A Construction Kit for Visual Exploration Interfaces

M. Keck[1] and R. Groh[1]

[1] Technische Universität Dresden, Chair of Media Design, Germany

Abstract

With a continuously increasing amount of data and resources on the internet and in large document collections, effective visual exploration interfaces are becoming more and more important. In recent years, many novel approaches have been proposed for the exploration of complex, multidimensional data sets. However, little guidance is available for designers to create similar solutions and to reuse established patterns. In this paper, we propose a construction kit for visual exploration interfaces. It provides a set of building blocks that can be easily combined with each other. These building blocks can support the designer in the creation of novel visual exploration interfaces but also in the analysis and variation of existing interface solutions. Furthermore, we present a workshop method that evaluates the application of the construction kit for the creation and analysis of visual exploration interfaces.

CCS Concepts

• ***Human-centered computing*** → ***Visualization theory, concepts and paradigms;*** *Visualization design and evaluation methods;* • ***Information systems*** → *Web searching and information discovery;*

1. Introduction

Exploratory search tasks can be supported by interactive visualizations that provide an overview of the data set and its structure and allow the user to browse and filter the information space. The resulting visual exploration interface is particularly useful, when little is known about the data and the search goals are very vague [Kei02]. Although many approaches to exploring complex data sets exist, little guidance is available for novice designers and developers to create new solutions for specific use cases. To this end, we propose a construction kit for visual exploration interfaces that is suited for multidimensional information spaces.

Construction kits originate mainly from the field of mechanical engineering, product design, and architecture. A construction kit consists of several building blocks, which define a design space and can be assigned to a specific problem domain [FL88]. This means that different design variations can result from the selection and combination of different building blocks. Recent research has also focused on the development of design spaces for the application domain of information visualization, such as data comics [BWF*18], timelines [BLB*17] and graphical abstracts [HB18].

The main aim of this research is to support the designer in the conception phase of the design process and to learn from previous successful visualization projects. New interface solutions can be created by combining different building blocks of the provided design space. Furthermore, resulting interface solutions can be saved as design patterns for reuse. To this end, we use the pattern approach conceived by Christopher Alexander to model design experience in architecture [AIS77]. He introduced the idea to capture a recurring design problem in the form of a design pattern that suggests a proven solution. In the past, this pattern approach has been also adapted to HCI problems [Bor01]. Examples are the pattern collections for *Interaction Design* [Tid10] and for *Websites & E-commerce* [DLH06]. Design patterns and design spaces were already successfully applied in educational scenarios. Packs of cards can serve as "suggesting tool" [LHS10] during the design process and can be used for a directed brainstorming (cp. [LHS13, ide19, HA17, BWF*18, RS19]).

The contribution of this paper is twofold. First, we introduce a construction kit for visual exploration interfaces, which is focused on multidimensional data sets in product search scenarios (e.g. searching for a hotel or a technical product). This construction kit combines characteristics of design spaces and design patterns. Our second contribution is the introduction of a workshop method that shows the application of the construction kit in two directions: bottom-up to develop novel visual interfaces and top-down to identify and analyze key aspects of existing interface solutions.

2. Interface Construction Kit

The construction kit consists of several *building blocks* that can be combined to a *pattern*, which describes one part of a visual exploration interface. Patterns can be composed to *construction plans*, which describe complex visual exploration interfaces. The following subsections address these three levels of the construction kit in more detail.

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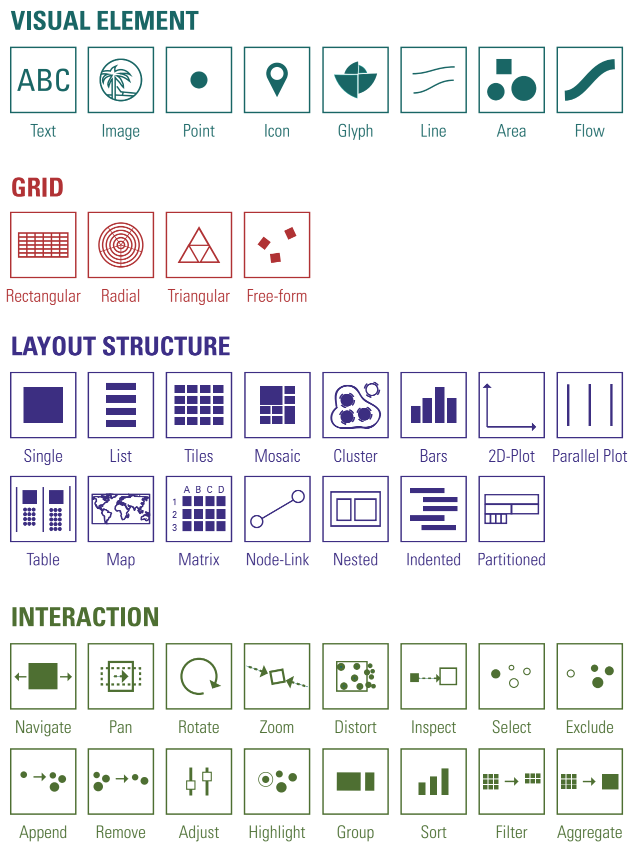

