Applied Soft Computing xxx (2014) xxx–xxx

Contents lists available at ScienceDirect

Applied Soft Computing

journal homepage: www.elsevier.com/locate/asoc

Soft computing for overflow particle size in grinding process based on hybrid case based reasoning

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ARTICLE INFO

Article history:
Received 31 December 2013
Received in revised form 4 September 2014
Accepted 19 September 2014
Available online xxx

Keywords:
Overflow particle size
Soft computing
Case based reasoning
Community finding

ABSTRACT

The overflow particle size of cyclone is one of the most significant performance indices in the process of ore grinding. Given the measuring difficulty under the current industrial conditions, a hybrid method, which combines community finding (CF) of a complex network with case-based reasoning (CBR) is proposed in this study. The CF method with a new evaluation criterion for the vertex combination degree is designed to select the typical cases from the constructed communities, and a k-nearest neighbors (k-NN) based strategy with multi-similarity threshold is proposed in the case retrieval process. To verify the effectiveness of the proposed method, a number of comparative simulations by using the real-world data coming from a copper–molybdenum concentration plant are carried out, and the results indicate that the proposed method can provide a good measure quality for the industrial application.

1. Introduction

The overflow particle size is one of the most significant quality targets in grinding process, which has to be strictly controlled to ensure the performance of the subsequent production processes such as magnetic separation, flotation, etc. However, in concentration plants, the overflow particle size is rather difficult to be directly measured by generic instruments or devices, since the particle size analyzers used to be largely impacted by industrial noises or instrumental failures [1].

Soft computing method, regarded as an effective tool for supervising and controlling the industrial processes, could be a positive attempt for the industrial variables measurement. At present, a series of soft computing approaches have been successfully applied to data prediction, fault diagnosis, error estimation, condition monitoring and so on [2–6]. It was clearly to know that a mechanism-based soft computing could lead to the perfect measuring results [7], but it is extremely hard to employ a mechanism-based model to describe a complex industrial process accurately. In the perspective of data-driven approaches, a number of machine learning-based methods were proposed in literature. For instance, a partial least squares regressor was used to build up a stock index prediction model in Ref. [8]. This method required a large number of sample data, and was too sensitive with respect to the measurement errors. Recently, a soft computing for the state estimation of a three-phase asynchronous motor was proposed in Ref. [9] for evaluating the relative performance under various devices conditions. Similarly, it was however difficult to build a state space model, and the unpredictable disturbances might bring about obvious errors. Besides, an artificial neural network was modeled for the earthquake prediction in Ref. [10], but the reported approach suffered from a long period of training time and the results could be easily trapped into local optima. Since it was extremely hard to meet the industrial measuring requirements when a real-world system was complicated, a class of hybrid modeling method integrated with the mechanism and the practical operational data analysis could be a potential research direction [11,12]. In such a way, a hybrid model based on rough set classification and multiple regression was presented in Ref. [11]. Also, a combined neural network with support vector machine was designed in Ref. [12] for the machinery fault detection. However, due to the characteristics of time-varying and nonlinearity of the industrial systems, it was necessary for soft computing to update the system models online so as to adapt to the operational conditions [13–15].

It was noticeable that case based reasoning (CBR) using the operational experiences only needs to add new cases to the case base instead of updating the model construction, and provides a class of feasible approach [16–20]. In practice, given the cover range and the typicality of the sample data are crucial for the CBR, a number of sample selection methods were proposed in literature. For example, a K-means clustering method was reported in Refs. [21,22] to

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http://dx.doi.org/10.1016/j.asoc.2014.09.035
1568-4946/

