Knowledge Modelling and Comparison of Cyanide-free Gold Leaching Processes – Research Summary

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Abstract. There is increasing pressure from authorities in many countries to find cyanide-free methods for gold processing due to environmental and safety risks. Therefore, it is now under investigation whether the knowledge extraction and formalization procedure can be applied for comparing cyanide-free leaching methods for a certain type of raw material. Research is needed to determine and code the similarity models related to cyanide-free processes. The task is challenging, since most of the processes are still in the development phase and there is not much information available on the new-coming processes.

Keywords: Case-based reasoning, Gold leaching, Cyanide-free

1 Introduction

At the moment, primary gold production is based on cyanide leaching of gold ores [4]. Cyanide has been the sole industrially utilized gold leaching method for decades, but due to health and environmental risks, great legislative pressure is building up for searching optional leaching methods. Currently there are several cyanide-free extraction processes under development for gold ores and concentrates, such as the ones based on chloride [3], bromine-bromide [4], and glycine [5]. Only one cyanide-free gold leaching method, thiosulfate, is in industrial use [2].

The author is conducting doctoral studies in Aalto University, Finland with the aim to develop a tool for comparing cyanide-free gold leaching methods. The tool will uti-lize case-based reasoning (CBR), which uses fuzzy logic to compare real life cases with the user's input material [1]. A CBR tool already exists for comparing established, in-dustrial process chains [6]. In that project, CBR was selected as the decision method, because it enables the comparison of cases with several different variables and exact matches are not needed as it merely compares the similarity of previous cases with the new case in question [7]. However, the research topic of this doctorate is very different due to the early stage of development in the field of cyanide-free gold processing. The case base will be composed of laboratory experiments instead of whole industrial pro-cesses. Where Rintala et al. [6, 7] developed a CBR tool for selecting whole process chains for gold processing, from ore to final product, this project aims for a tool comparing an individual treatment i.e. gold leaching stage. The preliminary title of the doc-toral thesis is “Knowledge modelling and comparison of cyanide-free gold leaching processes”.

In addition to the CBR tool, new hydrometallurgical research will be made in the field of cyanide-free gold leaching. When possible, this new information will be incorporated into the CBR tool, either as additional cases or as a basis for constructing similarity models.

2 Research tasks

The tasks of the research project are divided into two categories; implementation of the process selection tool (T1) and evaluation and development of existing cyanide-free leaching methods (T2).

2.1 Task 1

The first task is divided into four sub-tasks. First, the amount and quality of the relevant and available information needs to be mapped (T1.1). Then a simple prototype tool is developed for general use (T1.2) and a user interface will be constructed (T1.3). After the construction of the prototype tool, a more complex tool will be implemented for professional use (T1.4).

2.2 Task 2

Task 2 is also divided into four sub-tasks. First, the most promising cyanide-free gold leaching methods are determined for further inspection (T2.1). Simultaneously, an extensive literary research is conducted to support both T2.1 and the construction of the CBR based tool (T2.2). Then the functionality of selected leaching processes is experimentally verified (T2.3). Challenges detected during the experiments are taken under closer inspection and attempts will be made to discover solutions to these processing difficulties (T2.4).

2.3 Research period abroad

A half-year research period is being arranged to the research group of Professor Thomas Roth-Berghofer in the University of West London (UWL). Their group has extensive knowledge on CBR applications and this collaboration will greatly benefit both univer-sities.

2.4 Schedule

The schedule for the research work that will be carried out are presented in Table 1. The doctoral dissertation will be composed simultaneously with the research work over the three-year-project.

Table 1. Schedule for the research tasks.

