerations.

2.1. *Defining Visualization*

Central to various discussions of visualization [2,8,9,10,11] is the idea that a visualization solution should lead to an insight. Insight is defined by Dove and Jones [11] as "something that is gained" and as "something that is experienced".

Despite the concept of insight being central to a number of visualization discussions, there exist many definitions and views of what visualization is.

Some of the descriptions of visualization include:

- "cognitive tools aiming at supporting the cognitive system of the user".[12]
- "a form of 'computer-aided' seeing information in data".[13]
- "a set of technical means and methods that allow a clear graphical representation of data".[14]
- "a study of transformation from data to visual representations in order to facilitate effective and efficient cognitive processes in tasks involving data".[15]

The latter description, which is provided by Chen et al. [15], is proposed to be the most complete description of visualization from the list of descriptions.

The description by Chen et al. [15] underpins this articles working definition of **visualization**, which is articulated as:

> *A field of study concerned with the transformation of data to visual representations, where the goal is the effective and efficient cognitive processing of data.*

Having briefly expressed a working definition for visualization, the next section outlines the concepts of *information* and *knowledge.*

2.2. *Defining Information and Knowledge*

Literature [1,12,16,17] suggests that *data*, *information*, *knowledge* and *wisdom* is ambiguous, and that distinguishing between them is not straightforward. The statement is supported by Chen et al. [1] and they argue that although ambiguous, the concepts are indeed distinctive.

The rest of this section considers descriptions of *information* and *knowledge* as provided by Ackoff [18] and Chen et al.[1]

Ackoff [18] postulates that human understanding progresses from *data* to *wisdom*, and that accordingly each level of human understanding is built upon a previous level as depicted in Figure 2.

Ackoff [18] argues that some form of processing is required to progress from one level to another. *Information*, for instance, can be acquired by extracting it from *data*. *Knowledge*, in turn, can be acquired from *information* by means of instruction or experience. Cognitive processing of *knowledge* leads to *understanding*, and *understanding* ultimately leads to *wisdom.*

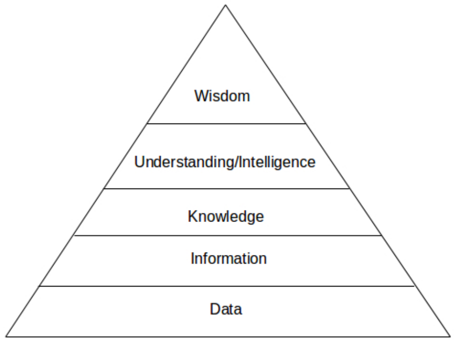

Fig. 2. Hierarchical view of the Ackoff hierarchy of human understanding. [18]

Ackoff [18] furthermore defines *information* as "contained in descriptions, answers to questions that begin with such words as who, what, where, when and how many" [18]; *knowledge* as know-how [18]. In contrast Chen et at. [1] argue that Ackoff's descriptions for *data*, *information* and *knowledge* are considered only in the perceptual and cognitive space, and postulate that these concepts should, in addition, be considered in the computational space as well. Chen et al. [1] furthermore propose that both *information* and *knowledge* are special forms of *data*.

Information is considered by Chen et al. [1] to be "data that represents the results of a computational process, such as statistical analysis, for assigning meanings to the data, or the transcripts of some meanings assigned by human beings". *Knowledge*, on the other hand, is considered by Chen et al. [1] to be "data that represents the results of a computer-simulated cognitive process, such as perception, learning, association, and reasoning or the transcripts of some knowledge acquired by human beings".

Subsequent to the preceding considerations of *information* and *knowledge*, working definitions for *information* and *knowledge* are presented as follows.

Information is, considered in the context of this study, to be:

> *The result of extracting meanings from lower level data, either through a computational process or by means of human transcription.*

Knowledge is considered to be:

> *The result of a cognitive process, either through computer simulation or by means of human knowledge transcription, resulting in a higher level of human understanding.*

Having considered what *visualization* is in section 2.1, and having outlined in this section what *information* and *knowledge* is, the next section consequently outlines working definitions for the concepts of *Information Visualization* and *Knowl-*

edge Visualization.

2.3. *Defining Information Visualization and Knowledge Visualization*

In pursuing an understanding of what *Information Visualization* and *Knowledge Visualization* is, the difference between them is articulated first.

Eppler and Burkhard [8], propose that the difference between *Knowledge Visualization* and *Information Visualization* can be considered according to the *object* (what is visualized), the *purpose* (why the knowledge is visualized) and the *methods* (how the knowledge is visualized) of the visualization.