Figure 1: *Building blocks of the construction kit*

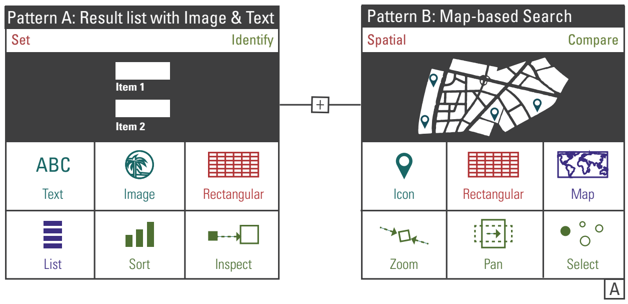

Figure 2: *Construction plan of a hotel search interface consisting of two patterns that are connected by the "juxtaposed" connector*

2.1. Building Blocks

The collection of building blocks is based on a comprehensive analysis of related work, which includes visualization taxonomies (e.g. [Shn96, Kei00]) and collections (e.g. [Lim13, Rib19, Kir16, Mei13]). Furthermore, various visual exploration interfaces were reverse-engineered to abstract and refine the design space. Our analysis resulted in a design space with four dimensions: *Visual Element*, *Grid*, *Layout Structure*, and *Interaction* (see Figure 1).

Dimension 1 – Visual Element. This dimension describes how a single data object can be represented, e.g. as *text*, as an *image* or as a visual marker (e.g. *point*, *line* or *area* [Ber83]). Furthermore, data objects can be encoded using more complex visual elements, such as *icons* or *glyphs* [BKC*13].

Dimension 2 – Grid. The grid describes the arrangement of visual elements in an interface, e.g. *rectangular*, *radial* or *triangular*. The building block *free-form* allows the free placement of visual elements without a two-dimensional reference system, e.g. the free arrangement of images on a multi-touch table.

Dimension 3 – Layout Structure. The layout structure refers to the organization of visual elements within the interface and describes the most visually salient aspect. It includes building blocks, which represent the elements in a sorted or grouped structure (e.g. *list*, *tiles*, *mosaic*, *cluster*). Further techniques encode different attributes of the data objects (e.g. *bars*, *2D-plot*, *parallel plot*, *table*), their spatial structure (e.g. *map*) and their relations (e.g. *matrix*, *node-link*, *nested*, *indented*, *partitioned*).

Dimension 4 – Interaction. The last dimension refers to different interaction techniques that are used to manipulate the view or the data objects (cp. [Maz09], p. 106). The building blocks that can be used to transform the view consist of *navigate*, *pan*, *rotate*, *zoom*, *distort*, and *inspect*. The other building blocks influence or modify the presented data objects, such as *select*, *sort*, *filter*, and *aggregate*.

The building blocks were abstracted and refined in several iterations to avoid redundant combinations. As a result, many well-known visualization techniques can be created by the combination of different building blocks. The following list provides a few examples of visualization techniques that are presented in [Rib19]:

- *Line Graph:* Combination of the building blocks *Line*, *Rectangular* and *2D-Plot*
- *Parallel Sets:* Combination of the building blocks *Flow*, *Rectangular* and *Parallel Plot*
- *Radar Chart:* Combination of the building blocks *Line*, *Radial* and *Parallel Plot*
- *Chord Diagram:* Combination of the building blocks *Flow*, *Radial* and *Node-Link*
- *Sunburst:* Combination of the building blocks *Area*, *Radial* and *Partitioned*