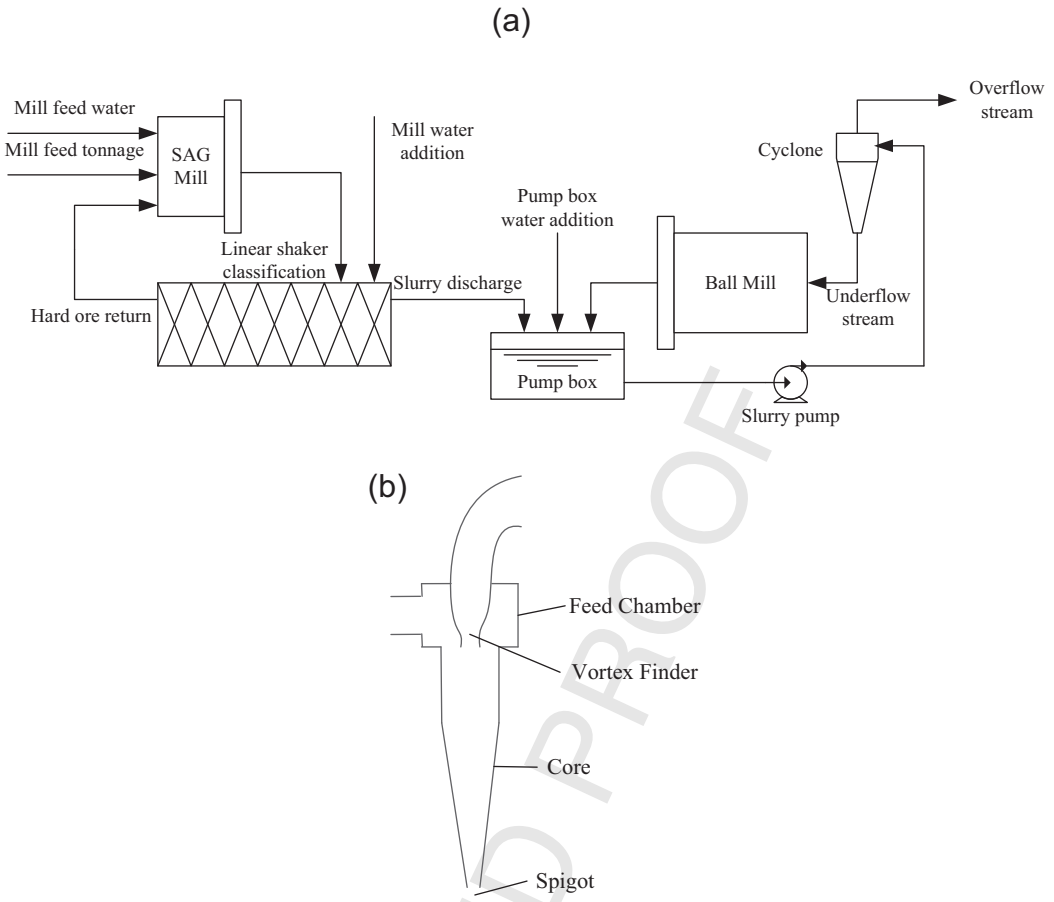

Fig. 1. (a) Diagram of grinding process. (b) Structure of a cyclone.

select the typical samples. However, it was usually hard to determine the amount of original clusters and the clustering centroid, which greatly influence the results. A Renyi entropy evaluation was used to ensure the sparseness and typicality of the sample sets in Ref. [23], but the distribution density function was rather complex to be solved for such an industrial application. A gray correlation grade used to analyze the relationships between different systems was presented in Ref. [24]. However, this method is invalid when the sample data fluctuate wildly. Recently, it was worthily paid more attention to the complex network model, which had been applied to some industrial instances, see the construction of a knowledge system in Ref. [25], the financial market analysis [26], the recognition of biologic neuronal systems [27], etc. The complex networks were employed to analyze the basic cell circuit and simulate the interrelation of the cell structure [28], to represent a shape contour [29], and to establish a climate model based on the characteristics of climate changing in time and space [30]. These studies mentioned above indicate that a complex network model can be viewed as an effective tool to represent the internal relationships of a system.

In this study, combining the community finding of complex network with CBR, a hybrid soft computing for the overflow particle size is proposed. Firstly, in the process of case base construction, the community is found by using the industrial data based on the network modularity. By the proposed concept of the vertex combination degree (the evaluating indicator), the case base is constructed via selecting the typical samples from each community. Secondly, in the case retrieval process, a k-NN based strategy with multi-similarity threshold is designed to ensure a reasonable number of the cases similar to the current operational condition. Finally, in the case reuse process, the community distribution of the searched cases is taken into account so as to improve the modeling accuracy. To illustrate the effectiveness of this method, a number of comparative experiments for a typical grinding process were conducted, and the practical application in a concentration plant indicate that the proposed method provides a higher accuracy and lower computational complexity.

The rest of this paper is organized as follows. In Section 2, the practical problem in a grinding process is briefly described. The proposed CF-CBR method is illustrated in detail in Section 3. In Section 4, the validation experiments are carried out; while, Section 5 draws some conclusions resulting from this study.

2. Problem descriptions

This section presents a typical grinding process to clarify the technical background of the proposed soft computing study. The mineral bearing ore are transported to the crushing process to form the suitable size of ore particle, then are passed into the grinding process for the fine size. During grinding, water is added to create “slurry”. A typical grinding circuit can be illustrated as Fig. 1(a), in which the first-step grinding consists of a SAG (semi-autogenous grinding) mill and a linear screening classification, and the second-step grinding involves a ball mill and a cyclone. Cyclone is a continuous classification (sizing) device that uses centrifugal force to accelerate the settling rate. When the slurry enters the cyclone, the fine grade ore goes into the overflow stream, and the coarse ore goes into the underflow stream. The underflow contains the coarser solids produced at the higher density discharges from the spigot; whereas, the fluid steam, which discharges through the vortex finder at the cylindrical end of the cyclone body, is referred to as the “overflow”, which contains the finer solids produced at

Please cite this article in press as: Z. Lv, et al., Soft computing for overflow particle size in grinding process based on hybrid case based reasoning, Appl. Soft Comput. J. (2014), http://dx.doi.org/10.1016/j.asoc.2014.09.035