Proceedings of the 2013 Federated Conference on
Computer Science and Information Systems pp. 1037–1040

Agent Based System for Assistance at Industrial Process Control with Experience Modeling

Gabriel Rojek
AGH University of Science and Technology
Faculty of Metals Engineering and Industrial Computer Science
Department of Applied Computer Science and Modelling
al. A. Mickiewicza 30, 30-059 Kraków, Poland
Email: rojek@agh.edu.pl

***Abstract*—The problem of automatic or computer aided control is still unsolved in many areas of real production processes. In such cases the only one solution is to employ human operator that uses his experience and knowledge in order to manually control parameters of the process. Such approach has many disadvantages relating to characteristics of human work what is the main ground for presented here research. As the solution a methodology is proposed, which follows the decision processes of human operator using his experience. In order to predict capabilities of proposed methodology a test system is designed and implemented with the use of agent technology.**

I. Introduction

THE MAIN genesis of presented here work is an effort to design and to build a computer system supporting control of an industrial process, that is difficult to control with known computational techniques. The main reason for this difficulty is the lack of proper analytical model of such industrial process. This lack prevents obtaining proper values of process parameters by simply computing of optimal values from determined dependence in the form of mathematical equations. Possible solutions can be found in main areas of intelligent control which are fuzzy control, neural networks, expert systems and genetic algorithms [1]. Presented methodologies have some restrictions, which prevent against their use in every case of control problem. One of such restrictions is need for specifying rules or knowledge about proper control (in case of fuzzy control or expert system), what is impossible in many domains of control of industrial processes.

An example of an industrial process, that analytical model is unknown, is the oxidizing roasting process of sulphide zinc concentrates. It is also impossible to formulate knowledge or rules, which specify proper control of this process. Possible solution for control of this process was realized with the use of genetic algorithms and neural network, which predicts the value of fitness function on the basis of previous registered process signals [2]. This approach leads to interpolation of some signals, which are measured with very low frequency. Because some signals are measured once per minute and other only once per day, such interpolation results in obtaining of unreal values of signals, what can be a source of faults and errors and can have disadvantageous influence on process control. The goal of presented here work is presentation of a methodology, that eliminates need for data pre-processing in order to avoid adding of missing data, what is unnatural for decision taking by human workers. The proposed system, as the implementation of presented methodology, should follow decision process of human using his experience, that coincides with case-base reasoning (CBR) methodology (presented in e.g. [3], [4]).

Financial support of the AGH 11.11.110.085 is acknowledged

This paper contents 6 sections. In the 2nd section the oxidizing roasting process of sulphide zinc concentrates is presented. The 3rd section presents remarks on experience using and gathering, what is the basis for design of the multi-agent system that is presented in the 4th section. The 5th section presents implementation aspects and tests of developed system, which tests enable to predict usefulness of proposed solutions. The last section presents conclusions.

II. An Example of Industrial Process

The oxidizing roasting process of sulfide zinc concentrates is the first stage of industrial zinc production. During the roasting process, the aim is to obtain a minimum content of sulphide sulfur in the composition of the product. The generic scenario of control made by a human worker during one production day (that is full production cycle) is presented onto Fig. 1. Shown scenario of control indicates differences in frequency of signal measuring, however all signals have hypothetical influence on quality of products. All signals can be classified into one of three generic groups: independent, controllable and dependent signals.

Independent signals (I) are these parameters, which cannot be modified or changed during production cycle, so it is impossible to change their values in direct or indirect way. In the case of analyzed industrial process independent signals are parameters of chemical composition of raw materials, that are measured only once per a production day. **Dependent signals** (D) are these parameters, which cannot be directly modified. Value of a dependent signal is a hypothetical function of other process parameters and possible time delay. This function is unknown in a case of analyzed process. An example of dependent signal is the pressure or temperature at the upper part of a furnace. **Controllable signals** (C) are these, which can be directly changed or updated during the controlled

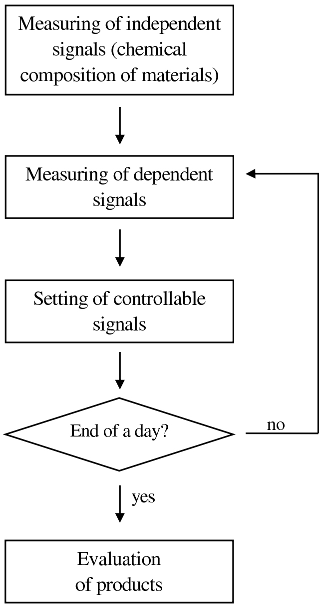

Fig. 1. The generic scenario of process control performed for one day of production

process. The rotary speed of a fan cooling the controlled process can be given as an example of a controllable signal in a case of analyzed process.