2.2. Patterns

Building blocks can be combined to a pattern by assigning at least one building block from each dimension. Figure 2 (right: Pattern B) shows an example for a map-based search, which arranges search results on a map. This pattern can be created by combining the building blocks *icon*, *rectangular* and *map*. Furthermore, the building blocks *zoom*, *pan* and *select* of the dimension *Interaction* can be used to explore the resulting visual presentation and to select particular results. The resulting pattern does not only consist of the building blocks, which describe *how* the interface is designed. It also contains the underlying data set (*What*) and the task that can be solved with this pattern (*Why*), according to Munzner's what-why-how analysis framework [Mun14]. The introduced pattern can be used for *spatial data* and allows the *comparison* of distances between different search results and a point of interest. Once a mean-

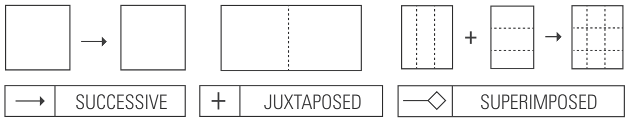

Figure 3: *Connectors of the construction kit*

ingful pattern has been created and tested, it can be transformed into a design pattern for reuse. A design pattern is further defined by a name, an illustration, an example, a problem description, a solution approach, the context in which the pattern can be used, and cross-references to other patterns according to the definition of [AIS77].

2.3. Construction Plans

Patterns can be combined to a construction plan to describe complex visual exploration interfaces. The construction process is supported by three different connectors (see Figure 3):

- *Successive* (patterns are shown successively),
- *Juxtaposed* (patterns are shown next to each other), and
- *Superimposed* (patterns are combined in one view).

Figure 2 shows an example of the pattern that is described in section 2.2 (Pattern B). This pattern is connected with the *Juxtaposed* connector to a result list pattern (Pattern A), which shows a list of items and can be used to present details of the results. The resulting construction plan captures an interface, which is provided on the hotel search platform kayak.com. The result list pattern contains the building blocks *text* and *image* as visual element, the grid building block *rectangular* and the layout structure *list*. The representation can be sorted (building block *sort*) and further details of the selected hotel are provided by unfolding the list (building block *inspect*). In addition, the selection of a hotel on the map can influence the current position of the list. This is shown by a *reference building block* in pattern B, which refers to pattern A (indicated by the small square on the bottom right in Figure 2).

3. Workshop

We ran a workshop to investigate the structure and the elements of the construction kit, and to what extent this approach can support the participants in the analysis and the development of visual exploration interfaces. The goal of this workshop was to create an interface concept for a given data set and task.

Participants. The workshop was attended by 10 participants (3 women), aged between 25 and 62 (mean value (M) = 32.9, standard deviation (SD) = 10.83). The group consisted of 3 designers, 3 software engineers, 2 computer science PhD students and 2 master students of media computer science.

Procedure. The workshop was carried out over 2,5 hours and was divided into six parts (see Table 1). A short introduction explained the structure and the elements of the construction kit. Furthermore, well-known interfaces were presented and deconstructed into individual patterns and building blocks in order to gain an understanding of these abstract descriptions (step 1).

Step	Task	Working Method	Time
1	Deconstruction task	entire group	15 min
2	Morphological analysis	individual work	40 min
3	Creation of two patterns	individual work	15 min
4	Pattern presentation	entire group	35 min
5	Creation of constr. plans	teams of 3 and 4	30 min
6	Presentation of the concept + construction plan	entire group	15 min

Table 1: *Structure of the workshop*

In the next step, each participant could select a building block from the dimension *Layout Structure* and was asked to carry out a morphological analysis [Zwi69], which describes a creativity technique for investigating all possible solutions to a given problem complex (step 2). For this reason a worksheet with a combination table was offered, which contained all building blocks of the dimension *Visual Element* in its columns. The participants had the task to sketch solution approaches that combine the selected building block of the dimension *Layout Structure* with the respective building block of the dimension *Visual Element*. This sketching task was carried out without a given data structure or a concrete search task with the goal to generate different ideas and also to test unusual combinations. After 20 minutes, the participants were asked to select two favorite solutions of this combination table and repeat the morphological analysis with the building blocks *rectangular*, *radial*, *triangular*, and *free-form* of the dimension *Grid* (see Figure 4, left).

