



ALGERIAN JOURNAL OF SCIENCES

Section -A-
Nature and Life Sciences
Science and technology

<http://univ-eltarf.dz/fr/>



Modeling Based Multi-Agent System of an Industrial System

Kenza Redjimi^{a,*}, Mohammed Redjimi^a

^aDépartement d'Informatique, Université 20 Août 1955 - Skikda, Algérie.

Informations	Résumé
Mots clés : Multi-Agent System (MAS), Industrial System, modeling and simulation, Agent/Group/Role (AGR)Model. *Correspondance : inf33222@gmail.com Reçu le, Révisé le, Accepté le	Industrial systems become more and more complex. This complexity is due to the great number of elements that composes them and their interactions. This paper describes a multi-agent approach for modeling such systems. All of their parts are considered and modeled by using adequate agents. These preoccupations were identified to find convenient multi-agent models for their resolutions. Then, we implemented our application by using a MADKIT multi-agent platform. The main goal of this work is to build a simulator based on reactive agents able to translate this complex industrial system into a data processing program that can represent its structure, its behavior, its interaction, its control loops and verify the integrity and proper functioning of the system. A concrete application of this approach was materialized by building an industrial boiler.

1. Introduction

The spectacular advances in the field of new technologies and their applications in practically all sectors, including the industrial field, contribute to making these domains more and more complex. Industrial systems acquire more and greater degree sin complexity resulting in the regular introduction of new elements and of the great number of interactions between the different parts of these systems. In order to develop such a system, to predict their behaviors and before beginning to build them, these systems are modeled and tried. In the other hand, the modeling and simulation of an actual system make it possible to handle, to observe and to improve understanding of its functioning. Different abstraction levels are considered and studied and this concerns fields ranging from natural phenomena to technological fields as for example, studies of biological systems, meteorological phenomena, road traffic management, etc. Most of the modeled phenomena reach today's complexities and high degrees of smoothness, which requires the use of models and thus, the data-processing tools become more and more performing and flexible. The modeling of systems has been the subject of many studies and researches considering its important impact on the phenomena implemented. So, and according to P. Fishwick's view [1], modeling is represented by symbiosis between formalism and the techniques of modeling which follows the same target: "to release the best metaphors and analogies to allow understanding better any phenomena".

According to C. Oussalah's view [2]: "modeling is ear morphism between an actual system and a model that finality is to give a simplified and observable representation of the structure and behavior of the actual system".

The experimentation of practical works can be observed as modeling of actual cases in the laboratory. The observation of the workers carrying out their tasks by timing the times spent in the factories observed by Taylor, the labors of the military, the models of planes built and tested in blowers, the mathematical equation scarrying of the differentials, the variables to various degree and constants, which represent the actual phenomena for which the resolutions for fixed sets of entries give the solutions to these phenomena for proper defined conditions are as many examples of models which as faithfully represent as possible different realities.

However, its should be reflected in terms of accuracy, quality, and cost. For example, the construction of a model of the plane represents costs enough higher for relatively low quality. Moreover, the handling of such models is not easy and not flexible and cannot be reused. This concept of reuse is very significant if we want to test our model in various situations. The data-processing tool represents a very accurate solution in several cases and its use in the field of modeling and simulation is very wide spread ensuring excellent qualities for which the improvement is continuous at very reasonable costs.

According to Fishwick's view [3], the data-processing simulation can be understood as follows: 'Computer simulation is the discipline of designing a model of an actual or theoretical physical system, executing the model on a digital computer and analyzing the execution output'.

Complex industrial systems are characterized by their large size, the complexity of the constituent subsystems and their dynamics, and the massive information over load. For example, the maintenance and management of complex process equipment and processes, and their integrated operation, play a crucial role in ensuring the safety of plant personnel and the environment as well as the timely delivery of quality products. Given the size, scope, and complexity of the systems and interactions, it is becoming difficult for plant personnel to anticipate, diagnose and control serious abnormal events in a timely manner [4].

