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Short Paper

Visual Access to Performance Indicators in the Mining Sector

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Abstract

We introduce a visualization system that provides visual interactive access to information relevant for decision making in the mining sector. The mining sector is one of the most important industries in developing countries, especially in Africa. Stakeholders like governments, investors, and the civil society play an important role in the growth of the mining sector. They are interested in information reviewing individual country performances towards mining. The Mining Investment and Governance Review (MInGov) dataset explicitly addresses this issue. However, the complex data structure introduces challenges for the intuitive and easy understanding of the information. Together with mining sector experts, we conducted a design study with the goal to provide visual interactive access to investment- and policy-related information. We report on a domain characterization of the MInGov dataset, its potential users, and their tasks. Based on this analysis, we design a visualization system that supports mining-related decision making. Finally, we evaluate the visualization system in a user workshop with domain experts.

Categories and Subject Descriptors (according to ACM CCS): H.5.0 [Information Interfaces and Presentation]: General—

1. Introduction

The mining sector is one of the key industries ensuring economic growth in many resource-rich developing countries. As Martin Lokanc from the World Bank Group says, “Mining projects, when well-managed, offer an opportunity to transform resource wealth into sustainable development in many poor countries” [Wor17]. Several stakeholders play an important role for realizing a sustainable development. *Governments* need to provide regulatory conditions in the mining sector that attract *investors*, while in parallel serving the wealth of the country’s *civil society*. As a response to the growing demand of these stakeholders for understanding country-specific mining conditions, the World Bank Group has designed a methodology for collecting a dataset describing these conditions: The Mining Investment and Governance Review (MInGov) [Wor17]. The resulting dataset allows investors, governments and the civil society to assess the governance quality as well as the sector competitiveness and attractiveness of the respective country. In 2016, MInGov was conducted in seven countries. The target is to cover all mining-related countries and periodically collect data to monitor progress. The results are published in individual country reports and as open datasets [Wor17]. However, stakeholders requested an intuitive access to the complex datasets to make them usable. Moreover, the charts to be included in the country reports have to be generated manually in a tedious process.

The goal of this design study is to support decision making in the mining sector by providing visual interactive access to MInGov data. The domain characterization with the involved user group revealed three core requirements: The visualization system has to allow (a) the exploration of individual country datasets, (b) the comparison of different country datasets, and (c) the export of charts for the inclusion in individual country reports. The contributions of our approach are threefold. First, we provide a domain characterization describing the underlying data, relevant user groups, and the tasks to be addressed with the data. Second, we introduce a visualization system that allows the identified users to conduct the described tasks in an effective and efficient way. Third, we present the results of a usability workshop conducted with real-world users demonstrating the efficiency and effectiveness of the system.

2. Related Work

Commercial visualization systems have been reviewed by us concerning their suitability for our approach. Examples include Tableau, Tibco Spotfire, Microsoft Power BI, QlikView, and SAS Visual Analytics. An extensive review of these systems was already provided by Mittelstädt et al. [MBW*12]. However, the specific structure of the dataset and the tasks to be supported required some customized visualization techniques. This includes techniques providing (a) topic overviews in a matrix-like structure, (b) drill-down functionality to the question level, and (c) overviews of topic scores and weights via a specific treemap layout. None of the reviewed visualization systems includes these techniques.

Decision making is described as an abstract task in information visualization and visual analytics research (e.g., [SME08] [KWS*14] [OSS*17]). However, most of these approaches lack a detailed explanation on how the decision making is conducted and supported by visual interactive solutions. In fact, most of them focus on the externalization of knowledge without providing details

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on how this knowledge is transferred into a decision. In this design study, we define user tasks according to the decision making process by Simon, containing the three steps *intelligence* (information foraging), *design* (definition of alternative solutions), and *choice* (selection of the "best" alternative) [Sim60]. This model was already used in the research agenda of geo-spatial analytics for decision support by Andrienko et al., without applying it to an actual design study [AAJ*07]. In the context of political decision making adapted concepts were presented [KNRB12] [RDK*15]. Visual analytics approaches in the field of political decision making have been introduced by Boosherian et al. [BMPM12] and Ruppert et al. [RBMK14] [RBU*14]. They also support the comparison of alternative solutions, represented by numerical data. The visualization of ordinal data in the context of decision making was discussed by Migut and Worring [MW10]. They visualize data in a mosaic plot to tackle binary classification problems. In summary, our approach is a new application of Simon's decision making process to a visualization design study on ordinal data in the mining sector.

