

Distributed control and monitoring based on cooperating agents: an application for manufacturing system

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Abstract

Control and monitoring of current manufacturing systems has become increasingly a complex problem. To expand their reliability we propose in this work a distributed approach for control and monitoring using the Multi Agents Systems. This approach is based on the decomposition of the complex system into subsystems easier to manage, and the design of several agents each one on these agents is dedicated to a particular task. A software application supporting this approach is developed for the cement clinker system of the Ain Touta cement plant. It is chosen to test the approach on real data. The results show that our distributed approach produces better results than the centralized health monitoring and control.

Keywords: Distributed control; MAS; Distributed diagnosis; health monitoring

1. Introduction

One of the most important goals of automation is to increase the reliability, availability and dependability of technological processes. This is the reason why we implement control and monitoring systems. They not only improve the performance and productivity of a complex system but also protect lives and property. Classical monitoring by a single entity which have, from a global view of the system poses reliability problems due to the complexity of physical system to be monitored and the fixed and no robust architecture of monitoring system[1, 2]. To avoid the problems posed by these centralized architectures, we propose in this work a distributed approach for control and monitoring. Reducing complexity, fault tolerance, reducing costs while maintaining, robustness and flexibility are the advantages of this distributed approach.

In order to manage the distribution, our approach is based on multi-agent systems (MAS) where each agent has a task to perform and the interactions between the agents allow the achievement of the global goal[3, 4]. Many works such as[5, 7] take benefit of the traditional advantages of MASlike modularity, speed (with parallelism), and reliability to build distributed and concurrent resolution of problems. In this paper, we propose MAS for the control and monitoring of complex

systems. To validate this MAS model, we have developed a software application under JAVA for a real case study. The cement clinker system of Ain Touta cement plant has been chosen as a field of application.

2. Distributed control and monitoring of complex system

Control and distributed monitoring of complex system (Figure 1) involves the structuring of this into elementary subsystems (SS) and the design of many autonomous and communicating controls and monitoring agents. Each agent collects information about the operation of his associated subsystem, processes this data, and cooperates with other agents to determine the state of the process. The adoption of a distributed structure for industrial control and monitoring has engendered the distribution of its two phases: detection and diagnosis. Thus, we propose two types of agents: Detector Agents (ADs) and Local Diagnostics Agents (ADLs). To construction ADs, we use FDI techniques (Fault Detection and Isolation) such as [8, 9] however the elaboration of ADLs is focusing on the consistency approach [10, 11] which has seen significant research activities from the Artificial Intelligence diagnosis (DX). The work motioned in [12] is the first result of this combination.

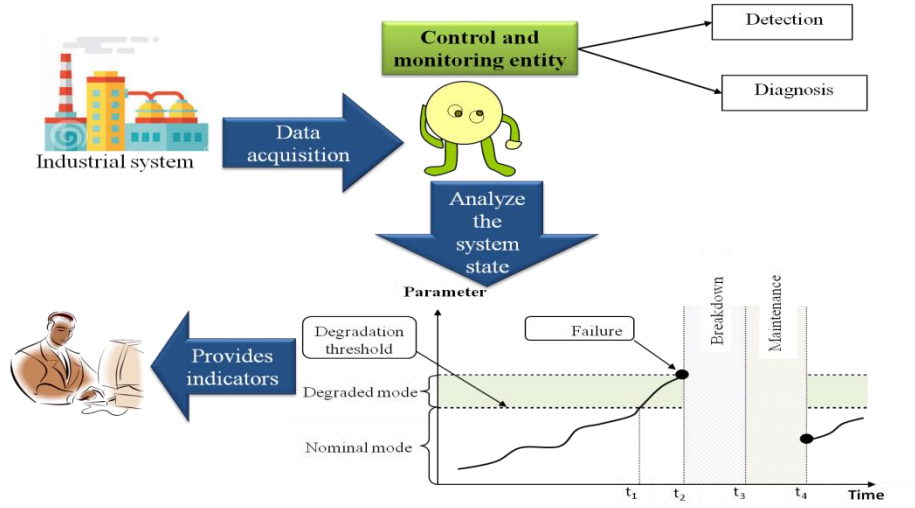


Figure1. Distributed control and monitoring

Therefore, a controlled SS_i is defined by the model $(SD_i, COMPS_i, OBS_i)$ where SD_i represents a set of first-order logical formulas that describe the structure of SS_i , $COMPS_i$ represents the components of SS_i and OBS_i is a set of first-order formulas that represent observations available by sensors positioned on SS_i .