Thanks to multi-agent systems, it is possible to model real systems in which very complex behaviors emerge from relatively simple and local interactions between elements. Therefore, a multi-agents system gives more description that is natural and simulates a system by help of entities that compose it. It allows model to appear closer to reality and it is particularly well adapted to describe a system from the stand point of the activities of its components, that is to say when the behavior of the individuals is complex and sometimes difficult to describe with equations [5-7].

Another point of consideration is that MAS modeling is easier interpretable by a human observer, because the given description is more natural. The validation by an expert will be facilitated because he will be easily able to refer to the real world.

The rest of this paper is organized as follows: Section 2 presents the multi-agent systems. Section 3 presents the industrial system to be simulated. The proposed multi-agent Model is described in section 4. The implementation of the system is shown in section 5. Finally, section 6 concludes this paper.

2. The Multi-Agent Systems (MAS)

Multi-agent systems are an emerging conceptual paradigm to simulate the interaction of multiple autonomous agents in an environment [8,9]. Multi-agent systems have many applications; our interest is in their use to build an operational simulator of an industrial system. In general, a system is called multi-agent if the system contains at least one agent that perceives a simulated environment through its actions that influence the environment and are influenced by the perceived situation in the environment.

2.1. What is a Multi-agent System?

According to Ferber's view [10], the term 'multi-agent system' refers to a system consisting of the following parts:

- The environment E consisting of the following elements:
 - A set of objects O. Objects can be perceived, created, destroyed and modified by agents.
 - A set of agents A, which are able to perform actions and represent the active entities of the system.
 - A set of locations L determining the possible position of the objects (from the set O) in space.
- A set of relations R which link objects and also agents to each other.
- A set of operations Op enabling the possibility for agents to perceive, manipulate, create, destroy objects of O, in

particular representing the agents' actions.

- A set of operators U with the task of representing the application of the operations from Op and there actions of the world to this attempt of modification. The operators from U are called the laws of the universe.

2.2. Agent definition

According to the heterogeneity of the studied field, there is no common agreement about a definition of the term agent. One primary characteristic that differentiates agents from an ordinary program is that the agent must be autonomous. Several definitions of agents include this characteristic, for examples:

- The term 'agent' refers to an entity (software or hardware) able to functioning continuously and autonomously in environments shared by other agents [11].
- An agent is an entity capable of evolving in an environment through the acquisition of information emitted by the latter and by acting on it [12].
- "An autonomous agent is a system situated within and a part of an environment that senses that environment and acts on it, in pursuit of its own agenda and so as to effect what it senses in the future" [13].

Although not stated explicitly, Russell's definition implies the notion of autonomy as the agent will act in response to perceived changes in the environment. The other four definitions explicitly state autonomy. But all definitions add some other characteristics, among which interaction with the environment is mentioned by most. Another identified feature is the property of the agent to perform specific tasks on behalf of the user, coming thus to the original sense of the word agent, namely someone acting on behalf of someone else.

One of the most comprehensive definitions of agents is the one given by Wooldridge and Jennings view [14] in which an agent is:

"A hardware or (more usually) a software-based computer system that enjoys the following properties : autonomy-agents operate without the direct intervention of humans or others, and have some kind of control over the interactions and internal state; social ability-agents interact with other agents (and possibly humans) via some kind of agent-communication language; reactivity: agents perceive their environment and respond in a timely fashion to changes that occur in it; pro-activeness: agents do not simply act in response to their environment, they are able to exhibit goal-directed behavior by taking initiative".

2.3. The Environment

Common to all environments is that they provide percepts to the agent and that the agent performs actions in them. Multi-agent theory regards the environment as an integral part of the framework. In general, two classes of environments can be distinguished: artificial and real environments. Agents that are computer programs and exist in artificial software environments are called software agents.

Russell and Norvig [15] discuss a number of key properties of environments that are now adopted by most researchers in the domain:

- Accessible versus in accessible: Indicates whether the agents have access to the complete state of the environment or not.
 - Static versus dynamic: indicates whether the environment can change while an agent deliberates or not.
 - Discrete versus continuous: indicates whether the number of percepts and actions are limited or not.
- The most complex class of environments are those that are inaccessible, non deterministic, dynamic and continuous. The first three properties of this list are properties typically occurring in MASs.