Keller and Tergan [12], on the other hand, propose that the difference between *Knowledge Visualization* and *Information Visualization* resides in the field of study where it is relevant. Accordingly Keller and Tergan [12] postulate that *Knowledge Visualization* has its origin in Social Sciences and *Information Visualization* originated in the field of Computer Science.

In addition to the views of Eppler and Burkhard [8] and Keller and Tergan [12], the view of Burkhard [19] on the difference between *Information Visualization* and *Knowledge Visualization* is considered as well.

Burkhard [19] proposes that both *Information Visualization* and *Knowledge Visualization* exploit the ability of humans to process visual representations. The difference however, according to Burkhard [19], is situated in how the ability is being used. Based on this difference, Burkhard [19] proposes that *Information Visualization* "aims to explore abstract data and to create new insights", whereas *Knowledge Visualization* "aims to improve the transfer of knowledge between at least two persons or groups of persons".

Definitions for both *Information Visualization* and *Knowledge Visualization* are consequently derived by considering a) Chen et al.'s [15] view of visualization (section 2.1), b) definitions for information and knowledge (section 2.2), and c) the preceding discussion on what the difference is between *Information Visualization* and *Knowledge Visualization.*

Information Visualization is consequently derived as:

> *The transformation from lower-level data to visual representations of meanings extracted from the data, where the extraction is either a computational process or a human transcription process; the aim is to explore data and create new insights.*

An example of an Information Visualization view, as provided by Ku et al. [4] is depicted in Figure 3.

Knowledge Visualization is furthermore considered as:

> *The transformation from knowledge to visual representations of the knowledge, where the knowledge is the result of a*

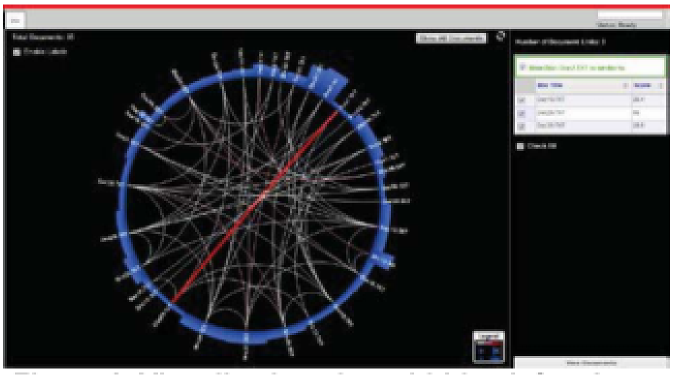

Fig. 3. Information Visualization view used in the Textual Analysis of Similar Crimes (TASC) system.[4]

> *cognitive process resulting from either computer simulation or human transcription; the aim is to improve the transfer of knowledge between humans.*

An example of *Knowledge Visualization* by means of a visual metaphor, as provided by Eppler and Burkhard [8], is depicted in Figure 4.

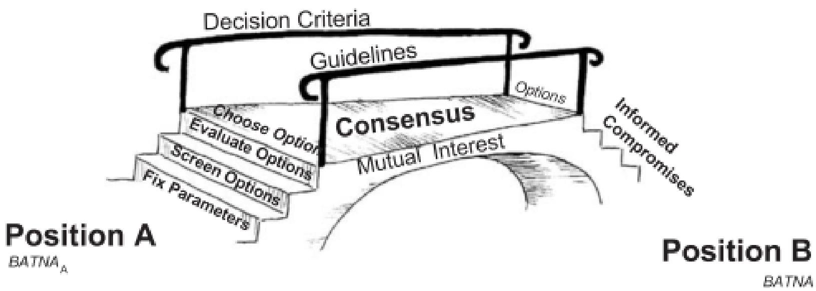

Fig. 4. Example of a visual metaphor to visualize knowledge.[8]

It is argued that the difference in purpose between *Information Visualization* and *Knowledge Visualization* can be contrasted by viewing the provided illustrated examples in Figure 3 and Figure 4. In these examples, *Information Visualization* can be considered as the exploration of information in order to create insight, and *Knowledge Visualization* is viewed as the transfer of existing knowledge.

Table 1. Summarizing visualization concepts.

