


A Rule-Based Quality Analytics System for the Global Wine Industry

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ABSTRACT

The global wine-making industry has faced challenges due to the increasing demands of consumers, particularly in emerging markets such as China, Brazil, India, and Russia. Controlling the quality during wine production is one of the key challenges faced by global winemakers to produce wine with appropriate sensorial properties tailored to specific markets. The wine production quality is constituted from a number of environmental factors such as climate, soil, and temperature, which affect the sensorial properties and the overall quality. This paper proposed a rule-based quality analytics system (RBQAS) to capture physicochemical data during wine production and to investigate the hidden patterns from the data for quality prediction. It consists of IoT for data capture on a real-time basis, followed by association rule mining to identify relationships between sensorial and physicochemical properties of wine.

KEYWORDS

Association Rules, Data Mining, Global Wine Industry, Physicochemical Property, Predictive Analytics, Quality Management, Sensorial Property, Wine Production

1. INTRODUCTION

With customers nowadays having higher expectations on products, firms are urged to improve their product quality with continuous effort, in order to remain competitive in the market. The foremost is to ensure the conformance of products with given requirements and standards and this conformance can be achieved through systematic measurement and control to detect special causes of variation. Jabnoun (2002) proposed five processes involved in quality assurance: setting the standards, providing the inputs that enable workers to conform to standards, measuring performance, analyzing the measured performance data, and taking corrective actions. However, these quality assurance processes tend to be reactive. Problems are corrected only when the defects are identified. A more proactive approach is needed to predict the quality and take corrective actions earlier before the products with poor quality are produced.

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The global wine industry is forced to be more aware of the quality assessment and testing, due to the increasing demand. Wine making is sophisticated, which is determined by a number of factors such as climate, soil and temperature. These environmental factors lead to the physicochemical properties of wine, such as pH, density and acidity, affecting the sensorial properties and the overall quality of wine.

Without knowledge support driven from historical data, decision makers are not effective in determining optimal winemaking conditions which have a great impact on both the physicochemical and sensorial properties of wine.

To optimize the cost and quality, it is essential to have effective determination on the winemaking conditions, as the input resources are highly related to the production cost. Furthermore, the lack of technological resources makes it difficult for the industry to classify the wines based on the chemical analysis as it takes lot of time which imposes impact on the financial.

Faced with the challenges from the global market, in this paper, a rule-based quality analytics system (RBQAS) for the global wine industry is proposed to capture physicochemical data during wine production and to investigate the hidden patterns from the data for quality prediction. This system is developed with the motivation and mission to provide wine manufacturers a better structured and managed quality analytics system, which can provide global wine makers a more standardized quality.

The proposed RBQAS consists of data capture on a real-time basis, using the latest IoT technology, followed by association rule mining to identify relationships between sensorial and physicochemical properties of wine. Association rules are mined on a quality data set for quality analytics of wine. It relates combinations of quality attributes (wine quality) and subsets of independent attributes (the physiochemical properties of wine). The rules represent valuable knowledge to predict and improve the wine quality.

Nevertheless, there are two challenges faced by the wine manufacturers when applying association rule mining for quality management. The first challenge is the extremely large number of rules obtained, it becomes impractical for wine manufacturers to identify critical rules for quality prediction. The second problem is that the discovered rules without validation could be with poor generalization potential. These highlight the importance of rule reduction and rule validation in quality analytics.

The previous works using data mining approaches with different algorithms mainly focus on the prediction of wine quality, however, do not show the causal effects and correlations of the parameters.

Accordingly, this paper addresses the following three research questions:

1. How to conduct a rule-based quality analytics to discover the relationship between sensorial and physicochemical properties of wine?
2. How to reduce the amount of association rules for the ease of decision making in quality analytics?
3. How to identify and remove rules with poor generalization potential so that the rules could be general enough for applications on a global scale?

The rule-based algorithm proposed in this paper advances the existing research, by offering a better understanding on the causal effects of the parameters on wine quality. Specifically, the proposed algorithm supports both descriptive and predictive analytics, wine manufacturers are provided with decision support in determining the appropriate chemical parameters and corrective measures for better wine quality. Furthermore, the knowledge discovered by the RBQAS can serve as an additional supplement to wine manufacturers' experience and is feasible to be generalized for wider applications in the wine industry.

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