Multi-agent Systems and Cloud Computing for Controlling and Managing Chemical and Food Processes

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Received: October 01, 2012 / Accepted: October 29, 2012 / Published: December 25, 2012.

Abstract: Cloud computing can offer a very powerful, reliable, predictable and scalable computing infrastructure for the execution of MAS (multi-agent systems) implementing complex agent-based applications such when modelling, simulation and real-time running of complex systems must be provided. Multi-agent systems appears as an adequate approach to current challenges in many areas. Between important qualities of MAS also belongs to, that they are open, interoperable, and heterogenous systems. The agent is active, a program entity, has its own ideas how to perform the tasks of the own agenda. Agents: perceive, behave “reasonably”, act in the environment, communicate with other agents. Cloud infrastructures can offer an ideal platform where run MAS systems simulations, applications and real-time running because of its large amount of processing and memory resources that can be dynamically configured for executing large agent-based software at unprecedented scale. Cloud computing can help chemical and food companies drive operational excellence; meet growing and changing customer demands; accelerate new product innovation and ramp-to-volume manufacturing in key markets; reduce IT spending; manage and mitigate supply chain risks; and enable faster and more flexible delivery of new IT system. Production type of SOC (service-oriented computing) can be inspired by a “Cloud”, for the production of “Cloud” offers an attractive and natural solutions in several computing trends such as delivery system over the Internet, use of utilities, flexibility, virtualization, a “grid” distributed computing, outsourcing, Web 2.0, etc.. Production of the “Cloud” is also considered as a new multidisciplinary field that includes “network” production, virtual manufacturing, agile manufacturing, and of course cloud computing. Examples of cloud computing and MAS applications in food and chemistry development and industry, proposition of using multi-agent systems in the control of batch processes, modified ACO (ant colony optimization) approach for the diversified service allocation and scheduling mechanism in cloud paradigm, examples of applications in a business area were studied in the paper.

Key words: MAS, cloud computing, UML (unified modelling language), FIPA (foundation for intelligent physical agents), Jadex (MAS).

1. Introduction

Cloud computing can offer a very powerful, reliable, predictable and scalable computing infrastructure for the execution of MAS (multi agent systems) implementing complex agent-based applications such when modelling, simulation and real-time running of complex systems must be provided. On the other side,

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software agents can be used as basic components for implementing intelligence in cloud computing systems making them more adaptive, flexible, and autonomic in resource management, service provisioning and in running large-scale applications.

Agent is an active, permanent intelligent computer entity, it has its own ideas, how to accomplish own agenda tasks. Agents are: perceived, reasonable intelligent acted, behaved, take effected to an environment, communicated with others agents. Agents may have represent some of equipments as the reactors, valves, pumps, boilers, heaters, sensors, units
of the equipments, or the whole unit and others. Agents may have also represent operations (recipes, control and diagnostic procedures, etc.) in the industry of chemical and food processes. Communication, cooperation, negotiation of agents especially recommended by FIPA (foundation for intelligent physical agents) [1].

Cloud computing is a paradigm that focuses on sharing data and computation over tiered, measurable network nodes. Examples of such nodes include a computer user terminals, data centers, Web services. Such network nodes are known as the “Cloud”. “Cloud” is actually a metaphor for the type of network and Internet is an abstraction for the complex infrastructure that is “hiding”. The main idea of using such existing infrastructure is enforced to bring all services into the “Cloud”, denoting the above and creating the ability to access these services regardless of time and location.

More generally companies in the chemicals industry face a number of common challenges springing from global economic trends, movements in the commodities markets, and ongoing change among customers, suppliers and the broader global environment. Cloud computing can help chemical and food companies drive operational excellence; meet growing and changing customer demands; accelerate new product innovation and ramp-to-volume manufacturing in key markets; reduce IT spending; manage and mitigate supply chain risks; and enable faster and more flexible delivery of new IT systems. Ongoing globalization will require chemical companies to change their operating and business models. As well as playing a role in meeting the industry challenges, cloud computing also will help companies approach and operate many parts of their business in a radically different way, achieving a permanent step-change in their operational effectiveness and competitiveness. Key elements of the chemicals industry’s future operating models will include the following: innovation enabled and driven by global R&D (research and development) networks; new products and new markets; an increase need for customized solutions; an increased role of IT to enable co-production; continued outsourcing of noncore functions and shared services; increased competition in talent recruitment; and additional value contribution from IT.