In a case of the oxidizing roasting process of sulfide zinc concentrates dependent and controllable signals are measured very often comparing to frequency of independent signal measure. The low frequency of some measures at industrial process control is caused by measured technique - the chemical composition has to be measured manually.

A. *Decision Problem*

The goal of industrial process control is obtaining products that are characterized by optimal properties. In a case of analyzed industrial process the goal is to obtain minimal concentration of sulphide sulphur in the roasted products, so the **quality evaluation** (Q) is average concentration of sulphide sulphur in the roasted products during production day. Formal definition of decision problem can be presented in the form of statement: how to choose values of controllable signals (C) knowing values of independent (I) and dependent signals (D) in order to obtain best possible quality evaluation (Q). In other words, the quality evaluation is hypothetical function of all signals $Q = f(C, I, D)$, however during process control only controllable signals (C) can be directly changed. Controllable signals (C) should be adjusted to measured values of all other signals in order to maximize quality criterion (Q).

III. Experience and Its Model

Having a goal to follow decision processes that take place in the mind of a human operator of presented industrial process, his work during a day period should be analyzed. A day period is full production cycle. At the beginning of production day the operator knows values of independent signals (I), it means he knows chemical composition of raw materials used for production. The operator assumes, that this chemical composition is constant for the whole production day due to frequency of independent signals measure, which is done only once at the beginning of every production day. Before the start of process control the operator should decide how to control this process, what means how to set present values of controllable signals (C) taking into consideration currently measured values of dependent signals (D). This decision is based on his experience. The experience contains many episodes from past production, which are referred to as cases. Every case in experience contains information concerning solved problem, how this problem was solved and how production was evaluated.

As it was mentioned in the above paragraph, before the start of process control the operator should decide how to control this process with the use of his experience. Accordingly to presented criterion of evaluation, the human operator first searches for cases that concern the same or similar problems and next chooses one case, which brings the best effect described by value of evaluation criterion. Afterwards the human operator is trying to control the process in the way, how it is remembered by him as the solution in chosen case. It means the human operator is following the way, how he has set values of controllable signals (C) knowing measured values of dependent signals (D). This stage of experience using goes on till the end of current production day. When the current production is ended, the human operator obtains information concerning evaluation of made products. So, this time it is possible to update his experience with the case, which concerns just ended production day (in order to use it in the future).

A. *Case-Based Reasoning*

Presented model of using and gathering experience coincides with case-base reasoning (CBR) methodology. This methodology is relaying on experiences made in the past during solving of concrete problem situations, instead of using any general knowledge related to a problem domain [3], [4]. From a technical point of view a CBR decision system uses a case-base, which is collection of past made and stored experience items, called past cases, or cases. Each time a new problem has to be solved, a CBR cycle is performed, that consists of 4 sequential processes, which are called also phases:

1) Retrieve the most similar case or cases for a current problem that hast to be solved.
2) Reuse the information in the retrieved case in order to solve the current problem.
3) Revise the proposed solution.
4) Retain the experience (the current problem, its solution and results) in order to use it for future problem solving.

The extensive discussion related CBR methodology and its implementation in the domain of industrial process control can be found in [5].