After that, the participants were asked to selected again two favorite solutions in order to create a pattern for each solution (step 3). For this purpose, worksheets with pattern templates (see Figure 4, right) and building block stickers were provided. In addition, suitable data structures and tasks, as well as a rough sketch should be assigned to each pattern.

Afterwards, the results were presented to the entire group (step 4). The patterns were collected on a whiteboard and the participants were asked to assign tasks that can be solved best with the respective pattern.

The next task focused on the development of a concept for a given application scenario (step 5). For this purpose, the participants were divided into 3 groups and each group got one of the following tasks:

- a new project member wants to get an overview of different topics in a project (task: *Analyze*),
- a project manager wants to know, who worked on a certain topic with a specific software (task: *Search*),
- a project manager wants to compare, how much each team member was involved in a specific project (*task: Compare*)

The participants could use blank sheets for sketching, and pattern templates and stickers to reuse or adapt the collected patterns. Furthermore, additional design patterns were provided that served as inspiration cards and contained well-known visualization techniques, such as parallel sets, parallel coordinates or simple lists. The participants could use both, the collection of created patterns and the inspiration cards to solve their search task. Furthermore,

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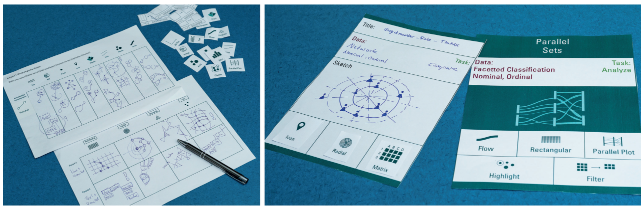

Figure 4: *Worksheets for morphological analysis and building blocks as stickers (left), created pattern and inspiration card (right)*

the connectors *successive*, *juxtaposed*, and *superimposed* were provided as stickers to combine these patterns.

In the last step, the groups should present their solutions to the entire group (step 6) by using a construction plan to explain their interface concepts.

Results and Discussion. During the workshop, 20 different patterns were created (two by each participant in step 3) and three different interface ideas could be developed (one by each group in step 5). Right after the workshop, each participant was asked to complete a questionnaire to give feedback on A) the workshop, B) the building blocks, C) the patterns and D) the construction plans. The questionnaire used a 7 point Likert scale (-3 = strongly disagree to 3 = strongly agree).

A: Workshop. The first part of the questionnaire focused on the workshop method, the time and team size. The morphological analysis (MA) was considered as helpful to generate new ideas (M = 1.9). The time for the morphological analysis (M = 1.4) and the group work (M = 1.6) was sufficient for most participants (see Figure 5 - A). However, some participants needed more time for the morphological analysis, which is reflected in the lower mean value. Hence, the combination tables could not be completed by all participants and the task had to be terminated after 40 minutes, in order to synchronize the following tasks. The average team size was rated positively (M = 1.4). The group with four participants stated that they would prefer smaller groups. This aspect can be considered in a following workshop with teams consisting of 2-3 participants.

B: Building Blocks. The *usefulness*, the *learnability*, the *understandability*, the *suitability to communicate ideas*, and the *suitability for generating ideas* of the building blocks were rated positively, with all mean values ≥ 1.7 (see Figure 5 - B). The participants highlighted that the presentation of the building blocks, consisting of a sketch and a label, was clear and helpful. Furthermore, they felt supported by the building blocks in the brainstorming process.

C: Patterns. The *usefulness of the patterns* and the *inspiration cards*, the *learnability*, the *suitability to communicate ideas*, and the *suitability for generating ideas* of the patterns were also rated positively with all mean values ≥ 1.3 (see Figure 5 - C). However, some participants criticized that the inspiration cards, which were additionally provided in step 5, were not introduced in detail during the workshop. Hence, the resulting construction plans consisted mainly of patterns, which were presented in step 4 to the entire group.