3. GLOBAL DESCRIPTION OF THE SYSTEM TO BE SIMULATED

In this section, we will show the architecture and the operation of the process concerning the steam generator.

3.1. The feed water station

The feed water station is a method that feeds the steam generator, it is constituted by:

- The condenser (15E01)
- The degasser (15B02)
- The feed water tank (15B01)

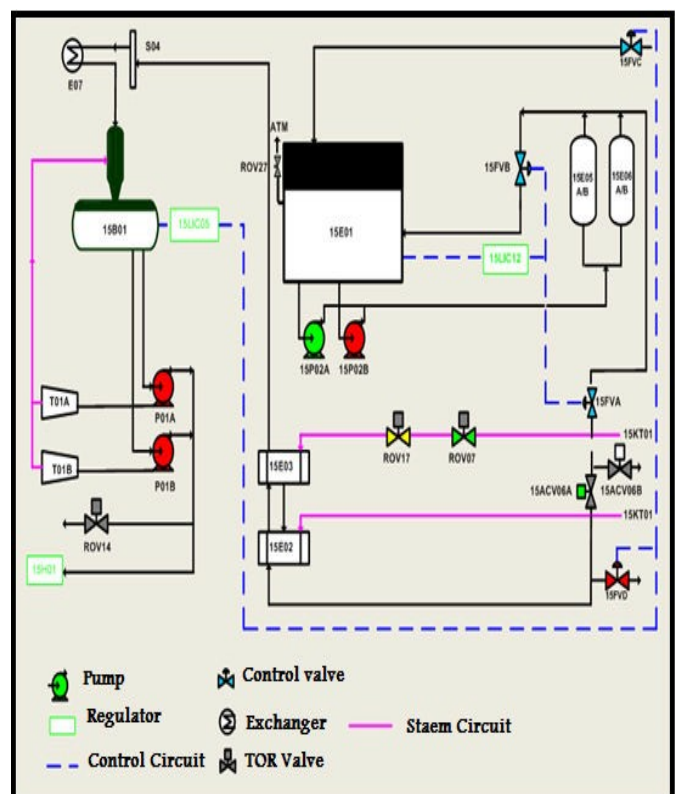


Fig.1. Technical drawing of the feed water station.

- 1) *Circuit description:* The extraction water comes from 15E01 by the bottom, it gets through a valve and a mesh filter before its inhalation by the pumps 15PM02A/B.

The water is inhibited with 12 bars towards the maintaining ejectors 15E05A/B, and it will feed the heaters while passing by 15FVA towards the degasser and the 15FVB returns towards the condenser. Those two valves' functions are insplitrange and controlled by 15LIC12(level15E01). Then, the water crosses 15 ACV06A/B(A towards the heaters, B towards the channel rejection).

The 15 FVD goes towards U50 and 15FVA supplement of Unit50 towards the 15 E01, and are controlled in split range by the 15LIC05 in order to maintain a constant level in the feed water tank.

The extraction water is then conducted towards 15E02 and 03 in contact with steam racking 2 and 3 of the 15KT01. The two heaters are provided with By-pass, the extraction water goes then to feed the degasser.

3.2. The steam generator

A boiler is a steam generator; it aims to raise the temperature of the water until the change of its status, that is to say, to become steam, and then to bring it to proper defined pressure and temperature.

In the construction of a boiler, we distinguish:

- A metal frame with it strim, masonry casing.
- The boiler: tubes, box back, screens, spray, superheaters, balloons...
- The combustion chamber: burners, air, and auxiliary circuits.