Concept	**Working definition**
Visualization	*A field of study concerned with the transformation of data to visual representations, where the goal is the effective and efficient cognitive processing of data.*
Information	*The result of extracting meanings from lower level data, either through a computational process or by means of human transcription.*
Knowledge	*The result of a cognitive process, either through computer simulation or by means of human knowledge transcription, resulting in a higher level of human understanding.*
Information Visualization	*The transformation from lower-level data to visual representations of meanings extracted from the data, where the extraction is either a computational process or a human transcription process; the aim is to explore data and create new insights.*
Knowledge Visualization	*The transformation from knowledge to visual representations of the knowledge, where the knowledge is the result of a cognitive process resulting from either computer simulation or human transcription; the aim is to improve the transfer of knowledge between humans.*

A summarization of the derived working definitions of visualization, information, knowledge, *Information Visualization* and *Knowledge Visualization* is presented in Table 1.

Having derived working definitions for both *Information Visualization* and *Knowledge Visualization*, the next section considers design principles and guidelines that can be utilized to influence the development of *Information Visualization* representations.

3. Information Visualization design principles and guidelines

Ku et al. [4] suggest that principles and guidelines for developing *Information Visualization* views, serve as guidelines and not strict rules. In accordance with available literature, a set of principles and guidelines that can be considered during the design *Information Visualization* views is presented in this section. The principles and guidelines are deliberated in accordance to the following concerns:

- User interactions and views (section 3.1).
- Additional information required by the user of the visualization (section 3.2).
- The profile of the user (section 3.3).
- The Eppler and Burkhard Knowledge Visualization framework [8] (section 3.4).
- Forsell and Johansson's [20] heuristic set for Information Visualization evaluation (section 3.5).
- Elmqvist and Fekete's [21] guidelines for implementing visual hierarchical aggregates (section 3.6).
- Visualization shortcomings (section 3.7).

In the next seven sections, these concerns, which relate to *Information Visualization* design principles and guidelines are discussed.

3.1. *Information Visualization design guidelines and principles related to user interactions and views*

The intended interactions of the user with the visualization are viewed by Dix [2], Shneiderman [22] and Ku et al. [4] as important considerations with regards to the design of a visualization solution. Dix [2] proposes that the visualization design starts with a consideration of the tasks that the user should be able to perform and in addition categorises user tasks according to whether the user is a data consumer or a data analyst.

Focus-and-context, details-on-demand and brushing-and-linking user interactions are highlighted by Ku et al. [4] as important user interactions to consider during the design of a visualization solution. The focus-and-context or fish-eye-view user interaction is also discussed by Dix [2].

- The **focus-and-context** or **fish-eye-view** interaction allows for the user to focus on specific information while, at the same time, getting an overview of how that information relates to the bigger context.
- The **details-on-demand** interaction allows for a visualization solution to only display details when requested by the user. The details-on-demand interaction helps to overcome problems with regards to the limited display size by showing the user only what he/she wants or needs to see.
- The **brushing-and-linking** interaction allows for the change in one view to dynamically change another view.

In addition to the mentioned user interactions, various authors refer to the typical user information search interactions as defined by Shneiderman [12,22,23]. According to Shneiderman [12] his "visual information seeking mantra" provides a starting point for designing the user interface of visualization. He provides this starting point by defining seven typical user interactions that are performed when searching for information, namely:

(1) Get an **overview**.
(2) **Zoom** in on specific items.
(3) **Filter** out items not interested in.
(4) Get **details-on-demand**.
(5) View how items **relate** to each other.
(6) Keep a **history** of user actions.
(7) Allow the user to **extract** sub-collections of information.

Factors related to what the user can view are provided by Dix [2] and it is proposed that they could be considered during the design of the visualization solution. The following questions can therefore be considered during the design of the view for the visualization of information:

- What can the user see?
- What does the user need to see?
- What would the user like to see?

The preceding questions can guide the visualization design to take the user view into account and it can be used as a starting point for designing a visualization solution.

The next section discusses visualization design issues related to additional information that are required by the user of the visualization.

3.2. *Information Visualization design guidelines and principles related to additional information required by the user*

The user's need for additional information, in order to make sense of the visualization is discussed by Chen [3] and Chen et al. [1] Chen [3] postulates that there are two types of prior information that the user is required to have access to, namely:

- Information on how to operate the visualisation.
- Domain information to assist the user in interpreting the visualization.

Chen [1] adds that, in addition, the user requires information about the data itself.

The next section discusses the profile of the user as a consideration to take into account during the design of a visualization solution.