The overall model of the system is defined by $(SD, COMPS, OBS)$ or

$$SD = \bigcup_{i=1}^n SD_i + STRU / STRU : \text{connection between } SSs. (1)$$

$$COMPS = \bigcup_{i=1}^n COMPS_i (2)$$

$$OBS = \bigcup_{i=1}^n OBS_i (3)$$

And the agent model that we propose has the following characteristics:

- 1) Many ADs for collecting OBS_i of each SS_i : The measured values (observations) by the sensors are sent to the ADs. Each AD_i consults his knowledge base and makes a comparison between the estimated values by model and the observed values.
- 2) An ADL_i associated to each SS_i : It uses the results of AD_i associated with this SS_i and has a private model $(SD_i, COMPS_i)$ not visible by other $ADLs$. It generates the local minimal R-conflict according to the following definition:

Definition 1: An R-conflict for is a set of components $\{c_1, \dots, c_k\} \subseteq COMPS_i$ such as $SD_i \cup OBS_i \cup \{\neg Ab(c_1), \dots, \neg Ab(c_k)\}$ is consistent. A minimal R-conflict is an R-conflict which does not strictly include R-conflict any R-conflict

- 3) Each ADL_i must know his local neighbours: it needs to know which SSs are in and out of his associated SS_i .
- 4) Each ADL_i cooperates to calculate local diagnosis: the local diagnosis Δ_i obtained by ADL_i is calculated by taking into account the results (local diagnostics) of the other agents $ADL_j, \dots, ADL_k$. This is translated by the coherence-based diagnostic method as follows:

Definition 2: $\Delta_i \subseteq COMPS_i$ is a diagnostic associated to $ADL_i(SD_i, COMPS_i, OBS_i)$ if and only if $SD_i \cup OBS_i \cup \{\neg Ab(c) \mid c \in COMPS_i - \Delta_i\} \cup \{AB(c) \mid c \in \Delta_i\} \cup \dots \cup \{AB(c) \mid c \in \Delta_k\} \cup SD_i \cup OBS_i \cup \{\neg Ab(c) \mid c \in COMPS_i - \Delta_i\} \cup \Delta_j \dots \cup \Delta_k$ is consistent or more concretely $SD_i \cup OBS_i \cup \{\neg Ab(c) \mid c \in COMPS_i - \Delta_i\} \cup \Delta_j \dots \cup \Delta_k$.

- 5) Global diagnostic calculation: local diagnostics are merged by evaluation agent and posted to the users by interface agent.

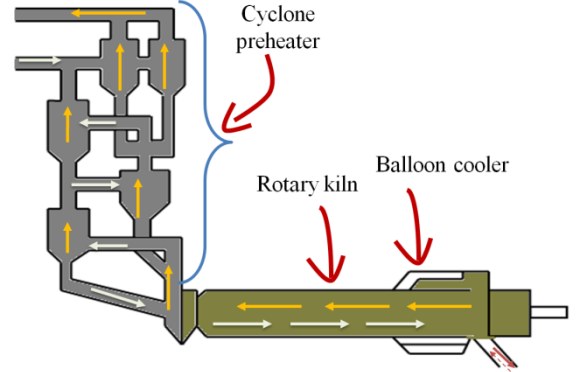


Figure 2. Schema of the clinkerization workshop

3. Industrial application

The clinkerization of Ain-Touta cement plant (SCIMAT) is the studied system (figure 2). According to Figure 2, the flour is preheated by the cyclone preheater and then passed into rotary kiln for cooking. Our approach is applied particularly to the control and monitoring of rotary kiln and balloon cooler.

Many variables are important in this system but we have studied only a set of them in order to evaluate our SMA model. So, this study led to the decomposition of this

system into three SSs. Figure 3 shows these SSs and our SMA model.