Cloud infrastructures can offer an ideal platform where run MAS-based systems simulations, applications and real-time running because of its large amount of processing and memory resources, that can be dynamically configured for executing large agent-based software at unprecedented scale. Agents implemented in cloud systems can adapt to available virtual machines by using the basic properties of agents such as autonomy, pro-activity, negotiation and learning. Since “Clouds” are elastic, they can expand and shrink based on demand of users or applications. This property is very useful for the scalable execution of the MAS applications and simulation that are able to adapt to the available resources. In summary, agent can find in cloud computing infrastructures the appropriate platform where to run and access large data.

Cloud computing and services as new opportunities and challenges for corporate IS/IT cloud computing are a natural next step in development in the evolution of products and services related to information technology systems, on-demand. It is a sort of “computer style” in which the corresponding capacity of information technologies are provided as a service enabling users to access those services and technologies through the Internet, without the need for management expertise and technological infrastructure that supports these services.

Post-type e-mail service is probably the first type of “Cloud”. There is some shift in the computer industry on the provision of PaaS (platform as a service) and SaaS (software as a service) for users and businesses, the company access to the request (on-demand), regardless of the time and location.
Hosting of services and type of cloud computing is becoming increasingly popular, and is him predicted a bright future. Why is this so? The main reasons include the fact that services such as “Cloud” can satisfy the needs of individuals, small businesses and multinational corporations at reasonable price. If the customer wants to host a Web application, or possibly seek out a suitable repository for files of his Web gallery, then services such as “Cloud” is a very good solution in terms of performance and price. The customers pay only for what they actually consume.

The principle of providing on-demand services is applied to the provision of software. This model is also known as SaaS (software-as-a-service) of salesforce company. For enterprise software for several years is a successful pioneer in the SaaS.

SOA (service oriented architecture) is an approach to loosely coupled, independent of protocol and standards-based distributed computing, where applicable resources are available on the network (Internet) in the form of Web services. SOA is becoming a promising solution for business technology enabling increased agility and flexibility for consumers. Program components are services based on standard protocols.

Business processes are created by a combination of services and composite applications (or in future or still now agents [2]). Composite applications are a new way for application development within SOA. The portal is used for imaging, visualization and collection of relevant data. If you use the services within the SOA, these services may be called for: (1) implementation of business process of the choreography process [3] service, or directly; (2) the data aggregation and visualization within the portal or Web applications; (3) creating of new visual, display applications that are run (triggered) by composite services via composite applications.

The integration process of the manufacturing companies architecture using standards for the use of fulfillment SOA success. Using standard significantly increases the “resistance” to changes in technology and technological parameters, such as standard communication protocols allow easy connection between the different buses or communication means, J2EE (Java 2 Enterprise Edition) standard allows cross-referencing (interoperability) between different application servers, content standards for the semantic exchange of messages reduce the necessary number of required transformations, i.e., transmission, message flow on the bus. Ref. [2] gives an overview of integration standards and recommendations in relation to the particular type of XML format and content of messages in different levels of production plants and companies.

2. Service Providers of Cloud Computing

Some services of cloud computing are offered as a so-called generic, universally applicable (e.g., Amazon) [4], which provide sophisticated on demand hosting services, while others offer almost everything is needed to make the software as a programming model, tools and control (management) system, (Ref. [5]).

Amazon Elastic Compute Cloud (EC2) [4, 6] provides a virtual computing environment that allows users to run applications based on Linux, Open Solaris, Fedora. The user can either create a new environment in the so-called AMI (Amazon machine image), which contains applications, libraries, data and associated configuration settings, whether IBM DB2, Oracle 11 g, My SQL Enterprise, Microsoft SQL Server, or can choose from a library of globally applicable AMI. The user then needs to record—“upload” created or selected AMI to Amazon Simple Storage Service (Amazon S3), before it can be done starting, operation, termination and monitoring recorded—“upload” AMI instances (e.g., great resort—large instances of the 7.5 gigabytes of memory, 4 EC2 computing units (each with 2-me virtual cores with 2 EC2-me computer units), 850 gigabytes of local memory instance, 64-bit platform).
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Amazon EC2 “teaches, fills-charges” used at a time when the instance is running (run). Amazon S3 is working entrusts—charges for any user data transfer (upload and download).

Google App Engine [5, 6] allows a user to run Web applications written using the Python programming language. Other than supporting the Python standard library, Google App Engine also supports APIs (application programming interfaces) for the data store, Google accounts, URL fetch, image manipulation, and email services. Google App Engine also provides a Web-based administration console for the user to easily manage his running Web applications. Currently, Google App Engine is free to use with up to 500 MB of storage and about 5-million page views per month.