Objective	2016		2017		2018	
T1 Implementation and development of cyanide-free process selection tools						
T1.1 Information qualification	■	■				
T1.2 Prototype tool	■	■	■			
T1.3 User interface			■	■		
T1.4 Tool for professional use				■	■	■
Process evaluation and experimental research						
T2.1 Process selection	■	■	■			
T2.2 Literature research	■	■	■	■	■	■
T2.3 Experimental research	■		■	■		
T2.4 Process development				■	■	■

2.5 Progress so far

This project began in February 2016, when the author started as a doctoral candidate in the research group of Hydrometallurgy and Corrosion in Aalto University. Since then, a conference paper for ICCBR'16 has been completed and a non-peer-reviewed paper has also been written for a gold processing conference ALTA2016. Altogether, the project has advanced as planned; all tasks scheduled to begin during spring 2016 have been initiated (T1.1; T1.2; T2.1; T2.2; T2.3).

3 CBR Tool

3.1 Selection of Methodology

Rintala et al. [7] compared three decision support systems (Decision tree, Multi-criteria decision making, Case-based reasoning) and three optimization methods (Artificial neural network, Ant colony optimization, Genetic algorithm) for aiding professionals in designing hydrometallurgical processes. The main reasons for them selecting CBR as the best option for hydrometallurgical applications were that the exact relations between parameters aren't needed and that the system can be used with incomplete input data. [7] Though this project is different from the one conducted by Rintala et al., it is similar with regards to the knowledge being fuzzy and the case sources often lacking information. Therefore, CBR was selected also for this project as the used methodology.

3.2 CBR Application

A preliminary knowledge model has already been constructed using the myCBR 3.0[1] open source software and a detailed description of it will be given in the author's poster

[1] http://mycbr-project.net/

presentation in ICCBR'16. Naturally, this is just a simple beginning, on which the author intends to build upon later during this project. In order to illustrate the tool, the preliminary model is described here in short.

The system utilizes attributes presented in Table 2. The attributes were selected based on a review article analysis and interviews of hydrometallurgical professionals.

Table 2. Selected attributes for the preliminary knowledge model

Attribute	Type of attribute
Method	Symbol
Mineral 1	Symbol
Mineral 2	Symbol
Gold content [g/t]	Floating point number
Extraction [%]	Floating point number

The case base of 24 specimens was compiled from various scientific articles that presented experimental data on cyanide-free leaching of gold ores. As an example, an imaginary case is presented in Table 3.

Table 3. An exemplary case

Attribute	Value
Method	Thiosulfate
Mineral 1	Pyrite
Mineral 2	Hematite
Gold content [g/t]	7.5
Extraction [%]	89.6

Similarity models were developed for each attribute. Only two methods were present in the cases and therefore the similarity between those values was either 1 or 0. Attributes of the type Floating point number were given linear distance functions, whereas the mineralogical attributes Mineral 1 (most abundant in the ore) and Mineral 2 (second most abundant in the ore) were assigned similarity values based on the types of metallic and non-metallic chemical elements present in the minerals. The cases were assigned global similarities from 0.00 to 1.00 based on the combined local similarities.

One possible way for a researcher to utilize the tool is when they are faced with a gold ore that has not been experimented on with cyanide-free leaching techniques. They would analyze the material, query its mineralogy and gold content and as a result they would get the previously conducted experiments on most similar gold ores. This way they could aquire relevant information about the cyanide-free techniques applicable for their particular material. Then they could perform experiments on the material, thus producing a new case for the case base.

At the moment, the solution does not describe the leaching technique in more detail than just the leaching agent and the acquired result in the form of the *Extraction* attribute. As the tool is developed, more process parameters will be added such as temperature, pressure and solid-liquid ratio.

Towards the end of this PhD, an evaluation will be performed in the form of an actual material that will be queried and laboratory scale test that will be conducted on the basis of the results given by the CBR tool. Alternatives to CBR have yet to be considered in this project.

4 Doctoral Thesis

The doctoral dissertation will be a thesis by publication, consisting of a published conference paper and journal articles. At the moment, the scheme for the publications is as follows:

- Applicability of case-based reasoning for selection of cyanide-free gold leaching methods
  Conference: ICCBR'16, Atlanta Georgia, USA (accepted)
- A case-based reasoning tool for comparing cyanide-free gold leaching processes
- Evaluation of a case-based reasoning tool for comparing cyanide-free gold leaching processes
- Challenges related to gold ore leaching in chloride solutions – from laboratory scale to industrial process

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