3. Domain Characterization

We describe the three ingredients to be analyzed prior to the design of a visualization system: data, users, and tasks [vW13]. The results built the basis for our user-centered design approach.

Data. The foundation of the MInGov dataset is a questionnaire containing 350 questions about a country's performance in the mining sector. These questions are answered by domain experts, desktop research, or secondary sources. The question answers are aggregated and categorized into one of four ordinal classes (very low, low, high, very high) representing the country's performance on the respective question. On top of the questions a hierarchy was defined, which we exploit for the design of overview visualizations. Questions are grouped into indicators, indicators are grouped into topics, and topics are grouped into themes. Some topics are additionally organized into groups along the mining value chain. This allows us to map them in a matrix-like structure, with themes on the vertical, and value chain levels on the horizontal axis (see Fig. 1 upper matrix). Finally, four stakeholder-specific topic weights are provided by the respective domain experts to reflect (1) government priorities, (2) investor priorities, (3) civil society priorities, and (4) country-specific priorities. More details on the dataset are given at the MInGov website [Wor17].

Users. We differentiate between three stakeholder groups: governments, investors, and civil society. The main goal of the government is to attract investors in order to generate economic growth. Therefore, they have to identify weak indicators that motivate the adaptation of regulations or the design of new policies. The main objective of investors is to make better investment decisions. They have to identify negative indicators to anticipate challenges prior to investments. Finally, civil society organizations aim at monitoring the mining sector performance. The provided transparency increases the understanding of critical government decisions. Moreover, civil projects can help to attract mining sector investments.

Tasks. Together with domain experts from the World Bank Group, we identified several tasks to be conducted with the MInGov dataset. The tasks and their order match the decision making process described in the related work section.

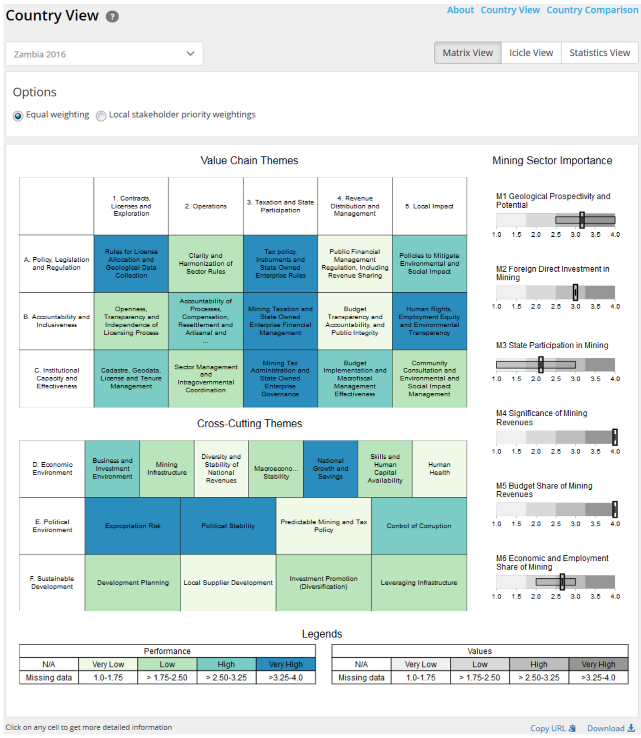

Figure 1: *Matrix View: topics are grouped into the theme-value chain matrix (top left), cross-cutting themes (lower left), and the Mining Sector Importance theme (right). The visualization can be exported via the 'export image' link (bottom right).*

