Visual Analysis of Aluminum Production Data with Tightly Linked Views

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Abstract

Monitoring, analyzing and determining the production quality in a complex and long-running process such as in the aluminum production is a challenging task. We aim to support production data exploration in the aluminum industry. To this end, we developed the first version of the interactive visual analytics tool ADAM. The main aspect of concern is product quality, which is obtained from the quality inspection of aluminum plates at the end of the production process. A set of tightly linked views of production parameters with cross-filtering capability support the inspection of factors possibly influencing the product quality. ADAM allows highly responsive forward and backward search in the quality and production parameter space, leading to an understanding of important parameters, and supporting production planning and process improvement. Our approach was designed in an iterative development cycle guided by domain requirements from a major aluminum producer. We introduce the domain problem, propose a visual analytics design to support the problem, and demonstrate by application to real production data the usefulness and possible insights which can be obtained.

CCS Concepts

• ***Human-centered computing*** → *Visual Analytics; Data Exploration;*

1. Introduction

Due to the digitization of industry (sometimes labeled Industry 4.0) and the spread of data-driven industrial applications, the use of data analysis and visualization in various areas, including manufacturing, plays a crucial role in further growth, productivity, and innovation [LKY14]. With the growing amount and complexity of production data, effective visual exploration techniques are needed to support engineers in gaining insight from data and further optimizing and improving their production processes. Few visual analytics solutions targeting production scenarios have been presented in recent years [MHSG02], [JHP*14], [XMRC17]. The focus of our research is production data in the aluminum industry, precisely in aluminum casting, and none of the existing visual analytics solutions meets the specific requirements of this problem.

A simplified process of production in aluminum casting from recycle material until final products includes melting, alloying and further treatment, casting, homogenization, rolling and quality control. Ingots are shapes cast from melted aluminum suitable for fabrication processing using methods such as rolling, extrusion, and forging [VD12]. During a parallel aluminum cast, each batch results in several ingots via a casting pit. These ingots are rolled to plates and sheets. Material quality testing on rolled aluminum plates ensures high-quality standards in the final products [PABE08]. The explanation and eventual reduction of defects is a key priority in production process analysis to meet high-quality standards. The design of interactive visualization of this complex data is highly desired to explore the data, inspect for possible influences of production parameters on product quality, and to promote a better understanding of parameters in production. The contribution of our work is the system ADAM, an acronym for aluminum production Data Analysis and Monitoring. Its purpose is to meaningfully present various parameters of the production process to the end users i.e., material engineers in casting and rolling. ADAM is partly inspired by work on exploratory search [Mar06], [WR09], and visualization tools [BHJK18], [GFG*14], [WMA*16] and visualization techniques [KKE10].

2. Design Concept ADAM

In general, many domain experts are used to working with MS Excel for visualizing and exploring unwanted inclusions in ingots. To date, sensors at the various production steps deliver a stream of production data, which is time-dependent and typically high-dimensional. While the data is continuously captured, its preprocessing and analysis are a challenge, due to the size and heterogeneity of data. The dataset was collected from different data sources,