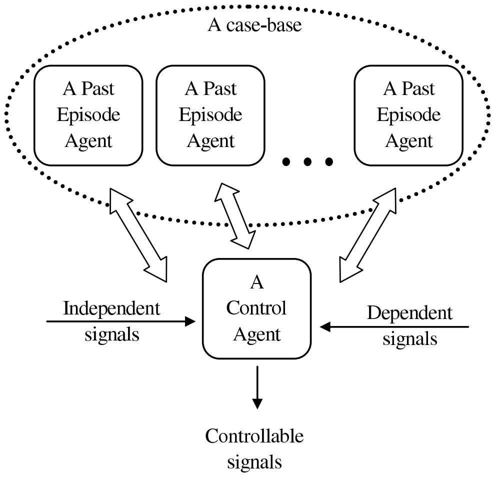

Fig. 2. The structure of proposed multi-agent system

IV. Design of Agent System Modeling Experience

Presented in the previous section assumptions indicate distribution of cases, that are autonomous items of human experience. The autonomy of experience items is the main reason for using of agent technology at design and implementation of this model. Considering autonomy of past cases, it is proposed to design the case-base as a set of autonomous agents, as presented onto Fig. 2. Every agent in this set, called Past Episode Agent should contain all data relating to represented by him episode – a past case of control of the industrial process. Presented onto Fig. 2 Control Agent has a goal to control current production process. The Control Agents communicates with all Past Episode Agents in order to follow processes of experience usage and gathering, which are characteristic for human operator. Referring to CBR methodology, the Control Agent should perform all four phases of the CBR cycle. All interactions in the system are initiated by the Control Agent, so this agent performs also (centralized) management of the whole system. Presented here conception of system does not relate to situational systems.

A. Past Episode Agent

According to the main assumption, that a Past Episode Agent should represent one past case, an agent of this type has to contain data structures related to notion of a past case. A past case should enclose information according solved problem, used solution and evaluation of made products for one past production day. Every Past Episode Agent has to contain:

- single values of independent signals (I) for the whole considered production day (as problem description of represented past case),
- array of values of dependent (D) and controllable (C) signals registered during considered production day (as solution description of represented past case),
- single value of quality evaluation (Q), that is average concentration of sulphide sulphur in made products.

A Past Episode Agent having such data structures filled with proper data models one episode of past production. A Past Episode Agent replays to messages sent by a Control Agents providing information according to stored data.

B. Control Agent

The main goal of a Control Agent is to control current production process. The functioning of the Control Agent starts at the beginning of a current production day. That time values of independent signals (I) characterizing chemical composition of raw materials used for production at the whole current day are known. After the start of its functioning, the Control Agent knows independent signals and starts to sequentially perform phases of CBR cycle: retrieve, reuse, revise, retain.

The main goal of the **retrieve phase** is to find a past case, which concerns similar problem to the current problem of control and contained in this case solution is evaluated as desirable. This goal is realized through below presented interaction between agents:

1) The Control Agent sends request of replay containing values of independent signals (I). This request is sent to all Past Episode Agents existing in the system.
2) Every Past Episode Agent replays to that request by sending back his values of independent signal and the Control Agent receives all replays concerning independent signals.
3) The Control Agent chooses a number of Past Episode Agents representing similar values of independent signals (I). This similarity is based on the Euclidean distance between values of independent signals measured for the current problem and the solved problems represented by Past Episode Agents.
4) The Control Agent sends request of replay containing value of quality evaluation (Q), that is average concentration of sulphide sulphur in the products. This request is sent only to previously chosen Past Episode Agents.
5) Past Episode Agents replay to request by sending back proper value, which indicates evaluation of production. The Control Agent receives all replays concerning evaluation of production. The Control Agent chooses one Past Episode Agent, which represents the best evaluation of made products (what means the smallest value of average concentration of sulphide sulphur in the products).

Execution of above presented interaction scenario results in selecting of one Past Episode Agent that represents a past case used at next phase of CBR cycle.

In the **reuse phase** the solution represented by the previously selected Past Episode Agent should be applied to the current problem of control. The past case contains description of solution in the form of values of dependent signals (D) and values of controllable signals (C). An artificial neuron net can be used to model relation between dependent signals (D) and controllable signals (C). The Control Agent in the reuse phase follows below stated steps:

1) The Control Agent sends to chosen Past Episode Agent request of replay containing array of values of dependent (D) and controllable (C) signals.
2) After receiving of replay, the Control Agent models relation between dependent signals (D) and controllable signals (C). This step the artificial neuron net is created and learned.
3) The Control Agent obtains current values of dependent signals (D) and on this basis predicts values of controllable signals (C) with the help of the learned neuron net. The predicted values of controllable signals should be applied in current process control. This step is repeated till the end of current production day (the reuse phase continues till the end of current production day).

The Control Agent during the **revise phase** obtains evaluation of products made during current production day. This evaluation is in the form of single value of average concentration of sulphide sulphur in the products. Result of the evaluation cannot influence control done by this agent, because production was ended before quality measures.