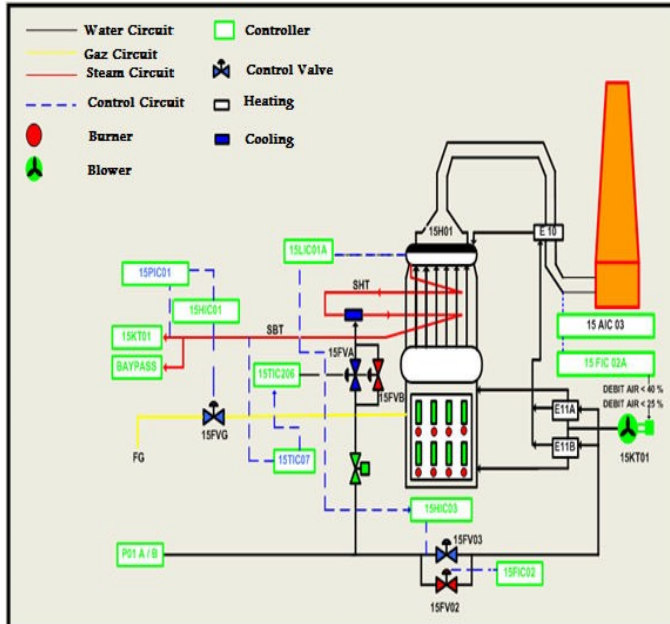


Fig.2. Technical drawing of the steam generator.

- 1) *The Principle of operation:* The water is brought to the boiler by a feeding-water pump. The power of the boiler is characterized by the intensity of steam expressed in kg produced per hour.

- *The air circuit Combustion:* The air is provided by two blowers fans, the first one is conducted by turning turbine and these condone operates through an engine (those two fans do not operate simultaneously), the air is then heated by

the air super heater before entering to the burners by using the heat of evacuated gases. The air flow is regulated according to the fuel to have complete combustion.

- *The water circuit:* The feeding of water is done starting from a pump controlled by two valves mounted in parallels, the first one is used to fill the balloon and the other one for regulation purpose (body of adjustment/regulation); from where it comes out to go then by an economizer in order to be heated by the calories of the evacuated smoke and returns finally to the higher balloon to produce the steam.
- *The steam circuit:* The saturated steams comes out from the higher balloon, goes by the super heater (in the hearth), its temperature increases while its pressure varies slightly. In the end, the final temperature of the produced steam will be regulated by the dish water (water injection). This dry steam is also called the load of the boiler.

4. Proposal for multi-agent model of the simulator

To model our system we have used the organizational model Aalaadin [16], which constitutes the basis of our design.

The organizational model Aalaadin is a project that focuses on the analysis, design, formalization, and implementation of multi-agent systems from an organizational perspective. The underlying conceptual model (AGR) is based on the concepts of agents, groups, and roles [17].

Therefore, we have split up our process into five groups; each group contains a set of agents. The following diagram represents the organizational structure of the simulator based on the proposed AGR model.

4.1. Groups and Roles of the simulator

- *The perturbation group:* This group is composed of:
 - *The APM Agent:* The agent system is a principal-agent; it is the meeting point of the system and the external environment. It periodically sends orders to agents and groups of the system until the adjustment of measurements; it ensures the connection between these groups thanks to these different communications. The APM Agent is a central agent that links all the groups of the simulator.
 - *The GUS (Gui User Interface) Agent:* Its role is to trigger the disturbances. Thanks to this agent the operator controls the system thanks to instructions of a load of the steam generator on this Agent system. The disturbing agent communicates with the Agent system by sending the instructions.

- *The feedwater tank group:* This group contains a set of agents in interaction to ensure the operation of the water supply boiler.
 - *Agent (15LIC05):* Is in charge of the level of the tank, its role relates to the regulation of the tank, by using the necessary values, provided by the other agents of the system, the Alimentation agent (15LIC05) sends the orders of opening and closing thanks to the agent Valve-tank (15FVC) in order to modify the flow of water, therefore, modifies the level of the tank (15B01).