- $\mathbf{T_1}$ Explore a country dataset and identify relevant variables (weaknesses and strengths) (*intelligence*)
- $\mathbf{T_2}$ Analyze individual countries in detail (e.g. as alternative to invest); allow drill-down to question level (*design*)
- $\mathbf{T_4}$ Weight topics based on stakeholder priorities (*design*)
- $\mathbf{T_3}$ Search for alternatives with similar properties (*design*)
- $\mathbf{T_5}$ Compare countries and make a choice (*choice*)

4. The Visual MInGov approach

Our visualization system was designed to support decision making in the mining sector in an efficient and effective way. Two views support the exploration of individual country datasets ($\mathbf{T_1}$): the Matrix View (Sec. 4.2) and the Statistics View (Sec. 4.3). They also allow a drill-down to the question level ($\mathbf{T_2}$). The Weighted Matrix View (Sec. 4.2.1) incorporates the weighting of topics based on stakeholder priorities ($\mathbf{T_3}$). A Similarity Search (Sec. 4.6) enables users to search for similar countries ($\mathbf{T_4}$). Different countries can be compared with the Country Comparison View (Sec. 4.5) ($\mathbf{T_5}$).

4.1. Color Map

In the visualization system, we map the country performance scores on a discrete color map representing the four performance categories very low, low, high, and very high. According to the domain experts, two sequential, colorblind, and print-friendly color maps were needed - one for the Mining Sector Importance topics and one for the other topics. Since, The Mining Sector Importance topics do

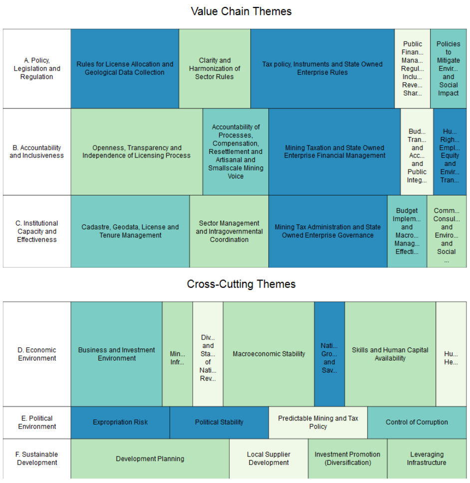

Figure 2: *Weighted Matrix View: Depending on the selected perspective (value chain or theme) and selected stakeholder priorities (here: country priorities) the sizes of the matrix cells are adapted.*

not provide insights in the country's performance, they need to be distinguishable from other topics. Based on these requirements, we selected two color maps with the ColorBrewer [HB03]: one multi-hue for the performance scores and one single hue for the Mining Sector Importance scores (see Fig. 1 (legends at the bottom)).

4.2. Matrix View

The Matrix View (Fig. 1) gives an overview of the topic scores of an individual country dataset (**T**$_1$). According to the domain experts the topics have a "natural" order which we consider in the visualization design. The questions in the dataset are grouped into 36 topics (colored cells and gray-scale bars on the right). The topics are grouped into seven themes (A-F, M). Some of the topics are additionally associated to the five levels of the mining value chain (1-5). These topics are organized in a matrix-like structure with the themes (A-C) as rows and the levels in the value chain (1-5) as columns. The remaining themes (D-F) are displayed separately below the matrix. The domain experts requested a distinguishable design for the "Mining Sector Importance" theme, since the underlying data does not provide information on the country's performance. Mining Sector importance topics are visualized via range charts depicting the minimal, maximal, and average question value within a topic (Fig. 1 right). The "Mining Sector Importance" scores are depicted via a gray-scale color map, while the other topic scores are depicted via a multi-hue color map (see Sec. 4.1). The Matrix View replicates the structure of the dataset defined by the domain experts. This structure does not allow an alternative display of the MInGov data. However, by removing one dimension in the upper matrix (value chain or themes), we obtain a tree that allows the application of alternative visualization methods. We integrated an icicle plot into our system. Users could choose between the value chain and the theme perspective, and then drill-down from the value chain (or theme) to the question level (**T**$_2$). Individual scores were depicted via a color map. The weighting was mapped on the cell height (**T**$_3$). We will not discuss this view in more detail, since the users preferred the Matrix View (see Sec. 5).