Microsoft Windows Azure [7] is a group of technologies, services and type of cloud computing. Components and their functions for the Microsoft Windows Azure is Windows Azure, offering based on Windows-based environment for launching and running applications and data on servers, remembering data centers Microsoft SQL Azure, which provides data services based on services and cloud computing in the SQL server database. App Fabric Windows Azure platform provides services and cloud computing of links, link applications that run within the framework of a “Cloud”.

Windows Azure is a platform for running applications such as Windows and remembering their data within an environment of “Cloud”. Windows Azure runs on a large number of servers that are located in Microsoft data center and is accessible via the Internet.

Microsoft Live Mesh [8] aims to provide a centralized location for a user to store applications and data that can be accessed across required devices (such as computers and mobile phones) from anywhere in the world. The user is able to access the uploaded applications and data through a Web based Live Desktop or his own devices with Live Mesh software installed. Each user’s Live Mesh is password-protected and authenticated via his Windows Live Login, while all file transfers are protected using SSL (secure socket layers).

Oracle Cloud [9] infrastructure (also known as infrastructure as a service or IaaS) provides a complete selection of servers, storage, networking fabric, virtualization software, operating systems, and management software to support diverse public and private cloud applications. Oracle engineers its hardware with application aware virtualization and management capabilities to enable the rapid deployment and efficient management of public and private IaaS.

With Oracle Cloud, you get enterprise-grade application and platform services based on best-in-class business applications and the industry’s leading database and application server, managed by experts with over a decade of cloud delivery experience. More than 25 million users rely on Oracle Cloud every day.

Sun Oracle Grid [10] allows users to run applications based on the operating system, Solaris OS and Java, C, C++ and FORTRAN. The user can create and debug his application and scripts run under the local development environment, which is configured similarly, such as Sun Grid. Then the user needs to create an archive “zip” file bundle (containing all the relevant scripts, libraries, executables binaries and input data) and upload it to the Sun Grid environment. Finally, the user can launch and monitor applications using Sun Grid Web portal or API. After working with applications, users can perform uploading-download applications created by the results to your local...
GRIDs Lab Aneka [11] is offered by Manjarasoft Pty Ltd Comp. It is based on the platform NET (Microsoft Azure Service Platform) and focused on design services such as “corporate nets”—enterprise grids. It is based on support application models, stable and reliable solutions with easy to update the communication protocols. To create a business network grids service provider only needs to run a hosted instance using hosting container, configurable system Aneka on each selected computer type PC desktop. The purpose of the container system is to initialize Aneka services and function, causing the interaction to the rest of the corporate network grids. The user can access the corporate network Grids-Aneka enterprise grid remotely with help so called grid bus broker—agent. Aneka system provides support SLA (service level agreements), and this means that the user can specify the requirements and negotiate quality QoS (quality of service) services.

Another type of service provider “Cloud” type is the company Mosso, belonging to the company Rackspace. Mosso company applies the principle of services such as “Cloud” next to the three specific products: for hosting Web sites on Windows platforms and Linux, for storage, file storage and for virtual private servers on Linux.


3.1 Manufacturing and MAS

Manufacturing and business processes must be capable of continuous structural and technological changes in practices and organizations. Must be reconfigurable. Architecture of systems of production processes and business processes within the ERP (enterprise resource planning) systems must allow a predictable response to difficult market conditions, have the ability to interact with the environment, the ability to incorporate instant real data, and other capabilities of immediate interaction. Control of chemical and food processes based on the prediction of properties of these processes using the classical optimization methods and techniques, setting up predictive models based on time tables often does not lead to the desired objectives, the solution is very complex and complicated. The above requirements but can be relatively easily addressed by the MAS (multi agent systems) also with the cloud computing.

Many of these requirements leads to the need to process in the algorithms with unpredictable changes of quantities, magnitudes, that they are inputting to the industry chemical and food processes (e.g., input substances chemical structure, in alone process things are drawing to the unexpected chemical or biochemical reactions and it changes its parameters, equipment parameters are changing, and operator often enter to the process with his interactive access, and others), often occur in monitoring, diagnostics and management of an industrial chemical and food equipments or processes. It is not possible beforehand to plan these unpredictable events, phenomenons. These and others factors and activities are hardly automated by means of standard classical monitoring, diagnostics and management systems, that is have not inside used, disposed multi-agent systems principles. This is one of the reasons, why multi agent systems are used for diagnostics fault states, management and control of industrial chemical and food equipments and processes. The model of the intelligent manufacturing agent is in the Fig. 1.