D: Construction Plans. The *learnability*, the *suitability to communicate ideas*, the *understandability*, and the *suitability for generating ideas* of the construction plans were also rated positively with all mean values ≥ 1.5 (see Figure 5 - D). Some of the partici-

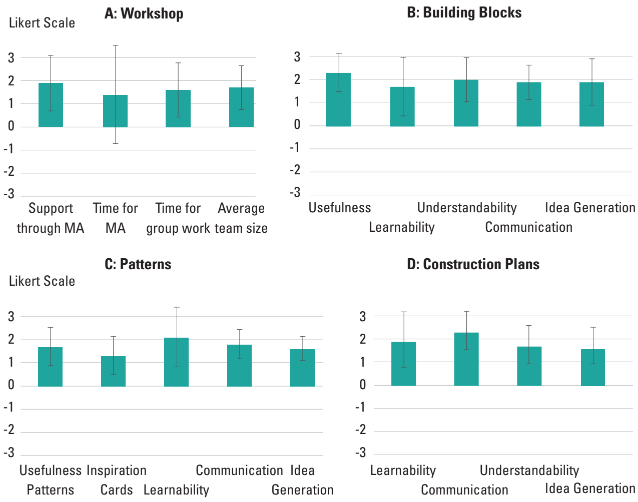

Figure 5: *Results of the questionnaires (error bars indicate the standard deviation)*

pants stated that the construction plans supported them very well in understanding the concepts of the other groups. This highlights the strength in communicating ideas by means of the building blocks (mean value for the communication aspect (M_C) = 1.9), the patterns (M_C = 1.8) and the construction plans (M_C = 2.3), which plays an important role in interdisciplinary teams.

4. Conclusions and Future Work

In this paper, we introduced a construction kit for visual exploration interfaces, which aims to support designers in the conception phase of the design process. The introduced building blocks define a design space and help to generate ideas. Resulting patterns are conceptually simple and provide a solid foundation for reuse and redesign. Furthermore, they can be combined in a flexible way to create complex search interfaces. In addition, we demonstrated the application of the construction kit in a workshop. The workshop showed that the construction kit is well suited as design and teaching method. The construction kit can be applied bottom-up in order to create new interface solutions, but also top-down to deconstruct existing solutions in order to identify and analyze key aspects. In the first workshop, we did not consider the building blocks of the *Interaction* dimension. An extension of the workshop with the integration of all building blocks is part of our future work.

In addition, the concept of the construction kit can be applied to different problem domains. Currently, most examples that were constructed and deconstructed with the construction kit belong to the problem domain of product search and focus on two-dimensional interfaces. Future work can involve the application of the construction kit concept to other problem domains, such as visual analytics and 3D interfaces, and the extension of the design space. Furthermore, the construction kit offers the potential to support the prototyping phase of the design process. The combination with the visual programming paradigm can enable the generation and reuse of code for the building blocks and established patterns.

The workshop material and the workshop results can be accessed on `http://www.visual-search.org/construction-kit/`.

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References

[AIS77] ALEXANDER C., ISHIKAWA S., SILVERSTEIN M.: *A Pattern Language: Towns, Buildings, Construction*. Oxford University Press, New York, August 1977. URL: http://www.amazon.fr/exec/obidos/ASIN/0195019199/citeulike04-21. 1, 3

[Ber83] BERTIN J.: *Semiology of Graphics*. University of Wisconsin Press, 1983. 2

[BKC*13] BORGO R., KEHRER J., CHUNG D. H., MAGUIRE E., LARAMEE R. S., HAUSER H., WARD M., CHEN M.: Glyph-based visualization: Foundations, design guidelines, techniques and applications. *Eurographics State of the Art Reports* (May 2013), 39–63. http://diglib.eg.org/EG/DL/conf/EG2013/stars/039-063.pdf. URL: https://www.cg.tuwien.ac.at/research/publications/2013/borgo-2013-gly/. 2

[BLB*17] BREHMER M., LEE B., BACH B., RICHE N. H., MUNZNER T.: Timelines revisited: A design space and considerations for expressive storytelling. *IEEE Transactions on Visualization and Computer Graphics 23*, 9 (Sep. 2017), 2151–2164. doi:10.1109/TVCG.2016.2614803. 1

[Bor01] BORCHERS J.: *A Pattern Approach to Interaction Design*. John Wiley & Sons, Inc., New York, NY, USA, 2001. 1

[BWF*18] BACH B., WANG Z., FARINELLA M., MURRAY-RUST D., HENRY RICHE N.: *Design Patterns for Data Comics*. 2018. 1

[DLH06] DUYNE D. K. V., LANDAY J. A., HONG J. I.: *The Design of Sites: Patterns for Creating Winning Web Sites (2Nd Edition)*. Prentice Hall PTR, Upper Saddle River, NJ, USA, 2006. 1