- *Agent(15B01)*: It represents the variation of the level of water inside the tank, it communicates with the Alimentation agent, by periodically sending the level in order to be regulated, and on the other hand it receives orders of the Alimentation agent(15LIC05).
- *Agent(15FVC)*: This agent controls the flow of water entering the condenser(15E01), it is in communication with the tank agent(15B01) and condensation agent(15LIC12) by providing the flow of water.
- *The condensation group* : This group contains a set of agents in interaction to execute the water condensation operation.
 - *Agent(15LIC12)*: It is the responsible for the level of the condenser (15E01), its role relates to the regulation of the condenser, by using the values provided by the other agents of the system, the Condensation agent(15LIC12) sends the orders of opening and closing using the condenser valve agent(15FVA) in order to modify the flow of water and to modify the level of the condenser.
 - *Agent(15E01)*: It represents the variation of the level of water in the condenser, it communicates with the Condensation agent(15LIC12) by sending this level periodically for which is regulated on the other hand it receives orders of the Condensation agent.
 - *Agent(15FVA)*: This agent controls the flow of water flowing out to the tank(15B01); it is in communication with the Condenser agent(15E01), the Condensation agent(15LIC12) and the Alimentation agent(15LIC05) by providing the flow of water.
- *The combustion group*: This group contains a set of agents in interaction making possible to execute the operation of combustion.
 - *Agent(15HIC01)*: The role of this agent is to control the combustion and to regulate the measured sizes which it constantly receives from various agents of the system. Indeed, if these measurements are not compatible with the load of the boiler it periodically sends orders of regulation to wards the Ventilator agent (15KT01) and the Gas valve agent that is to say agent(15FVG) in order to reach desired sizes.
 - *Agent(15KT01)*: Its role is to control the air flow; it periodically sends this flow towards the combustion agent(15HIC01) and receives the orders coming from his agent.
 - *Agent(15FVG)*: This agent controls the gas flow; it periodically sends this flow towards the combustion agent (15HIC01) which in turn transmits orders to it(opening, closing) in order to modify the gas output.
- *The hydraulic group* : This group contains:
 - *Agent(15LIC01A)*: Its role is to regulate the level of the balloon by using values provided by the various agents of the system, the Hydraulic agent sends the orders of opening and closing towards the water valve agent that is to say agent(15FV03) till this measured level become equal at the desired level(50%).
 - *Agent(15FV03)*: The role of this agent is to control the

flow of feed water tank coming from the feed water station, it periodically sends this flow towards the agent balloon (15H01) and the hydraulic agent (15LIC01A) and receives the orders(opening, closing) coming from the latter.

- *Agent(15H01)*: Its role is to calculate the level of the balloon by the use of the sizes provided by APM agent and the water valve agent (15FV03); it periodically sends this level towards the hydraulic agent (15LIC01A) to be controlled.

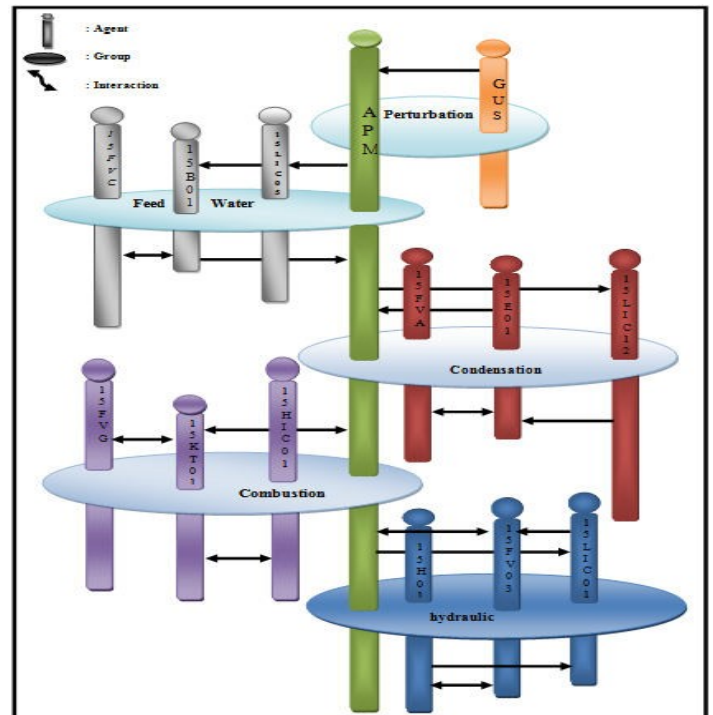


Fig.3. The organizational structure of the simulator

5. The system implementation

The simulator was developed by using the Mad Kit agent platform based on AALAADIN model. The two main interface so four project are presented in Figures 4 and 5. These two interfaces concern the steam generator section and the interface of the feed water station section. They allow the user to drive there generation steam operation and supply boiler with demineralized water by publishing guidance to various regulatory bodies and follow the operation of the process functioning.