3.2 Production, Manufacturing of the Cloud Computing

Moving production to conventional production of SOC can be inspired by a “Cloud”, for the production of “Cloud” offers an attractive and natural solutions in several computing trends such as delivery system over the Internet, use of utilities, flexibility, virtualization, a “grid” distributed computing, outsourcing, Web 2.0, etc.. Production of the “Cloud”
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is also considered as a new multidisciplinary field that includes network production, network-grid production, virtual manufacturing, agile manufacturing, and of course cloud computing. Production of the “Cloud” reflects both the concept of “integration of distributed resources”, and the concept of “integrated distribution of resources” [12]. In the production of “Cloud” are distributed resources “encapsulated, nested” in the service of the “Cloud” and centrally controlled.

A user under the “Cloud” may require services from design production, production services, testing and control to all other stages of the production cycle. Production platform services such as “Cloud” performs intelligent mapping, search, recommendation and implementation services. Production of the “Cloud” consists of 4 basic levels and that level of production resources, the level of virtual services, global production levels of service and application levels. The level of core resources includes the resources required over the life cycle of production. Key features of virtual manufacturing service level is to identify the sources of production, their virtualization as a service organization of their production of “Cloud”. Identification of resources is carried out, e.g., using RFID (radio frequency identification), EPC (electronic product code) encoding code. As a virtualization tool manufacturing facilities, production facilities are generally used agent technologies. Global level of service takes full responsibility for the operations and activities within the system of “Cloud”. Services such as “Cloud”, which are suitable for this mode are virtualized computing resources such as CPU, RAM, computer network. Services such as “Cloud” can be dynamically monitored, controlled and implemented. The application level provides an interface between the user and manufacturing resources of the “Cloud”. The level also contains the user computer terminals and tools for modeling, simulation and development of newly manufactured products.

**Fig. 1 The model of the intelligent manufacturing agent.**
4. Cloud Computing Challenges for Chemicals and Food Companies

Ongoing globalization will require chemicals companies to change their operating and business models. As well as playing a role in meeting the industry challenges, cloud computing also will help companies approach and operate many parts of their business in a radically different way, achieving a permanent step-change in their operational effectiveness and competitiveness. Key elements of the chemicals industry’s future operating models will include the following: innovation enabled and driven by global R&D (research & development) networks; new products and new markets; an increase need for customized solutions; an increased role of IT to enable co-production; continued outsourcing of noncore functions and shared services; increased competition in talent recruitment; and additional value contribution from IT [13].

As with the benefits of cloud computing, it is still too early to reach a comprehensive view of all the ways in which the cloud will change how chemicals companies operate. Strategists must investigate what new business services should be pursued using cloud computing, while CIOs (chief information officers) must track the evolution of the technology and the market for cloud services to ensure their strategic ambitions do not outrun the capabilities of the technology. More generally, chemicals companies that fail to embrace the cloud may find their IT options become increasingly limited over time, as will their ability to contain costs and collaborate effectively along the supply chain [13].

There is a growing view that if chemicals companies want to continue to take advantage of packaged software application in the future, they may find that most of this software is written only for the cloud and that if they have not created a cloud-friendly or cloud-relevant IT environment they will not be able to benefit. This view is supported by the fact that venture capitalists investing in the software industry are increasingly focusing on funding new entrants who are building their applications specifically for the “Cloud”.

When exploring the use of the cloud computing, chemicals industry CIOs (chief information officers) should carefully consider how the technology can meet the needs of their particular segment. While reducing the cost of noncore activities is relevant for most firms, other aspects of “Cloud” technology may be more relevant to specific business models. For example, a company operating as a specialty chemical provider may benefit more from the ability to rapidly adopt applications for marketing and pricing made available in the “Cloud”; then would a commodity producer that depends on repeatable, global processes to drive a consistent manufacturing process.

Also, experience shows that firms relying on innovation as their primary growth engine can offload large computing cycles to offsite servers to reduce the period of achieving experimental results.

More generally, companies in the chemicals industry face a number of common challenges springing from global economic trends, movements in the commodities markets, and ongoing change among customers, suppliers and the broader global environment. Cloud computing can help chemical companies drive operational excellence; meet growing and changing customer demands; accelerate new product innovation and ramp-to-volume manufacturing in key markets; reduce IT spending; manage and mitigate supply chain risks; and enable faster and more flexible delivery of new IT systems [13].