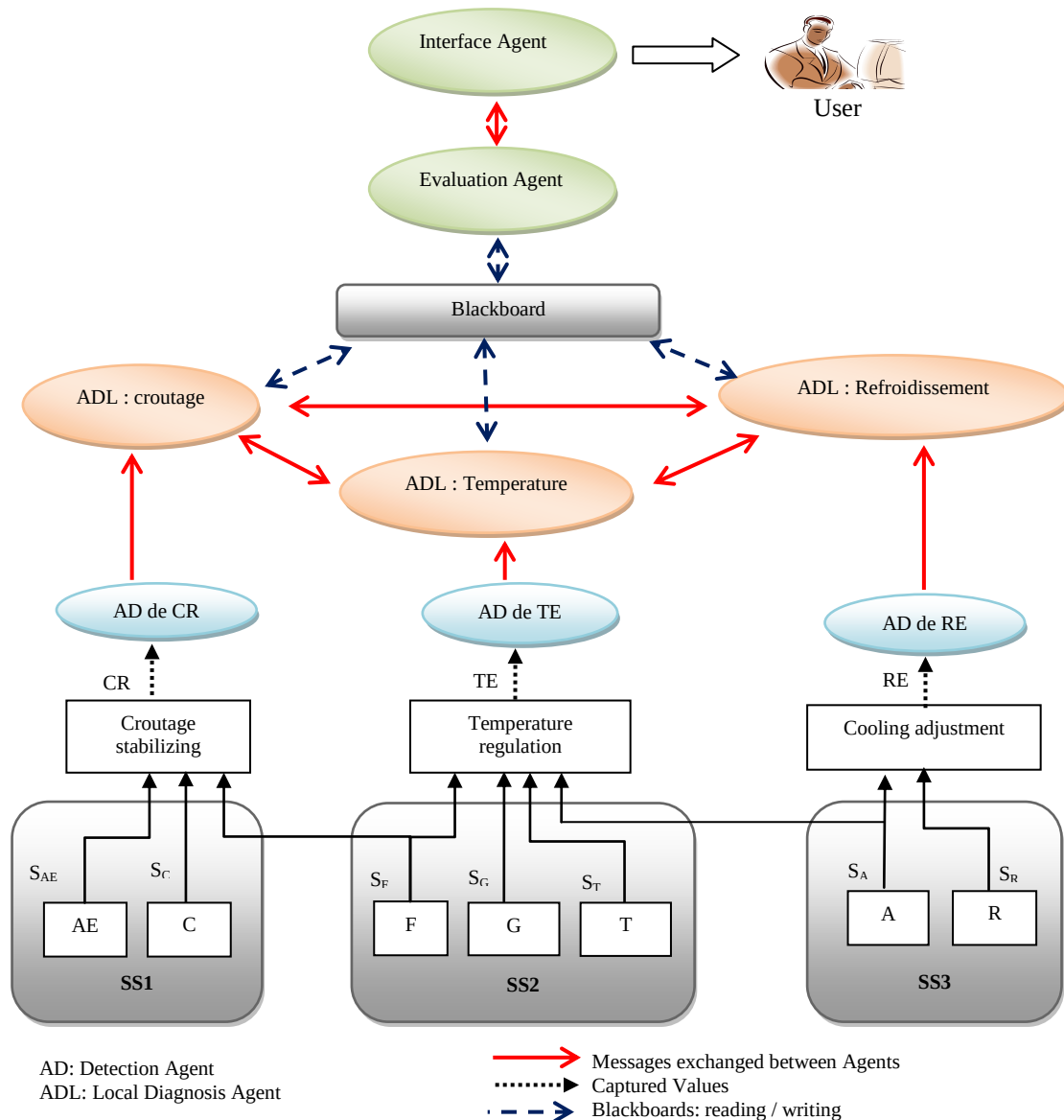


Figure 3. SMA for distributed control of rotary kiln and balloon cooler

These three SSs perform the following functions:

- 1) SS_1 to stabilize Croutage (CR): The variable CR varies according to the flame (F) generated by the burner, the outside air (AE) produced by the main ventilator and other crusting factors (C).
- 2) SS_2 to regulate the Temperature (TE): The variable TE varies according to gas pressure (G), the flame (F), the temperature of secondary air (A) which is the cooling air injected and other temperature factors (T).
- 3) SS_3 to adjust Cooling (RE): The variable RE varies according to the temperature of secondary air (A) and other cooling factors (R).

CR, TE and RE observations are managed qualitatively. They are entered through the SMA platform space that we developed using Java programming language and JADE multi-agent tool under Netbeans environment (Figure 4). These observations are sent to the ADs. Each AD_i compares observed values with estimated values in a model taking into account a tolerated margin of error. The result of this test is sent to the ADL_i by a message indicating the state of SS_i output. Each ADL_i calculates the local diagnostic for its associated SS_i by cooperating with other ADLs. It cooperates via blackboard and sending message to share information (SA and SF values) and partial results (local

diagnostics). Local diagnostics are merged by evaluation agent who organizes the diagnostic procedure between instant t and instant $t + \Delta t$. Then it calls interface agent to

display the overall diagnostic to users. These results are displayed in the results space of this platform.