3.3. *Information Visualization design guidelines and principles related to the profile of the user*

Bihanic and Polacsek [24] propose that the profile specific to a particular type of user could be considered during the design of the visualization solution.

Bihanic and Polacsek [24] furthermore suggest that a visualization design should allow for the restructuring of the visual representation, based on the requirements of the profile of the user. They, in addition, suggest that a visualization design should take as main inputs the user profile as well as the semantic data structure.

The next section considers applying the Eppler and Burkhard *Knowledge Visualization* framework [8] to the design of an *Information Visualization* solution.

3.4. *Information Visualization design guidelines and principles corresponding to the Eppler and Burkhard framework* [8]

Eppler and Burkhard's framework [8], depicted in Figure 5, provides guidelines for the visualization of knowledge by defining five questions to consider during the design of a *Knowledge Visualization* solution, namely:

(1) What is the type of knowledge to be visualised?
(2) Why is the knowledge visualised?
(3) For whom is the visualization intended?
(4) What is the context in which the visualization will be taking place?
(5) How can the knowledge be represented?

Fig. 5. Eppler and Burhard's Knowledge Visualization Framework. [8]

According to Eppler and Burkhard [8], the difference between *Knowledge Visualization* and *Information Visualization*, resides in *what* is visualised, *why* it is visualised and *how* it is visualised. These questions that can be used to highlight the difference between *Knowledge Visualization* and *Information Visualization*, corresponds to questions 1, 2 and 5 of the Eppler and Burkhard *Knowledge Visualization* framework.[8]

Therefore the same questions that define the Eppler and Burkhard framework can be asked during the design of both *Information Visualization* and *Knowledge Visualization* solutions, but with different answers to questions 1, 2 and 5, and similar answers to questions 3 and 4.

It is therefore consequently proposed by this article that Eppler and Burkhard's [8] *Knowledge Visualization* framework can also be applied to the design of an *Information Visualization* solution. Additional *Information Visualization* design principles are derived in the next section by considering Forsell and Johansson's [20] heuristic set for evaluating *Information Visualization* solutions.

3.5. *Information Visualization design guidelines and principles related to the Forsell and Johansson's [20] heuristic set for Information Visualization evaluation*

Forsell and Johansson [20] propose a set of heuristics for the evaluation of *Information Visualization* solutions.

For the purpose of this article, their heuristic set is also considered as guidelines for the design of *Information Visualization* solutions.

Based on the heuristic set for *Information Visualization* evaluation defined by Forsell and Johansson [20], the following is also considered as guidelines for the design of an *Information Visualization*:

- **Information coding**. The mapping of data elements to visual objects should be enhanced by realistic techniques.
- **Minimal actions.** Provide minimal user actions to accomplish a goal.
- **Flexibility.** Consider providing a number of ways (but to a minimum) to achieve the same goal.
- **Orientation and help.** The functionality to represent additional information should be considered.
- **Spatial organisation.** The effective organisation of the visual layout should be considered.
- **Consistency.** Design choices should be consistently applied throughout the solution.
- **Cognitive load.** The cognitive load on the user should be minimal.
- **Prompting.** Consider providing the user with information on alternatives when several actions are available.
- **Remove the extraneous.** Consider removing distracting information.
- **Data set reduction.** Consider means to reduce the data set.

This research article proposes that the preceding heuristic set for evaluating the design of an *Information Visualization* solution, can in addition serve as principles and guidelines to consider during the design of an *Information Visualization* view.

In the next section, Elmqvist and Fekete's [21] guidelines for implementing visual hierarchical aggregates is discussed.

3.6. *Information Visualization design principles and guidelines related to Elmqvist and Fekete's [21] guidelines for implementing visual hierarchical aggregates*

Elmqvist and Fekete [21] provide guidelines, specifically for implementing visual aggregates.

Visual aggregates are sometimes used in *Information Visualization* solutions; therefore it is proposed that guidelines for implementing visual aggregates are also incorporated into the *Information Visualization* design guidelines and principles. Visual aggregate design guidelines provided by Elmqvist and Fekete [21] include the following:

- Maintain a visual **entity budget**.
- Aggregates should **visually summarize** the underlying data.
- **Simplicity.** Aggregate visualizations should be simple.
- Aggregates should be **discriminatingly distinguishable** from items.
- **Fidelity problems.** Be aware that visual abstractions may be misleading.
- Visual aggregates should be **interpretable**.

The preceding list of design guidelines is specific to the design of visual aggregates. It is proposed by this article, that they can be incorporated into the guidelines for the design of an *Information Visualization* view.

