Multi-agent environment of cyber and physical production for the Industry 4.0 smart factory

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Multi-agent environment of cyber and physical production for the Industry 4.0 smart factory

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Abstract. The task is to create flexible automatic production equipped with cyber and physical systems of industrial purpose. Flexible automatic systems are the base of production of the Industry 4.0 smart factory. The Industry 4.0 smart factory main purpose is to create an item designing component (machine designing) without humans and with technical documentation in electronic way. The Industry 4.0 smart factory production must be studied as a multi-agent environment with some components (agents) in physical machine level and in virtual level. There is a scheme of multi-agent environment of the Industry 4.0 smart factory and its order how to interact for agents in physical and cyber level. To describe the digital production of a smart factory is done with terms of automatic control digital systems with random delay. To unite cyber and physical systems in a single production helps to create a multi-measure automatic system which functionality is described with equations in vector and matrix form.

1. Introduction

To organize interaction of cyber and physical systems (CPS) in the Industry 4.0 production they develop and implement [1, 2] new mechanisms of control which describe the behavior of intellectual agents in multi-agent calculation environment. Multi-agent environment [3, 4] in the Industry 4.0 is a system of some agents who interact with each other and have some intellectual capabilities.

Intellectual property of the Industry 4.0 agent gives [5] a CPS ability to initiate correction processes of item manufacturing production plans form in virtual level of multi-agent environment. Intellectual agents may calculate and exchange the data. Multi-agent environments of the Industry 4.0 include [6, 7] different components of industrial purpose (cross-platform production systems).

The behavior of multi-measure automatic system to describe the production of the Industry 4.0 must be studied [8-10] in the level of physical machines (cyber and physical systems) and in the level of the virtual program models done in a cloud of cyber world. The development of control mechanisms for multi-measure cyber and physical systems requires a formal components description of a multi-agent

production environment and a formal way to describe the interaction of agents in physical and virtual levels [11, 12].

2. Multi-agent environment of digital production

Digital production of the Industry 4.0 smart factory is a collection of cyber and physical systems of industrial purposes united in a technological line (sections) which function automatically. The interaction of cyber and physical systems in physical level is done with the technology of Machine-to-Machine (M2M) of technical means of robotized transport systems.

Transport system equipped with robot manipulator the blanks are transferred (parts) among cyber and physical systems which have some technological operations to do to manufacture an item.

Multi-agent environment of the Industry 4.0 digital production smart factory has three main components (figure 1):

- multi-agent physical environment which has technical means forms the infrastructure of automatic production in physical level;
- multi-agent virtual environment (cloud) which has automatizing means placed in a cloud environment;
- communication environment of digital production based on wireless technologies of IoT (Internet of Things) or on wired technologies of Ethernet.

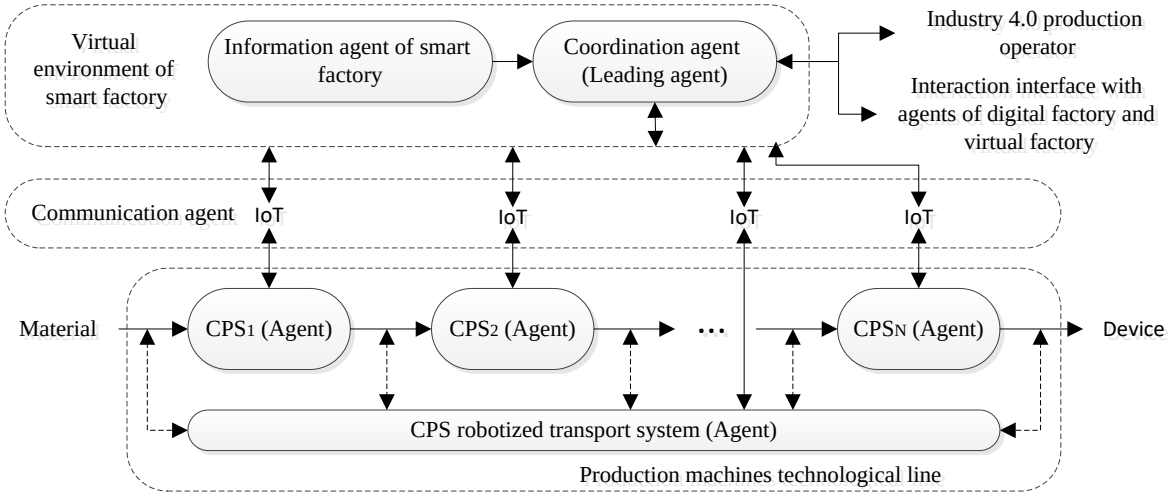

Figure 1. General scheme of multi-agent environment of the Industry 4.0 smart factory digital production.