CIOs said that they are finding real savings from cloud computing, but executives should not take the promises and projections of cloud savings at face value. The articles about companies that have saved money rarely explain how these savings were calculated, and several apparently rigorous analyses of cloud savings have been attacked as unrealistic. In Ref. [13]...
experience, even where U.S.—based firms move their internal applications to the cloud, they usually decide to retain a number of services in-house, because the costs of hosting a server internally, whether in an optimized data center located in the United States or in a captive facility offshore, are lower than that of an external cloud service.

Executives need to look closely into the costs of cloud computing for their organizations. They should seek rigorous return-on-investment case studies based on actual cloud usage, rather than estimates of anticipated savings. Hardware, after all, is a relatively small component of data center costs. They need to uncover the hidden management, transition and usage costs that reveal themselves only when organizations start to work with the technology. They need to evaluate the pricing models of different kinds of “Cloud” services. And they need to work with the finance department to develop a consistent and acceptable approach to measuring the costs and return from clouds. Only then can they reliably estimate the savings.

For chemicals businesses, the following are critical to realizing the greatest possible cost benefits from adopting “Cloud” technologies:

- Adopting common standards that make sharing of knowledge and services easier;
- Using standard, “fit-for-purpose” and clearly defined service levels as much as possible, geared to requirements of the specific service;
- Applying standard security and data privacy restrictions appropriately, taking into account the fact that most services offered by “Cloud” providers today are managed and provisioned on a cross-border rather than in-country basis;
- Overcoming any departmental “ownership” issues so as much work can be moved to the shared cloud as possible;
- Taking care to maintain flexibility around procurement and not get too tied into specific suppliers.

5. Results in Form of Cloud Computing and MAS Applications Examples in Food and Chemistry Development and Industry

5.1 Proposition of Using Multi-agent Systems in the Control of Batch Processes

The architecture in Fig. 2 shows a “guaranteed” (assured) multi-agent and cloud computing architecture, which includes physical layer devices and virtual resources, services layer of the “Cloud” layer of management services such as “Cloud” and MAS.

First Physical layer devices and virtual devices. Natural resources are all kinds of physical devices that support the services listed above the Cloud computing like a large number of servers in the datacenter, network devices, data storage and so on. Service of Cloud computing is a form of shared resource computing methods virtualization.

Second Layer services such as “Cloud”. Layer services such as “Cloud” can provide some form of service functions relating to the composition provided by the physical layer devices and virtual resources. The form of services that are currently offered services Cloud computing can be divided into managed services, SaaS services, Web services, utilities and services IaaS and PaaS type.

Third service layer manager of the “Cloud” and multi- agent system. Service layer manager of the “Cloud” and multi-agent system usually manages a wide range of services from the services layer of the “Cloud” and Assured of the “Cloud” in providing service repertoire (portfolio) services of the “Cloud” according to user requirements. As shown in Fig. 2, the management services of the “Cloud” service includes repertoire, service interfaces, interfaces, service summary, aggregation, service monitoring, service deployment, service measurement, service security, service assured management. Multi-agent management services such as “Cloud” includes a “Cloud” agent of the applicant, assured agent in the “Cloud” service
agent of the “Cloud” and the agent manager, primarily to support and requirements of the “Cloud”.

Multi-agent systems in the control of batch processes, in batch system the production can be operated in planned mode and in mode, following immediate customer demands, immediate market demands. In the first case authors are able to estimate future demands, author can apply optimization
procedures that can comprise avoiding of deadlock-type states, as the case may be of further undesirable states. However as for recipes which encompassing, enabling alternate operations, there is usually not possible to anticipate the way, which will be, from the alternative ones, chosen as it depends on circumstances, interactions which will appear only during recipe’s realization. Also unpredictable changes in production and deviations of processes change the schedule derived originally. In those cases, coordination mechanism is needed for avoiding of deadlock type states, as the case may be of further undesirable states.

In the second case coordination mechanism is needed for avoiding of deadlock-type states, if needed be of further undesirable states. In the second case the horizon of production is short and future demands are not easily estimated, the capacity of store houses is limited. New recipe should pass through production, if need will be on given equipment the product following several recipes can be produced in parallel. Here, coordination mechanism is needed for avoiding of deadlock type states, as the case may be of further undesirable states from the very beginning. In the production unpredictable errors can not apper further, which can be repaired using alternate operations [14].