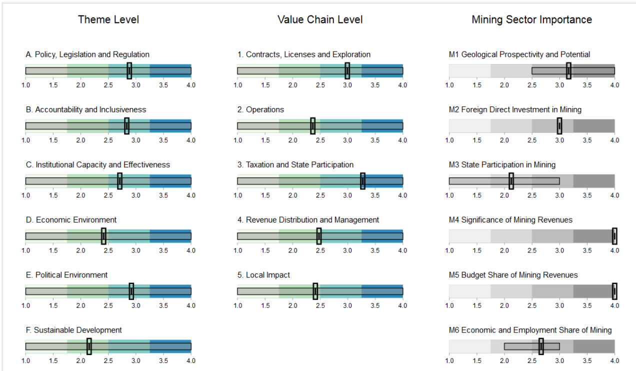

Figure 3: *Statistics View: Questions aggregated based on theme level, value chain level, or mining sector importance topics.*

4.2.1. Weighted Matrix View

The domain experts also requested the visualization of topic weights (**T**$_4$). This is realized in the Weighted Matrix View (Fig. 2). The area size of the topic cells is used to depict the topic weights. The mapping as shown in Fig. 2 is only applicable on two level hierarchies. Users can select whether they want to inspect the upper matrix from the value chain or the theme perspective. Based on the selection, the theme labels, or the value chain labels are removed. During the design phase, we also elaborated a visualization technique on the basis of a tree map, as an alternative to the weighted matrix (e.g., [JS91], [GACOR05]). Finally (together with the domain experts), we decided to withdraw the tree map since the reordering of topics caused by the tree map layout confused the users.

4.3. Statistics View

To get a high-level overview of the themes and the value chain levels, we included an additional Statistics View (Fig. 3). It aggregates the questions based on the overarching themes (left) and value chain levels (middle). To provide the full picture the mining sector importance topics are also shown (right).

4.4. Detail View

The Detail View (Fig. 4) allows the drill-down from topics to indicators to questions (**T**$_2$). The Detail View is accessed, whenever a user clicks on a cell or a bar in the Matrix or the Statistics View. A headline indicates the selected topic (e.g. "mining tax administration and state owned enterprise governance"). Below a list of indicators is presented, colored with respect to the average of the underlying question scores. Users can select one of the indicators to see the distribution of the question scores in the bar chart below. By selecting one of the bars in the bar chart, the underlying questions, their performance score, and their question type is shown.

4.5. Country Comparison View

The Country Comparison View (Fig. 5) raises the granularity of the analysis from single countries to the comparison of multiple countries (**T**$_5$). Users can compare several country datasets with respect to their value chain level, theme or topic scores. The comparison is realized by a radar chart. The domain experts preferred this compact representation over a grouped bar chart.

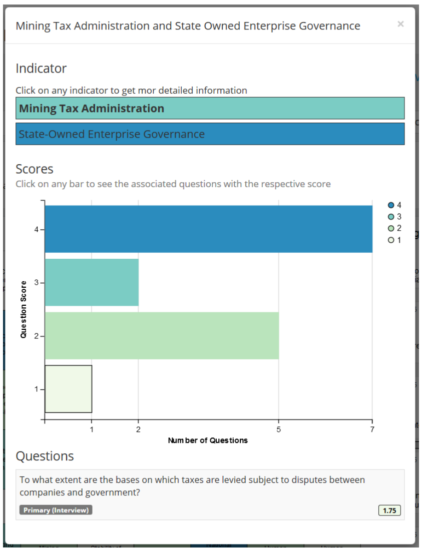

Figure 4: *Detail View (as shown when selecting the topic "Mining Tax Administration..."): Topic label, indicators assigned to the topic (in bars), and questions assigned to the indicators (in bar chart) are shown. Questions can be accessed by selecting a bar.*