In the next section, design principles and guidelines related to shortcomings of visualizations is discussed.

3.7. *Information Visualization design guidelines and principles related shortcomings of visualizations*

Keller and Tergan [12] highlight the importance of keeping the shortcomings of visualizations in mind when designing a visualization.

Since the descriptions for information and knowledge are ambiguous, it is proposed that the shortcomings described in the literature for both *Knowledge Visualization* and *Information Visualization* can be considered for the purpose of this article.

With regards to *Knowledge Visualization*, Keller and Tergan [12] consider visualization shortcomings to be related to visualization tools and the mapping of concepts to representations.

With regards to *Information Visualization*, Keller and Tergan [12] consider the following to be visualization shortcomings:

- Technical problems related to the representation of information, specifically where large data structures are used.
- Problems related to the visualization of information that is required by the user in order to make sense of the visualization.

A tabular summarization of the principles and guidelines presented in this section is provided in Table 2.

Table 2: Principles and guidelines to guide the design of an Information Visualization view.

Design principle/guideline
User interaction and view concerns
1. Consider providing focus and context user interactions.
2. Consider providing details-on-demand user interactions.
3. Consider providing brushing-and-linking user interactions.
4. Consider providing Shneiderman's user interactions.
a. Provide an overview.
b. Provide zoom functionality.
c. Provide functionality to filter out items.
d. Provide functionality to get details-on-demand.
e. Provide functionality to show how items relate.
f. Provide functionality to keep history of user interactions.
g. Provide functionality to extract sub-collections
5. Consider what the user can see, needs to see and would like to see.
Concerns related to additional information required by the user
6. Additional information required by the user should be provided.
7. Additional information on how to operate the visualization should be provided.
Concerns related to the Eppler and Burkhard framework [8]
8. The type of information to be visualised should be considered.
9. The purpose of the visualization should be considered.
10. The user profile should be considered.
11. The context in which the visualization will take place should be considered.
12. The visualization format should be considered.
Concerns related to the Forsell and Johansson heuristic evaluation set [20]
13. The mapping of data elements to visual objects should be enhanced by realistic techniques or additional symbols.
14. Consider the use of minimal user actions to accomplish a goal.
Continued on next page

Table 2 (Continued)

Design principle/guideline
15. Consider providing a number of ways to achieve the same goal.
16. Consider functionality to provide redo/undo of actions.
17. The organisation of the visual layout should be considered.
18. Design choices should be consistently applied in the solution.
19. The cognitive load on the user should be minimal.
20. Provide the user with information on alternative when several actions are available.
21. Consider removing distracting information from the visualization solution.
22. Consider means to reduce the data set.
Concerns related to Elmqvist and Fekete's [21] *visual aggregate implementation guidelines*
23. Maintain a visual entity budget.
24. Visual aggregates should visually summarise the underlying data.
25. Visualizations should be clean and simple.
26. Visual aggregates should be discriminatingly distinguishable from data items.
27. Keep in mind that visual abstractions may be misleading.
28. Visual aggregates should be interpretable.
Concerns related to shortcomings of visualisations.
29. Shortcomings related to the visualization tools should be considered.
30. Shortcomings related to the mapping of concepts with representations should be considered.
31. Shortcomings related to technical problems to represent information should be considered.

In the next section, it is discussed how the proposed *Information Visualization* design principles and guidelines can be used for feedback during the demonstration of the built artifact.

4. Artifact demonstration feedback

In this section it is proposed that a feedback questionnaire presented to an audience during the demonstration of the built artifact, can in parts be based on the *Information Visualization* design principles and guidelines presented in this article.

The three research cycles of design science research was discussed in section 1.

Hevner and Chatterjee [25] propose the use of the Design Science Research Methodology (DSRM) as defined by Peffers et al. [26] for conducting design science research.

According to Peffers et al. the DSRM provide a conceptual model for the process of conducting design science research.

