PetroVis: Exploratory Visualization for Petrographic Characterization

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ABSTRACT

The process of petrographic analysis aims to help oil and gas experts in building a prediction model which would better characterize and explain the behavior of the hydrocarbon reservoir. However, making informed decisions regarding a good characterization requires exploration and integration of very large amounts of data presenting many challenges in which high dimensionality is the most important one. We present PetroVis, our visualization prototype which we developed with the goal of supporting the visual analysis of petrographic data. PetroVis incorporates the use of multidimensional visualization techniques coupled with statistical methods in order to enable identification, classification, validation and interpretation of petrofacies. We developed PetroVis continuously guided by the feedback and suggestions from our domain collaborator.

Index Terms: Petrographic characterization, Multidimensional visualization, Parallel coordinates;

1 INTRODUCTION

Petrographic data is usually represented as a high dimensional database detailing rock samples from some geological basin, a basin is a depression in the crust of the Earth in which sediments accumulate [2]. In our work, we tried three different petrographic datasets representing the description of rock samples from three different basins. Experts analyzing such data are faced by many challenges due to the use of manual methods and the lack of effective visual analytic tools to support them while exploring their data.

We designed, implemented, and evaluated, PetroVis, an interactive exploratory visualization prototype aiming to support the analysis of petrographic data (Fig. 1). PetroVis consists of a set of visualizations organized through two analysis modes. The first aims at helping the experts visually analyze the data samples and correlate the attributes. The second provides advanced data correlation by integrating statistical methods to extend the parallel coordinates visualization. The preliminary findings from the evaluation we conducted highlight the potential benefits of using PetroVis to visually analyze the petrographic data.

2 PETROGRAPHIC-CHARACTERIZATION BACKGROUND

The process of petrographic data analysis generally includes different phases involving many tasks. In the first phase, geological samples are gathered from different wellbores and at different depths. The second phase involves the generation of petrographic characteristics through the microscopic examination of the gathered samples. The third phase incorporates the use of statistical packages including unsupervised clustering algorithms to generate the petrofacies (groups of samples sharing the same geological properties). Finally, petrofacies analysis is performed including properties correlation as well as validation and qualification of the petrofacies. Such analysis is usually carried out manually due to the lack of effective computational tools [2]. Clearly, experts' knowledge is needed to make sense of the analysis results prior to building the actual reservoir prediction model.

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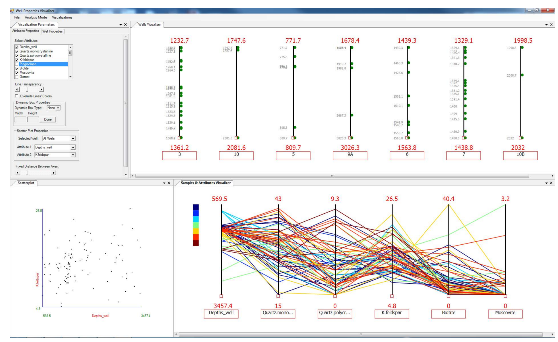

Figure 1: Overview about the main coordinated visualizations of PetroVis.

Before the manual validation of the petrofacies (clusters), and in a typical clustering scenario, the expert would run a script in the statistical package over some input dataset in order to generate the petrofacies. After that, the expert will check the samples in each cluster and compare them and their properties to assure that they are not misclassified. This task of validating the clusters also involves trying different clustering methods and tuning their parameters in order to optimize the generation of the potential petrofacies. Another important task for understanding the distribution of samples is the qualification (classification) of the data. Our domain expert collaborator described qualification wherein minerals (data attributes) are correlated in order to identify which of them affects certain petrofacies. For instance, qualification may enable grouping all the petrofacies who possess high amount of cement together. Interactive visual exploration of clusters, minerals and samples can be very helpful by supporting the cognitive power of experts leading to faster analysis.

2.1 PetroVis

Our choice to visualize the petrographic data was highly influenced by the structure and the dimensionality of the data. In general, domain experts are familiar with scientific statistical tools that include cross-plotting visuals for correlating two or three data attributes. Accordingly, we decided to use and extend the technique of parallel coordinates (PC) [3] as a widely used multidimensional visualization technique in order to support the exploration of the highly-dimensional petrographic data. In PC, each dimension (in our case, each property counted in the microscopic analysis) is represented as a vertical axis and they are organized as uniformly spaced lines. Each sample of the database is mapped to a polyline that traverses across all of the axes crossing each axis at a position proportional to its value for that dimension. To alleviate the possible cluttering of the data within the PC visualization we adapted certain strategies such as data brushing interactions and axis reordering [4].

An early implementation of PetroVis was part of the computational methodology proposed by Cevolani et al. [2] to study heterogeneities in petroleum reservoirs (Fig. 1). In that work, experts successfully used PetroVis to analyze a petrographic dataset. Here we present an improved implementation of PetroVis taking into consideration the earlier suggestions provided by the experts. We also describe the findings of the evaluation we conducted highlighting the potential benefits of using PetroVis in visually analyzing other petrographic datasets. We conclude with lessons we've learned from the characterization of domain and the development of PetroVis.

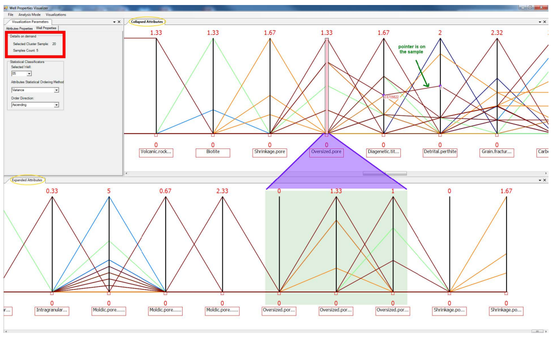

Figure 2: Mater/Detail visualization showing the mineral "Oversized.pore" as collapsed attribute (top) with its expanded attributes being highlighted upon interaction (bottom).