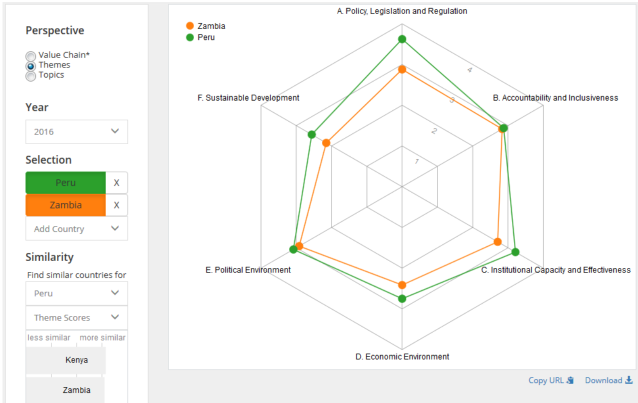

Figure 5: *Country Comparison. Countries are compared in radar chart. Value chain, theme, or topic level can be selected. Similar countries can be found with the Similarity Search (bottom left).*

4.6. Similar Country Search

Finally, we incorporated a retrieval of similar countries in the Country Comparison View (Fig. 5 bottom left) ($\mathbf{T}_4$). Based on the selected country and similarity measure the most similar countries are retrieved and depicted in a bar chart. The measure of similarity produces percentage scores, i.e., a perfect match has a score of 100%. Based on a discussion with domain experts, seven similarity measures were incorporated. The Euclidean distance between the following vectors is used: (1) all topic scores (excluding mining sector importance topics), (2) all value chain topic scores (excluding mining sector importance topics), (3) the mining sector topic scores, (4) all country specific weights, (5) all government weights, (6) all investor weights, (7) all civil society weights.

5. Usability Testing

We conducted a usability testing workshop with five mining experts at the Indaba conference [Ind17]. Users had to execute seven tasks with the visualization dashboard. After the task completion test an additional usability questionnaire allowed users to provide qualitative (open questions) and quantitative (Likert scale) feedback on the individual views and the overall system. In the second half of the workshop, we discussed our approach in the group.

In general, the designed visualization system was appreciated by the participants. As a user stated the "substance and data display are adequate for guiding governments in their agenda-setting". All participants were able to efficiently complete the tasks. While the users accepted the mapping of topic scores on color, the mapping of weights on the cell size was questioned. Participants noted that they could easily distinguish large from small cells. However, the identification of cells with the same size but different aspect ratios was difficult for the users. Only the icicle plot received mainly negative ratings. One participant questioned the added value provided by this view. Another stated that is was "difficult to view". Since the view was provided as an alternative to the Matrix View, we might remove it from the system. Although, the Statistics View was rated positive, we had to explain the participants that the bars are clickable for drill-down. The participants' missing awareness of interactivity in the views was a lesson we learned from the workshop. The Similarity Search was also rated very positive by the participants. One participant even requested more flexibility in the similarity measures, the seven similarity scores provided by the view should be augmented. Although, the dashboard was designed for larger displays, one user was successfully conducting the test with a mobile phone. Simply the height of the bars in the Detail View would have to be decreased to fulfill the usability on small screens.

6. Conclusion

We presented our approach on providing visual access to country-based performance indicators in the mining sector. First, we provided a domain characterization of the mining sector, discussing the structure of the MInGov dataset, the relevant stakeholders in the sector, and the tasks to be supported along mining-related decision making processes. Second, we introduced our visualization system that supports these tasks by providing an intuitive access to the categorical questionnaire data, organized in a hierarchical structure. Finally, we discussed the results of a user evaluation conducted with five domain experts at an international mining conference. We hope to inspire further visual analytics and information visualization design studies that support evidence-based decision making in the mining sector.

Our ongoing work, will be continued after this first milestone. As a first step in future work, the visualization system will be made publicly available to reach a wider range of users. Second, we will conduct an online evaluation to gain quantitative feedback. Based on this feedback and the feedback from the user workshop an improved version will be designed. In the meantime, further country datasets will be collected by the World Bank Group. It is also envisioned to repeat the assessment in a periodicity between one and two years, which adds another user task to our current list: the temporal comparison of a single country over several years.

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