The **retain phase** enables learning in the CBR cycle, what is analogy to experience gathering by a human operator. This phase starts, when the current problem was solved and evaluation of this solution is known. The current case contains already the description of the problem, description of the applied solution and the evaluation. The goal of Control Agent is now to retain this information by adding a past case that relates to just ended production day. Because every past case is represented by a Past Episode Agent, the Control Agent creates new agent of Past Episode Agent type.

V. System Implementation and Testing

Presented in the previous section description of a system was implemented as a test application, that operates on archival data of an industrial plant. On this stage of research it was impossible to deploy the application in order to influence real production. The lack of mentioned deployment disables to obtain evaluation of real products made under control of developed system, what is the reason for implementation problems. Those problems relate to the revise and retain phase, which require the real evaluation of products. Despite mentioned problems the whole system gives solution for control of the current production day.

Implemented Control Agents uses a neural network, which is a multilayered perceptron, composed of neurons with sigmoid function. All neurons are located in 4 layers composed of 9, 13, 11, 7 neurons. By the modeling step a supervised learning is used. Developed system works in the batch mode and was implemented using Java, JADE and Neuroph.

A. Performed Tests

Performed tests were done with real industrial data, but only 19 days of production were available (every day is full production cycle). The available industrial data was transformed to the case-base of presented system. In the result 19 Past Episode Agent were created (every individual agent represents one past case).

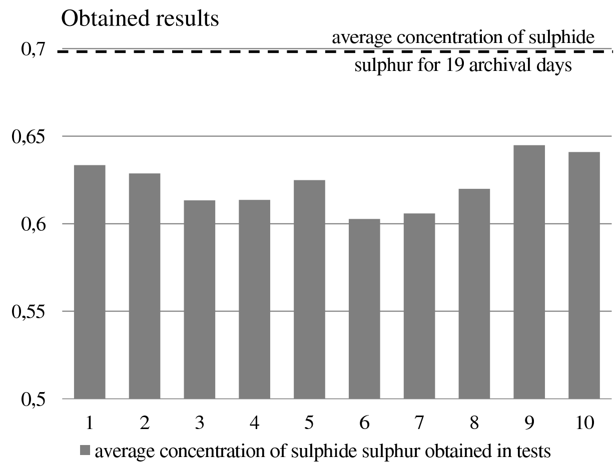

Fig. 3. Results obtained for 10 runs of the implemented system

Presented onto Fig. 3 results concern 10 tests of developed system. Every test relates to one production day, that is full production cycle. The quality measure for performed test was evaluated with the use of an external application, which predicts average concentration of sulphide sulphur in products made during considered production day. As it is shown onto Fig. 3 developed system enabled to obtain more optimal control for every test day, than is was done manually for 19 archival days, because the aim is to minimize concentration of sulphide sulphur in the products.

VI. Conclusions

Presented work shows that it is possible to design and implement an agent system, which follows mechanisms of experience using and gathering. Those mechanisms are consistent with case-base reasoning (CBR) approach and can be used as mechanisms for control of chosen industrial process. Made tests of presented system appoint, that developed system good reflects analyzed mechanisms and obtained results are estimated better than production, which was done in the past by a human worker.

References

[1] K. M. Passino, "Intelligent Control: An Overview of Techniques" in T. Samad, Ed., *Perspectives in Control Engineering: Technologies, Applications and New Directions*, IEEE Press, NY, pp. 104-133, 2001
[2] Ł. Sztangret, Ł. Rauch, J. Kusiak, P. Jarosz and S. Małecki, "Modelling of the Oxidizing Roasting Process of Sulphide Zinc Concentrates Using the Artificial Neural Networks", *Computer Methods in Materials Science*, vol. 11, pp. 122–127, 2011
[3] A. Aamodt and E. Plaza, "Case-Based Reasoning: Foundational Issues, Methodological Variations, and System Approaches", *AICom – Artificial Intelligence Communications*, vol. 7, pp. 39–59, 1994,
[4] R. Bergmann, K. D. Althoff, M. Minor, M. Reichle and K.Bach, "Case-Based Reasoning – Introduction and Recent Developments", *Kunstliche Intelligenz: Special Issue on Case-Based Reasoning*, vol. 23, pp. 5–11, 2009
[5] G. Rojek and J. Kusiak, "Case-based Reasoning Approach to Control of Industrial Processes", *Computer Methods in Materials Science*, vol. 12, pp.250–258, 2012