United multi-agent physical environment and multi-agent virtual environment may create united information space of the Industry 4.0 smart factory. To divide multi-agent environment in physical and virtual components may eliminate restrictions in calculation capabilities and volume of information resources granted for CPS physical part. Multi-agent production environment equipped with cyber and physical systems is unique because:

- A good amount of independent technological routes of item manufacturing in multi-nomenclature digital production;
- Parallel completion of a lot of technological operations which is controlled with computerized systems of central and non-central principles [11];
- Annual independent distribution of part manufacturing time tables which require the same technological equipment (probability of conflict arising in resources when the production task is being done);
- Periods of cyber and physical systems maintenance which have the same time table as the item manufacturing;

- Some periodical processes of technological operations completion of CPS particular group when the big amount of the same item is being manufactured;
- CPS specialty for a particular set of technological operations with restricted nomenclature of raw materials (materials);
- Completion of production operation in automatic mode with high percentage of load (in time) of cyber and physical systems.

3. Interaction of agents in multi-agent environment

Agents of multi-agent physical environment are cyber and physical systems of industrial purpose, transport system robot manipulators, cases for material storage, parts, blanks, items and finished products. Multi-agent production environment in physical level completes automatically the closed loop of technological operations to manufacture an item.

CPS calculation components in physical level are semi-automatic. Each CPS component is an independent agent with:

- Current and previous conditions where the agent was engaged in production cycle;
- Properties to use the agent in production cycle including agent reaction when conditions are changed (some interference) of production infrastructure and other.

Agent condition control in multi-agent physical environment is done with (collaboration of agents with IoT technologies and cloud calculations):

- Production operators to monitor the condition of technological operations completion and well functionality state of cyber and physical systems with IoT technologies (net access protocols to the resource components), technologies of Humane-to-Machine (H2M), augmented reality technologies and means of remote access (production operator is an agent);
- Coordination agent whose decisions is made with artificial intelligence to realize in production self-organization of cyber and physical system. CPS self-organization [12] is to coordinate production processes which are completed independently by each agent of multi-agent environment.

Coordination agent is a program (fragment code) of multi-agent virtual environment which has (see figure 2):

- Mathematical and ontological model [5, 10] of cyber and physical system (active agents);
- Resource agent (informative resource) as a part of library of digital production ontological dictionary, description algorithms of technological processes completion, standards to describe systems and components with protocols of M2M, Systems-to-Systems, H2M, algorithms of BigData to process vast amounts of production data, CPS classes libraries (CPS class elements is an automatic system of narrow industrial purpose). CPS classes have linear and hierarchy to create parallelism of technological operations completion and scaling of CPS dynamic nets;
- Calculation agents to create cloud calculations to find the control values for CPS physical level with virtual modelling. Calculation agent must collect, storage and process of static production data which are results after part completion in physical level and after virtual modelling of production processes;
- Control agent with prior information of production plans in smart factory and production tasks of some cyber and physical systems. Control agent activity is based on artificial intelligence technologies (mathematical apparatus of non-clear logic) and that mathematical task must be solved «about the purpose» (load dynamic distribution) which has initial set of data and resources to complete the task (group of tasks). Control agent calculates the time table and

optimizes the production processes, controls the terms of production task completion, plans to take a load of company resources and other functions. To make a decision for control agent is based on analysis of industrial data received from IoT from many CPSs of the same technological route in item manufacturing.

The task «about the purpose» distributes the available tasks in some calculation (production) resources in each moment of time. When one CPS fails the production task could be given to another one which currently awaits a task. It means that in automatic production of the Industry 4.0 there is no fixed combinations of CPSs in each moment of time to complete a set of technological operations. That guarantees the quality of cyber and physical automatic production.