Multiagent system for the control of batch processes presupposes “agentification” of recommendation following ANSI/ISA/IEC [15-19]. System will be constructed over some real technology controlling system, communication with that system is assumed mainly with the help of objects and files in XML format. Conceptional project of “agentification” and aspect of requirement for the creation of auxiliary objects and files in XML format are introduced subsequently.

Control by MAS is usually characterized by the fact that the system performs “bottom up”, that is from the bottom up and not a system of “top down”, that is via a centralized hierarchical system where there is usually a one top management centre. Agents are able to achieve their own desired goals, without being controlled by some supervising centre. This publication briefly describes the characteristics of the multi-agent systems, cloud computing, in more details describes cloud computing in the chemical and food industry, describes the advantages of using MAS in cloud computing and algorithms for selected chemical-technological and biochemical processes using MAS and cloud computing.

5.1.1 Structure of the Multi-agent System for the Control of Batch Processes

Structure of agents responds to the description of batch process using UML (unified modelling language) or as the case may be BatchML—batch mark-up language (XML-type language) [20] and B2MML—business to manufacturing mark-up language (XML-type language) [21] respectively. This is the question of generic agent-recipe (generates agents of recipes up to the level of control recipe agents), generic agent-equipment (generates agents-equipments of elements with particular parameters and properties), agent-control recipe, agent-equipment, agent-element of equipment, agent of phase, agents of special service recipes, agent-schedule, agents-building blocks of recipes. Structure of agents is further completed by: coordinator type agents, agents-of active equipment and units, transport agents, knowledge database agents, agents for collaboration with ERP (enterprise resource planning) systems and other [22, 23].

Multiagent system as applied in connection with the control of batch process by “agentification” of procedures following ANSI/ISA/IEC [15-19] recommendations is proposed to realize the connection with commercial systems for the control of batch processes e.g.: SattBatch of ABB Automation Products Company, ProduceIT Batch of ABB Automation Company, InBatch of Wonderware Company (including the feasibility of integration with FactorySuite 2000 system of Wonderware Company);
systems of comps. Siemens, Allen-Bradley, Modicon, Rockwell Automation, SAP and others. A generic agent-recipe generates agents of recipes up to the level of agents-control recipe.

Generic agent-equipment: generates agents-equipment or agents-elements of equipment with particular parameters and qualities.

Agent-control recipe is described with the help of XML types language, i.e., BatchML and MAML (multiagent mark-up language). MAML represents communication language of agents’ knowledges exchange mechanism—AIM (agent knowledge interchange mechanism) and from the point of view of communication and conversation of agents is an extension of XML language.

Agent-Equipment: maps status and properties of equipment elements. Actualizes relevant objects and files.

Coordinator type agents are divided into: agent-coordinator of recipes; agent-coordinator of “deadlock” allocation of processors; agent-coordinator of “deadlock” allocation of transport system resources.

Coordinator type agents are assigned for “deadlock”, type states, as the case may be other inadmissible states. Coordinator type agents check the events, that could be formed by the control system of batch system and that could cause “deadlock” type states or other inadmissible states. Agents gain and analyze information for this purposes. Further, those agents are specified to prevent states that must not be reaches following design parameters. This coordination is performed on-line on the base of currently occur events, interactions and its aspects are analyzed.

Splitting reduces complexity of problem. Agent of phase are representatives of production and transfer abilities. Phase executes specific activity in production process (mixing, warming, dosing, pumping, etc.) and is configured standardly using parameters of given recipe. Phase is the smallest element of procedural model. Phase executes specific process-oriented task. Phase can be executed in parallel or sequentionally, they can finish by themselves and are the lowest group of process activities. Phase could be considered as the smallest active indivisible activity in the framework of batch system control.

In case of parallel and alternate activities in the framework of one recipe, as need is of realization of more recipes in common equipment pretentions to coordination agents and complexity of state automata or Petri nets resp. would rise enormously.

Agents of special service recipes: it deals with rules of the type cleaning, disinfection of vessels, sanitation.

Agent-scheduling: in the case of planned run of batch production this agent can secure optimal scheduling of batch processes (see above). In the case when momentary requirements of customers are realized, in the response to momentary demand of market, as the case may be by the occurrence of unexpected events the FIFO (first in, first out) principle is applied in scheduling, as need is the units are in the framework of the recipe “booked” and allocated and released following priorities or on the base of heuristic rules.

Agents-building blocks of recipe: Those agents could be generated from the recipes elements library (generic agents of recipes) [22, 23].