The current implementation of PetroVis includes many interactions to support the experts while exploring their data. For example, the expert can perform data filtering (within any visual) to refine the samples subset, while being able to inspect any data sample using the mouse pointer (simulating the details-on-demand design guideline [5]). PetroVis focuses on supporting intra-well visual exploration wherein the analysis is carried out for each well individually through two coordinated (enhanced) PCs (Fig. 2). In this visualization, the data attributes that share certain properties are combined together. The combination is simple: it is the sum of the percentage of the attributes that represent the same mineral (as shown in the example in Fig. 2). In particular, the user can select one of the combined attributes and the other coordinated visual will automatically highlights the expanded attributes, if any, for that selected attribute.

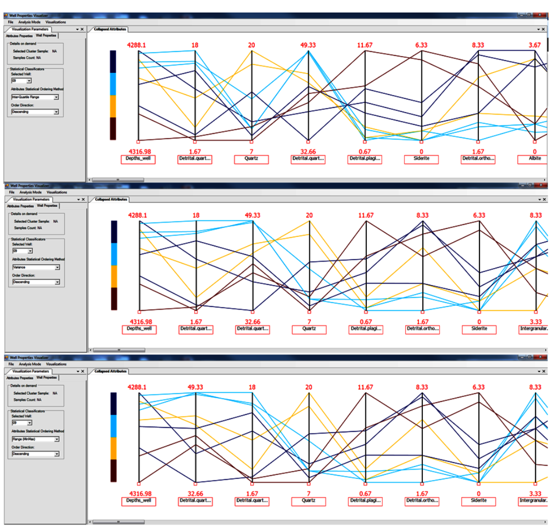

Figure 3: The result of applying three different statistical methods to refine the ordering of the attributes within the PC visualization.

In the early implementation of PetroVis, we introduced a new visualization wherein statistical methods are coupled within the PC visualization to refine the ordering of data attributes, aiming to simplify the high-dimensionality of the data [2]. Our idea is similar to the idea of importance-oriented dimension ordering discussed in the work of [1]. Our expert collaborator successfully tried this feature and strongly suggested to extend it with additional statistical methods. Indeed, we extended that feature by integrating the statistical methods of Inter-Quartile Range and Range (Max-Min), aiming to override the default ordering of the data attributes, thus allowing importance-based analysis (Fig. 3). In particular, the importance of each mineral in our PC visualization is evaluated with respect to the statistical distribution of the data samples' values. The density of the values for each attribute is used as a measure to assign an ordering rank to that attribute. Additional interactions are also incorporated allowing the user to select whether the ordering is carried out ascending or descending, and whether such interactive reordering is happening per well or per cluster.

The preliminary evaluation of PetroVis involved three domain expert participants, with feedback that reflected about the usability features of our tool, and confirmed its potential for petrographic data analysis. One expert participant expressed, *"A big importance is that we are able now to (exactly) visualize which minerals control the petrofacies"*. PetroVis was also evaluated as part of a real task-oriented scenario aiming at confirming the validity of the resulted clusters, the distribution of the samples, and the effectiveness of the clustering method. The results highlighted how PetroVis enabled the expert to identify and understand why certain data samples exist within specific clusters. Furthermore, the expert reported that such insight aided her in determining which of the clustering methods is better for her analysis. Though, we still believe that further evaluation including additional domain experts is needed to confirm the effectiveness of PetroVis for the analysis of petrographic data.

During the development of PetroVis, we noticed a resistance of the experts regarding trying the new visualization. For that, we adopted familiar domain visualization such as scatter plot, and integrated that in coordination with our new visualization. As a result, the experts were able to learn the new visualization more quickly.

3 Conclusion and Future Work

PetroVis represents a work-in-progress with many things to improve. Indeed, we received suggestions for improvements from the experts during the initial evaluation sessions that we conducted. For instance, we are planning to match the color maps used in our visualization with the color maps used within the experts' statistical tool, aiming to make it easier to compare and correlate the results.

PetroVis only supports intra-well analysis, but we believe in a real potential to extend this work further to support inter-well analysis, to correlate and qualify the data among multiple wells, and we are considering this as part of our future work.

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References

[1] M. Ankerst, S. Berchtold, and D. Keim. Similarity clustering of dimensions for an enhanced visualization of multidimensional data. In *IEEE INFOVIS*, pages 52–60, 153, 1998.

[2] J. T. Cevolani, A. E. Mostafa, E. A. V. Brazil, L. C. de Oliveira, L. G. da Fonseca, and M. C. Sousa. Computational methodology to study heterogeneities in petroleum reservoirs. In *EAGE SPE Europec*, 2013.

[3] A. Inselberg. The plane with parallel coordinates. *The Visual Computer*, 1(2):69–91, Aug. 1985.

[4] W. Peng, M. O. Ward, and E. A. Rundensteiner. Clutter reduction in multi-dimensional data visualization using dimension reordering. In *INFOVIS'04*, pages 89–96. IEEE Computer Society, 2004.

[5] B. Shneiderman. The eyes have it: a task by data type taxonomy for information visualizations. In *Visual Languages, 1996. Proc., IEEE Symposium on*, pages 336–343, 1996.