[FL88] FISCHER G., LEMKE A. C.: Construction kits and design environments: Steps toward human problem-domain communication. *SIGCHI Bull. 20*, 1 (July 1988), 81–. URL: http://doi.acm.org/10.1145/49103.1046496, doi:10.1145/49103.1046496. 1

[HA17] HE S., ADAR E.: Vizitcards: A card-based toolkit for infovis design education. *IEEE Transactions on Visualization and Computer Graphics 23*, 1 (Jan 2017), 561–570. doi:10.1109/TVCG.2016.2599338. 1

[HB18] HULLMAN J., BACH B.: Picturing science: Design patterns in graphical abstracts. In *Diagrammatic Representation and Inference - 10th International Conference, Diagrams 2018, Proceedings* (Germany, 1 2018), Stapleton G., Bellucci F., Moktefi A., Chapman P., Perez-Kriz S., (Eds.), Lecture Notes in Computer Science (including subseries Lecture Notes in Artificial Intelligence and Lecture Notes in Bioinformatics), Springer Verlag, pp. 183–200. doi:10.1007/978-3-319-91376-6_19. 1

[ide19] : *Ideo Method Cards*, 2019 (last visited: February 27, 2019). URL: https://www.ideo.com/post/method-cards. 1

[Kei00] KEIM D. A.: Designing pixel-oriented visualization techniques: Theory and applications. *IEEE Transactions on Visualization and Computer Graphics 6*, 1 (Jan. 2000), 59–78. URL: https://doi.org/10.1109/2945.841121, doi:10.1109/2945.841121. 2

[Kei02] KEIM D. A.: Information visualization and visual data mining. *IEEE Transactions on Visualization and Computer Graphics 8*, 1 (Jan 2002), 1–8. doi:10.1109/2945.981847. 1

[Kir16] KIRK A.: *Design for Information: An Introduction to the Histories, Theories, and Best Practices Behind Effective Information Visualizations*. Sage Publications Ltd, 2016. 2

[LHS10] LOCKTON D., HARRISON D., STANTON N. A.: The design with intent method: A design tool for influencing user behaviour. *Applied Ergonomics 41*, 3 (2010), 382 – 392. URL: http://www.sciencedirect.com/science/article/pii/S0003687009001136, doi:https://doi.org/10.1016/j.apergo.2009.09.001. 1

[LHS13] LOCKTON D., HARRISON D., STANTON N. A.: Exploring design patterns for sustainable behaviour. *The Design Journal 16*, 4 (2013), 431–459. URL: https://doi.org/10.2752/175630613X13746645186124, doi:10.2752/175630613X13746645186124. 1

[Lim13] LIMA M.: *Visual Complexity: Mapping Patterns of Information*. Princeton Architectural Press, 2013. 2

[Maz09] MAZZA R.: *Introduction to Information Visualization*, 1 ed. Springer Publishing Company, Incorporated, 2009. 2

[Mei13] MEIRELLES I.: *Design for Information: An Introduction to the Histories, Theories, and Best Practices Behind Effective Information Visualizations*. EBSCO ebook academic collection. Rockport Publishers, 2013. URL: https://books.google.de/books?id=HR_7AAAAQBAJ. 2

[Mun14] MUNZNER T.: *Visualization Analysis and Design*. A.K. Peters visualization series. A K Peters, 2014. URL: http://www.cs.ubc.ca/~tmm/vadbook/. 2

[Rib19] RIBECCA S.: *The Data Visualisation Catalogue*, 2019 (last visited: February 27, 2019). URL: https://datavizcatalogue.com/. 2

[RS19] RIBECCA S., SCHWABISH J.: *The Graphic Continuum Cards*, 2019 (last visited: February 27, 2019). URL: https://policyviz.com/product/the-graphic-continuum-flash-cards/. 1

[Shn96] SHNEIDERMAN B.: The eyes have it: A task by data type taxonomy for information visualizations. In *Proceedings of the 1996 IEEE Symposium on Visual Languages* (Washington, DC, USA, 1996), VL '96, IEEE Computer Society, pp. 336–. URL: http://dl.acm.org/citation.cfm?id=832277.834354. 2

[Tid10] TIDWELL J.: *Designing Interfaces*. O'Reilly Media, Inc., 2010. 1

[Zwi69] ZWICKY F.: Discovery, invention, research, through the morphological approach. *Science 163*, 3873 (1969), 1317–1318. doi:10.1126/science.163.3873.1317. 3

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