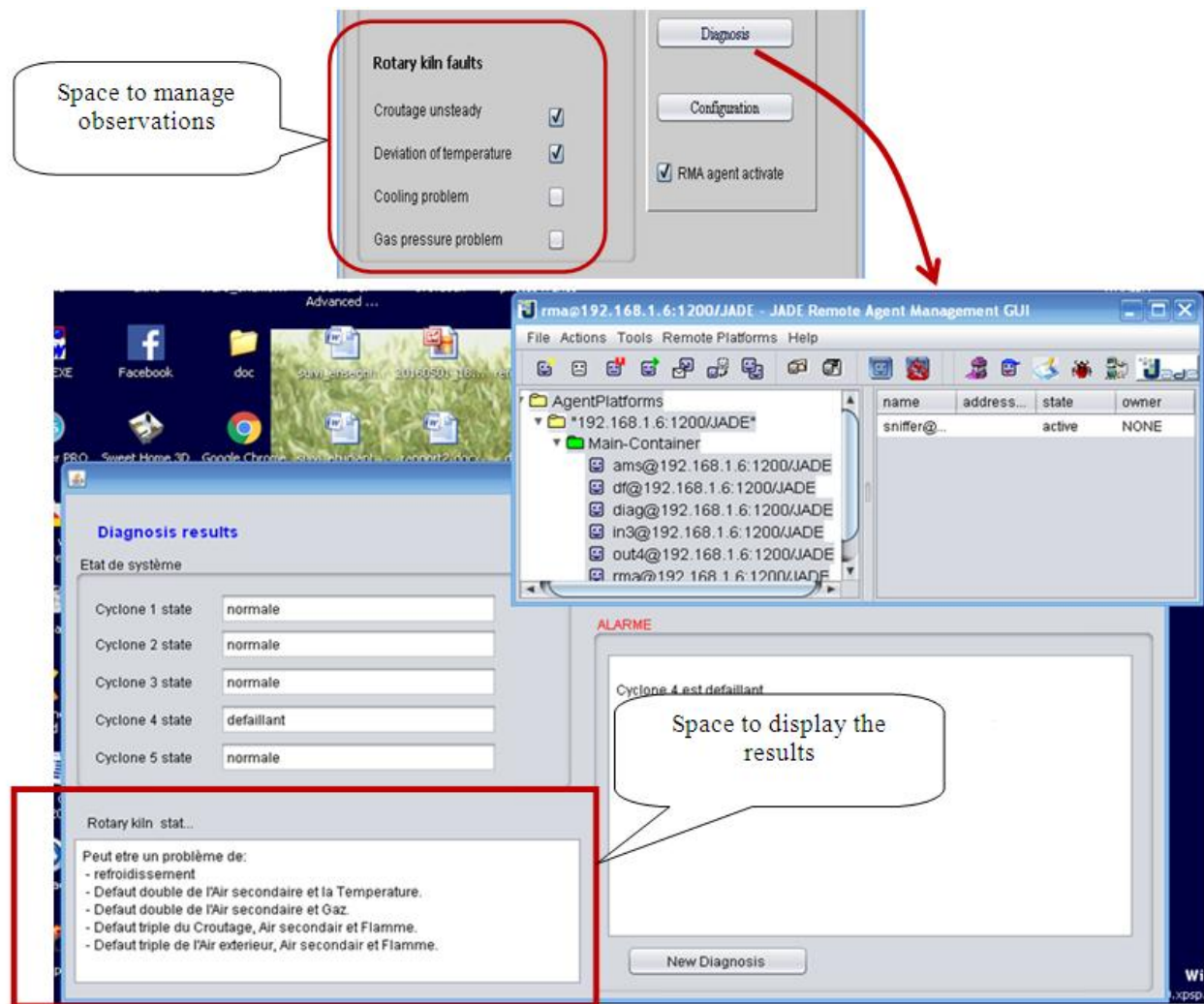


Figure 4. SMA platform to control rotary kiln and balloon cooler

4. Conclusion

In this work, we have proposed a distributed approach for controlling and monitoring a manufacturing system. This approach decomposes complex system into simple subsystems and designs a set of agents each one dedicated to a particular task. After analyzing the clinkerization system and the software test, we find that the distribution of control task into smaller tasks and the cooperative aspect of our SMA model play an important role which makes the control task more efficient.

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