Figures 6 and 7 show some examples of the java and MADKIT source codes.

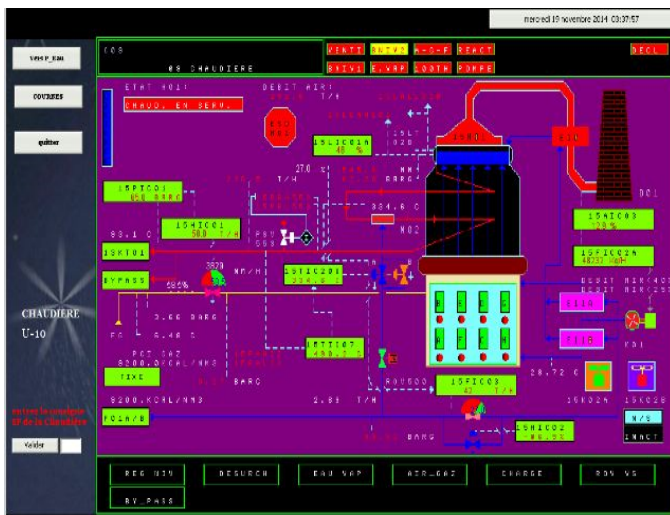


Fig. 4. The interface of the boilers simulator.

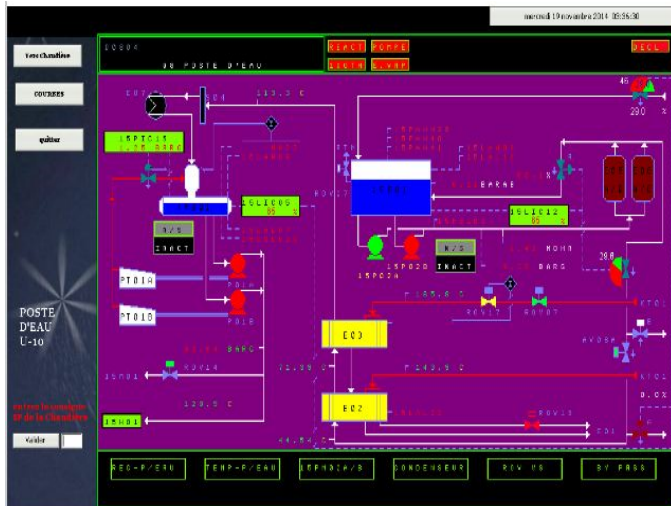


Fig. 5. The interface of the water station section simulator.

```
import java.awt.*;
import javax.swing.*;
import madkit.kernel.*;
import madkit.lib.messages.ObjectMessage;

public class Agent_vanne_eau extends AbstractAgent implements ReferenceableAgent
{
    ObjectMessage message_eau;
    synoptique_class eau_synoptique;
    grav eau_frame;
    //andeur_class consigne=new grandeur_class();
    int debit_eau;
    int debit_eau2;

    int vanne;
    //int remplacer=0;
    //String fermer="oui";

    Graphics2D eau_graphics_chaudiere;
    Graphics2D eau_graphics_synoptique;
    grandeur_class tempon_eau;
    int Dvapeur;
    int niveau;
    float op_eau;
    float changement;
    boolean bms;
    //-----\\
```

```
import javax.swing.*;
import madkit.kernel.*;
import java.awt.image.*;
import java.awt.event.*;
import madkit.lib.messages.ObjectMessage;
import madkit.lib.messages.StringMessage;
import java.util.*;

public class activateur_perturbation extends Activator
{
    public activateur_perturbation(String group, String role)
    {
        super(group, role);
    }
    //-----\\
    public void execute()
    {
        if(!agent_simulation.stop)
        {
            agent_simulation.perturbateur.walk();
        }
    }
    //-----\\
}
```