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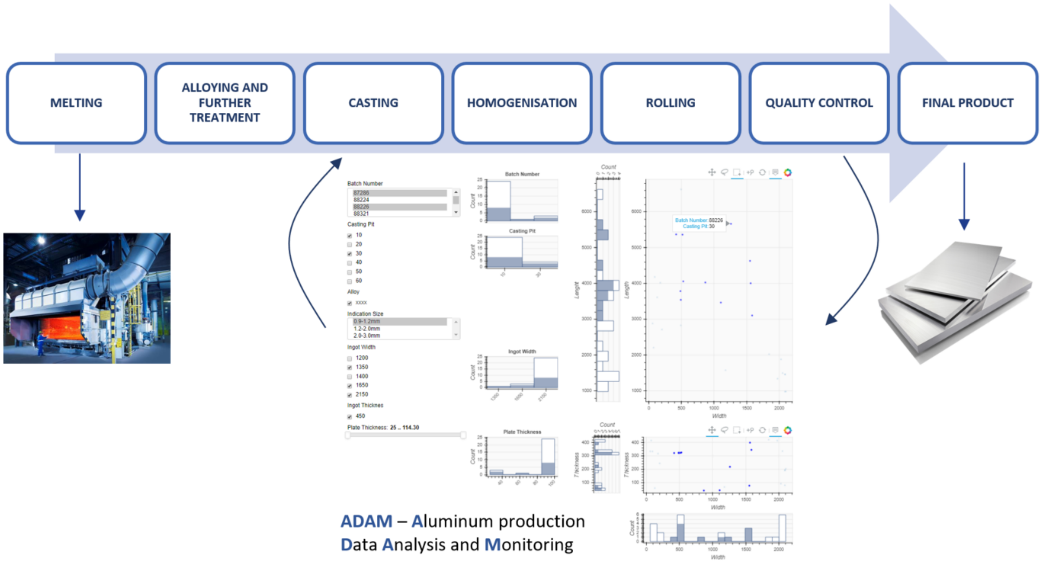

Figure 1: *ADAM System Architecture. Highlighted parts on histograms show the selected region of points.*

including sensor data from each step in the production process. As a required step, we have worked several months with domain experts in data preprocessing. Further, we iteratively designed a visual analytics solution. Two scatter plots for visualization were selected, showing the front and the top view of the ingot, linked with three frequency histograms which provide information about the number of defects in length, width, and thickness of cast ingot. Color-coded circles (blue, orange and red) in the scatter plots represent the values of defect indications with specific diameters. Filters such as a batch number, casting pit, ingot width, indication size, and plate thickness enable forward search by updating plots. All histograms in the tool are linked to scatter plots. Interactive changes made in one visualization are automatically reflected in all other visualizations. With the help of brushing it is possible to select a region of points in one scatter plot, that will highlight the parts for selected and nonselected points on frequency histograms and in the other scatter plot. Highlighted parts on frequency histograms will enable the backward search. For example, selecting a region of points and analyzing the highlighted parts on histograms which may differ significantly from the histograms containing complete dataset, may be an indication that only some batches, plate thicknesses, etc. would produce specific defect indication patterns and which the domain expert should investigate further.

3. Initial results

Recently, the first prototype of ADAM was successfully integrated into the aluminum producer's system landscape and tested by material engineers. We conducted informal interviews with material engineers who listed some of the benefits of the tool: interactive data exploration, reducing the search for information, and enhancing the recognition of patterns. The test users reported that a visual way of examining data has the advantage of quickly identifying subgroup differences. ADAM allows data exploration, providing insight into the data in various outcomes while investigating groups of multiple parameters that can cause defects indication. For example, we can easily analyze if plate thickness correlates with the number of defect indications. It is possible to see visually prominent patterns (for example vertical or horizontal lines) concerning the position of defects indications in front and top view, e.g., edge cracking, which occurs during rolling. Besides exploration, ADAM can also be used for comparison, e.g., comparison of histograms for different indication sizes.

4. Summary and Future Work

This work proposes to support production data exploration in aluminum casting with an interactive visual analytics tool ADAM. The purpose of ADAM is to help monitor, analyze and determine influence parameters in the production process with interactive cross-filtering, followed by multiple views of production data.

We are currently in the process of adding more filters in the tool to help with the analysis of parameters, such as different production shifts (the impact of cast workers), weather conditions during the cast and raw material that was used during the melt. Another important next step will be to implement data-driven guidance mechanisms (in the area located below filters) to support end-users by automatically computing the difference in the distribution of all production data, to a selected subset. Future research will also consider extending the tool with glyph-based visualizations. Visualization of the production data using a radar chart (radial parallel coordinates) approach, where axes show the different dimension and lines connect the different quantities along the dimensions, can allow comparison of quantities by shape. In addition, data clustering and glyph-based cluster comparison may help scaling with larger data sizes in the future.

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