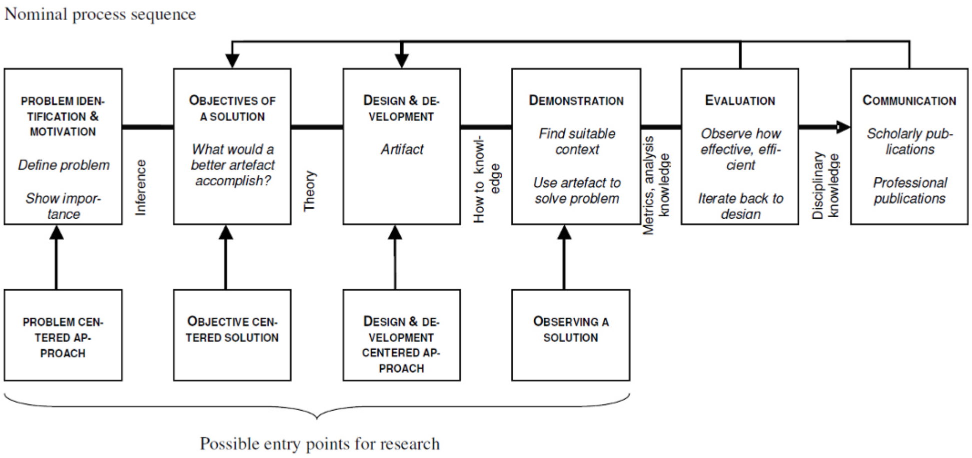

Fig. 6. Design Science Research Model. [27]

The design science research model as defined by Peffers et al. [27] consists of six activities as depicted in Figure 6. Design science research is therefore conducted by executing the following activities:

(1) Identify the research problem.
(2) Define the objectives of the desired solution.
(3) Design and develop an artifact.
(4) Demonstrate the use of the artifact to solve the problem.
(5) Evaluate whether the solution artifact meet the objectives of the research.
(6) Communicate the results of the research.

It is proposed by this article that during the demonstration of the artifact to an audience, they can be presented with a short questionnaire. This questionnaire can be used as feedback to improve the efficiency of the built artifact. Figure 7 contains a sample list of possible statements for which the individual can indicate whether he/she agrees or disagrees. These statements can test the design principles and guidelines listed in Table 2.

5. Conclusion

This research article suggests design science research as a methodology for conducting *Information Visualization* research, which is based on an artifact being the end goal of both design science research and *Information Visualization*.

Design science research furthermore requires that the artifact design should be based upon the current knowledge base. Therefore, as part of a larger *Information*

Please read the statements with regards to the demonstrated software below and indicate how strongly you agree or disagree. Please use the following rating system:

Strongly disagree	Somewhat disagree	Neither agree or disagree	Agree	Strongly agree
1	2	3	4	5

Number	Statement	Rating				
1.	The technique for visualising the facts contained in the textual records is appropriate.	1	2	3	4	5
2.	The visualisation technique employs a minimal set of actions to accomplish a task.	1	2	3	4	5
3.	Functionality to control the level of details is available.	1	2	3	4	5
4.	The visual layout of the visualisation is effective.	1	2	3	4	5
5.	The cognitive load on the user is minimal.	1	2	3	4	5
6.	The visualisation contains extracted information.	1	2	3	4	5
7.	There is too much information on the visualisation view.	1	2	3	4	5
8.	Additional functionality to show less data/information should be considered.	1	2	3	4	5
9.	The visualisation is clean and simple.	1	2	3	4	5
10.	Data items are easily distinguishable from each other.	1	2	3	4	5
11.	The visualisation can lead to misleading interpretations.	1	2	3	4	5
12.	The visualisation is interpretable.	1	2	3	4	5
13.	The user can view what he needs to see.	1	2	3	4	5
14.	The visualisation can be used to get some insights into the domain described by the data.	1	2	3	4	5

Comments/Recommendations:

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Fig. 7. Proposed demonstration feedback questionnaire.

Visualization study's *Rigor cycle*, the result of this article is a tabular summarization of *Information Visualization* design principles and guidelines (depicted in Table 2) gathered from a literature study.

In addition to providing design principles and guidelines, this article provided a sample questionnaire (depicted in Figure 7) that can be presented to an audience during the demonstration of the built artifact. It is furthermore proposed that the feedback questionnaire can be based on the design principles and guidelines presented in this article.

Future work includes the design of an *Information Visualization* view by implementing the principles and guidelines presented in this article.

The focus of this article is on the design of the *Information Visualization* view. The *Information Visualization* process however also includes the transformation from lower-level data to visual representations of meanings extracted from the data. These extraction and transformation processes that data undergoes to eventually lead to the visualization of the data, is known as the visualization pipeline.[1,28]

Future work therefore can include the compilation of a set of principles and guidelines for designing the *Information Visualization* pipeline.

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Acknowledgements

The author would like to acknowledge the assistance and support of the CSIR, as well as the support of his co-authors.

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