Agents of active device (equipment) or active production units as are reactors, mixers, separators, and others. As the agents of that types the models of behaviour of those units can be applied or as need is their behaviour can be modelled with use of neural nets.

Agents of Transport: enable transfer of material from one unit into the other. The question is of pipes in common with pumps, valves, separators, flow-meters and others. The transfer of material can pass further with the aid of various transport units, cars, as the case may be of robotic manipulation devices.

Knowledge database agent: agent can use data dealing with history of batches for creation of moreprecisioning models e.g. to perform data mining algorithms with the help of neural nets, i.e., to gain
knowledges from the course of batches.

Agents for cooperation with ERP type systems: description of interactions among agents is realized in the sense of method of UML language extension AUML (Agent UML). Communication, cooperation, negotiation of agents. Basic level: KQML (knowledge query and manipulation language) language, latest FIPA-ACL (agent communication language) [1].

Exchange of knowledges: MAML language. For the communication of agents the blackboard method is proposed, using common, if need is shared database. Preferred realization of multi-agent system is Jadex system [24, 25].

Multi-agents system development and implementation makes easy Jadex system, which is based on the Java language established, recommendation of the FIPA (foundation for intelligent physical agents) [1] organization corresponding and according to agents environments, allowing the development of target orientated agents, BDI (beliefs, desire, intentions) model suitable. Agent in the Jadex system has two basic parts: ADF (agent definition file) file, which is written in the XML (extensible mark-up Language) schema language and set of classes in the Java language enlarges on or specifies embedded classes in the Jadex system and specify how plans and targets are designed.

The description of producing, ripening tank T406 and recipe, which are some part of technology. link for yogurts producing in the MADETA Jindrichuv Hradec company of the MADETA Corp. in Czech Rep., is performed [26, 27]. Further, imaging and brief description of technol link for yogurts was produced with helping of contact controlling panel in SYSMAC CS series system.

Modelling and imaging, displaying of normal and fault states of the unit-yogurth ripening tank-un_T406 and its equipment are performed.

Agents in the Jadex system frames and those are described of the ripening tank-un_T406 behaviour, are helped, assisted in fault states detections and diagnostics. Simple model compares measured values from process with modelled, computing values, e.g., for operations: filling of tank; reactor and height level comparing in tank, reactor; substrate filling of tank, reactor; mixing; setting-up; reaction starting; heating; cooling; and others.

In points, the model program realization, implementation of fault states monitoring, diagnostics and management of the ripening tank-un_T406 is described.

Dynamic behaviour modelling of the tank-un_T406 by means of state diagrams, state automata and recurrent relations in Java language, in frame of using programming tools—agents of the Jadex multiagent systems are presented.

Further, the Jadex system extension is presented. Jadex extension is concerned with the classes, plans, that describe yogurth ripening tank-unit equipments, it means its normal, standard and also fault behaviour, that are represented by state diagrams—state automata.

The states are described in XML type language—SCXML (state charts extensible mark-up language) [28]. SCXML language provides the description for generic state-machine, state automata based on Harel state diagrams. SCXML language is able to describe complex state-machine, state automata, e.g., including sub-states, parallel states, synchronizing, parallelism, concurrency. The example of description of state diagram part-filling of unit-yogurth ripening tank-un_T406 by the milk and its syntactic description in SCXML language provides the description for generic state-machine, state automata [26, 27].

5.2 Modified Ant Colony Optimization Approach for the Diversified Service Allocation and Scheduling Mechanism in Cloud Paradigm

Lists of industrial processes control application for examples of MAS in dynamic optimization semi (fed-batch) bioreactors, using ant-agent colony algorithms for dynamic optimizations because the insect swarm, the colony does not need any supervision,
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using of MAS in the prevention of technological
accidents in the chemical industry and possibilities
used of multi-agent systems in design and control of
batch processes and productions are presented.

The paper [29] proposes an initial heuristic
algorithm to apply modified ant colony optimization
approach for the diversified service allocation and
scheduling mechanism in cloud paradigm. The
proposed optimization method is aimed to minimize
the scheduling throughput to service all the diversified
requests according to the different resource allocator
available under cloud computing environment.

The objective of the ant colony based cloud
computing initiative is to minimize the makespan. It is
well known that the problem of deciding on an optimal
assignment of requests to resources allocator is NP
(non polynomial) hard. In Ref. [29] is developed a
heuristic algorithm based on modified ant colony
optimization to solve this problem.