Fig. 6. Parts of the simulator code.

```
//-----\\
public Agent_vanne_eau(grav ge,synoptique_class ss)
{
    //consigne.valeur=20;
    eau_frame=ge;
    eau_synoptique=ss;
    eau_graphics_chaudiere=(Graphics2D)eau_synoptique.image_chaudiere.getGraphics();
    eau_graphics_synoptique=(Graphics2D)eau_synoptique.getGraphics();
}

//-----\\
void initialiser()
{
    debit_eau=51;
    vanne=40;
    op_eau=28f;
    changement=0.5f;
    bms=false;
}

//-----\\
public void activate()
{
    initialiser();
    foundGroup("ballon");
    requestRole("ballon","controler_vanne_eau");
}
```

Fig. 7. Code fragment of the balloon control.

6. Conclusion

Our work can be considered as an assistant of training and learning for beginner operators, workers new recruits and trainees enabling the m to understand and simulate the boiler without acting on the real system and without stopping processes and generate losses of money and time. So we can consider our simulator more as a teaching aid explaining the

Multi-Agents approach and treats one of its domains of use which is the simulation of systems and more particularly complex industrial systems. It can be considered as a tool to learn and understand the functioning of the machine in reality for all involved.

References :

- [1] P. Fishwick. Simulation Model Design and Execution: Building Digital Worlds,1995.
- [2] C. Oussalah. Modèles hiérarchisés multi-vues pour le support de raisonnement dans les domaines techniques. Technical report,1988
- [3] P. Fishwick ,A. Paul.1997. Computer simulation: growth through extension. Transactions of the Society for Computer Simulation International,14(1),13-23.
- [4] V. Venkatasubramanian, R. Rengaswamy., Kavuri, S.N.&Yin,K. (2003). A review of process fault detection and diagnosis part1,2,3, Computer& Chemical Engineering27(3):293-346.
- [5] M.Mess&B.Guerrits(2018)Multi_agent Systems, Lecture Notes in Logistics,611-636. Doi:10.1007/978-3-319-92447-2-27.
- [6] J.Ferber. Les systèmes multi-agents: vers une intelligence collective. Informatique, intelligence Artificielle Intere ditions Paris1995.
- [7] F.Chen&W.Ren(2019) On the control of multi-agent systems: asurvey. Foundations and Trends in Systems andControl,6 (4),339-499.
- [8] G.Weiss(ed.),Multiagent Systems–AM odern Approach to Distribute Artificial Intelligence. MIT Press, Cambridge, MA(1999).
- [9] B.Wang,J.Wang,B.Zhang,&X.Li,(2016)Globalcooperativecontrolfr ameworkformulti-agent systems subject to actuator saturation with industrial applications. IEEE Transactions on Systems, Man, and Cybernetics: Systems,47(7),1270-1283.
- [10] J.Ferber, Multi-Agent Systems. An Introduction to Distributed Artificial Intelligence. Addison-Wesley (1999).
- [11] Y.Shoham, Agent-oriented programming,ArtificialIntelligence,Vol.60, 1993.P.51-92.
- [12] S.J.Russell,Rationalityandintelligence.ArtificialIntelligence,Vol.9 4,1997.P.57-77.
- [13] S.Franklin, and A .Gasser. Is it an agent, or just a program? Ataxonomy for autonomous agents. In Muller, Wooldridge, and Jennings, eds. Intelligent Agents III. Agent Theories, Architectures, and Languages. Springer Verlag, 1997.P.21-35.
- [14] M. Wooldridge, and N.R. Jennings. Agent theories, architectures, and languages. In Wooldridge and Jennings, eds. Intelligent Agents, Springer Verlag,1995. P.1-22.
- [15] S.Russell, and P.Norvig, Artificial Intelligence: A Modern Approach, Pearson (2010)
- [16] J.Ferber, and O. Gutknecht, ' Aalaad in: a meta-model for the analysis and design of organizations in multi-agent systems', ICMAS(International Conference on Multi-Agent Systems),Paris, Y. Demazeau (ed),IEEEPress,pp.128-135.1998.
- [17] O. Gutknecht, and J. Ferber The Mad Kit agent platform architecture. Laboratoire d'Informatique, Robotique et Microélectronique de Montpellier, 2000.