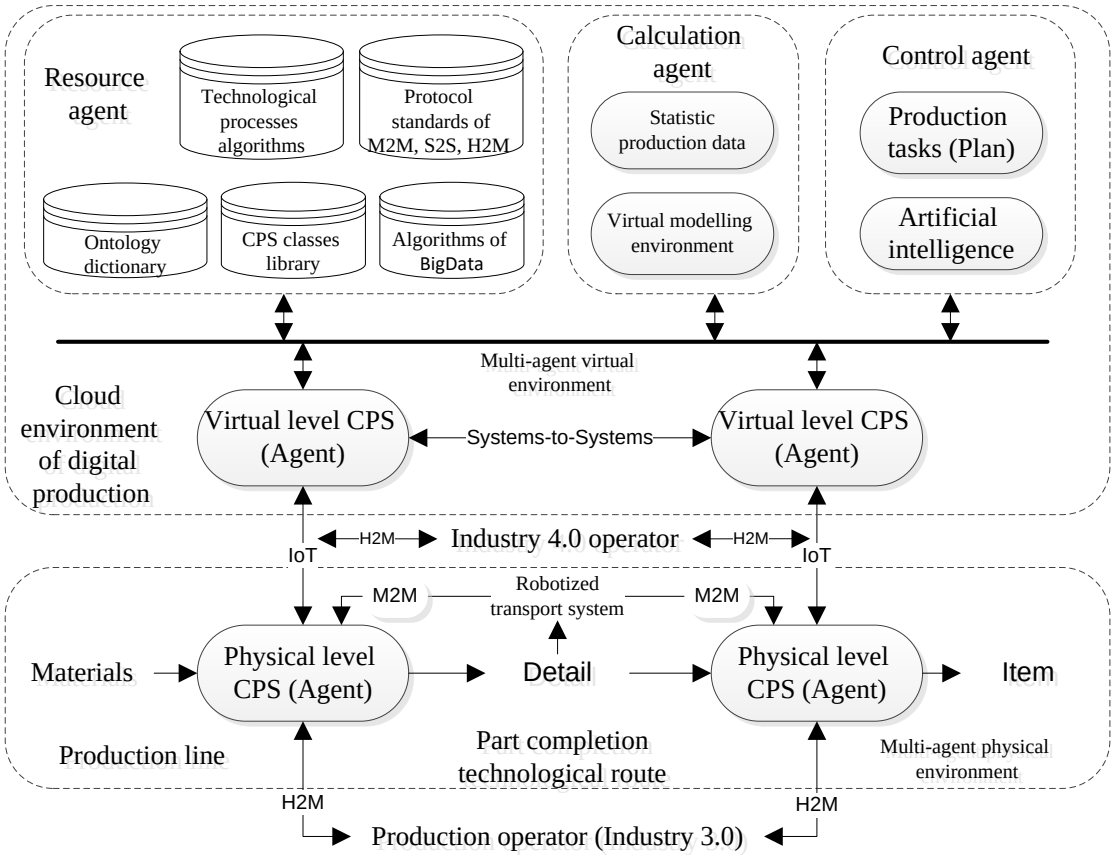

Figure 2. Scheme of interaction of operators and multi-agent environment of the Industry 4.0 digital production.

4. Conclusion

To project cyber and physical production means the synthesis task of complicated technical systems. Cyber and physical production is a multi-measure automatic discrete system which synthesis is done with criteria of automatic control.

Classical theory of automatic control may have step by step synthesis of cyber and physical system. The first step is the CPS mathematical model as automatic element and its dynamic properties. CPS model synthesis can be solved with in private or temporal for components (agents) of physical world and agents of virtual world where later the models will be united into a single mathematical equation in its discrete or continuous form (linear).

To unite some CPSs with schemes of linear and parallel connection (inserted and parallel) defined with technological routes of item manufacturing from which the resulting equations could be obtained

to describe the functionality of automatic closed loop (workshop). This way to describe cyber and physical production can be used for components of multi-agent environment and for components of virtual environments.

The last piece of cyber and physical production model synthesis is a resulting expression of vector and matrix of production components. Vector and matrix form of production description shows multi-measure automatic system at the same time in physical agents and virtual agents. They need for that variables of state of multi-measure system and control variables which together describes discrete automatic multi-measure systems of industrial purpose.

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