It has developed simulated cloud examples
(formulated in python lang. code version 2.5.2 under
P-IV machine) with derived from Google App Engine
and Microsoft Live Mesh to evaluate the proposed
modified ACO algorithm for scheduling request and its
respective services on cloud architecture. Practically,
in this model, there are incorporated 5 diversified
resource allocators like application programming
interfaces for the data store, Google Accounts, URL
fetch, image manipulation, and email services. Google
App Engine also provides a Web-based administration
console for the user with 25 different service requests
on these utilities.

5.3 Examples of Applications in a Business Area

How customers can be created and coordinated by
agents of the components of ERP systems and shows
the possible role of workflow—a system for managing
“the flow of work activities respectively, documents”
and Web services as a tool for coordination and agents
components of ERP systems [30]. In the area of
business processes gives us concrete examples of the
using of multi-agent systems in supply chain
management SCM of larger chemical companies,
optimizing the supply chain of food businesses and a
possible route optimization service, transport logistics,
chemical companies.

Infor Company [30] represents in worldwide 70,000
customers in 194 countries and 3,378 developers and
3,655 consulting experts. Infor customers are, e.g.:
American Airlines, American Express, AT&T,
Chicago Transit Authority, City of New York, GM,
Honeywell, Lockheed Martin, T-Mobile, Volkswagen,
etc.. In Europe there are to 28,000 customers. Among
the key products of Infor company there are ERP
solutions for industrial solutions, for SCM (supply
chain management), asset management (Web
solutions), WMS (warehouse management) and
performance management.

Another area that Infor company wants to attend in
the coming year is paid to offer solutions through SaaS
(i.e., a cloud computing and software as a service). The
company anticipates that customers of greater use of
so-called “hybrid” model (hosted solution combined
with the SaaS). It should Infor company cope with the
new umbrella Infor open SOA architecture, which
integrates individual solutions (a classic operation of
the application and availability of products through
SaaS) and allows them to create a comprehensive
picture with dynamic user interfaces “My Day”
utilizing Web 2.0 philosophy.

Solutions, which currently offers Infor company
through software as a service SaaS: SyteLine ERP,
SCM Transportation Management, Supply Chain
Management Supply Web, EAM and EAM iProcure,
Expense Management.

Other companies [31] offering corporate
applications in field service and type of cloud
computing are Epicor Software Corporation—EPIC
[32], QAD, Inc.—Qadi [33] and NetSuite Inc. [34].
The company develops and EPIC offers software for
ERP systems and their individual parts, i.e., systems
SCM (supply chain management), CRM (customer
relationship management), SRM (supplier relationship management), followed by the retail and service management (control of retail and services) enterprise performance management (control of corporate performance), IT service management (control of information technology services), etc. These parts such as integrated modules provide the cooperating company called Epicor 9. QAD Company, Inc. is a global provider of enterprise software applications, services and support service applications for manufacturing companies. Systems of this company are deployed in automotive, consumer industry, in food production and distribution of beverages, in high tech, etc. ERP and enterprise applications include QAD enterprise-type ERP-MFG/PRO. NetSuite Inc. Company is a supplier of corporate software vendor type of ERP, CRM, as well as of support for automated sales, marketing, financial management, inventory control, etc., supplied as required (on-demands).

6. Conclusions

Cloud computing and services as new opportunities and challenges for technological industry, chemical and food processes and for corporate IS/IT cloud computing is a natural next step in development in the evolution of products and services related to information technology systems, on-demand. It is a sort of “computer style” in which the corresponding capacity of information technologies are provided as a service enabling users to access those services and technologies through the Internet, without the need for management expertise and technological infrastructure that supports these services.

The architecture shows a “guaranteed” (assured) multi-agent and cloud computing systems, which include physical layer devices and virtual resources, services layer of the “Cloud” layer of management services such as “Cloud” and MAS.

MAS architecture and cloud computing for batch processes from the point of technological and also the company ERP view are also presented. Multi-agent system as applied in connection with the control of batch process by “agentification” of procedures following ANSI/ISA/IEC recommendations is proposed to realize in the connection with commercial systems for the control of batch processes [35, 36]. Examples of cloud computing and MAS applications in food and chemistry development and industry are presented in the last part of this paper. Proposition of using multi-agent systems in the control of batch processes is presented. Modified ant colony optimization approach for the diversified service allocation and scheduling mechanism in “Cloud” paradigm and examples of applications in a business area are also presented.

Acknowledgments

This task was elaborated under supports of project No. MSM 6046137306 MSMT CR.

References

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