20th ISPE International Conference on Concurrent Engineering
C. Bil et al. (Eds.)

doi:10.3233/978-1-61499-302-5-216

Provisioning Service Resources for Cloud Manufacturing

Lingjun KONG, Wensheng XU and Jianzhong CHA
School of Mechanical, Electronic and Control Engineering,
Beijing Jiaotong University, Beijing 100044, China

Abstract. Cloud manufacturing is a new service-oriented networked manufacturing paradigm which can integrate various physical manufacturing resources and manufacturing capacities and provide manufacturing services of the lifecycle for the product. It is a new research direction in the field of the advanced manufacturing. In this paper, a provisioning method of service resources for cloud manufacturing is studied. Firstly, the service-oriented architectures are investigated to decide the service architecture for the encapsulation of manufacturing resources. Then a three-step provisioning method of manufacturing services are proposed, a function-classification based manufacturing service interface is defined, and the encapsulation strategies for four categories of manufacturing resources including intelligence resource, knowledge resource, tool resource and manufacturing capacity are put forward, and the dynamic provisioning process of manufacturing service is described. By the proposed method, the four categories of manufacturing resources can be dynamically provisioned as services with well-defined service interfaces for cloud manufacturing.

Keywords. Cloud manufacturing, service-oriented architecture, encapsulation, provision

1. Introduction

Networked manufacturing (NM) [1] represents a manufacturing pattern which can deliver products to the market in time by sharing manufacturing resources from different manufacturing enterprises connected by network technology, information technology and manufacturing technology. In order to realize NM, various NM paradigms have been proposed such as application service provider (ASP) [2], manufacturing grid (MGrid) [3], agile manufacturing (AM) [4], global manufacturing (GM) [5], etc. By these NM paradigms, a lot of research results have been achieved in the filed of resource modeling, service encapsulation, collaborative design, supply chain management, etc. In order to further expand and deepen the application of NM, a new NM paradigm, called cloud manufacturing (CMfg) [6,7], is proposed. CMfg is a new service-oriented model developed from existing NM paradigms (e.g. ASP, MGrid, AM, GM) to provide on-demand, high quality, low consumption, reliable and safe services by the network and service platform under the support of cloud computing [8], internet of things (IoT) [9], cyber physical system (CPS) [10], service oriented technologies, enterprise information technologies and so on. It is also an important direction to be followed in the field of the advanced manufacturing [11].

The goal of CMfg is manufacturing tertiarization [12] which includes two aspects of meaning. The first aspect is manufacturing inner-tertiarization which means the manufacturing enterprises provide the manufacturing resources as manufacturing services among the manufacturing industry to increase the resource utilization rate, and its essence is to provide services of the whole manufacturing lifecycle for producers. The second aspect is manufacturing outer-tertiarization, which means the manufacturing enterprises expand the their business to the product-related services such as installation, maintenance, recycling, etc. in order to get higher additional profits, and its essence is to provide services of the whole product lifecycle for customers. The two aspects not only support and promote each other, but also develop along together.

The inner-tertiarization is the foundation of manufacturing tertiarization, and how to provision service resources for cloud manufacturing is a key research topic for the inner-tertiarization. In this paper, a study of provisioning manufacturing services is carried out. The paper is organized as follows. Section 2 selects the service architecture for manufacturing resources according to the resource characteristics. Section 3 proposes a three-step provisioning method of manufacturing services, which includes three technologies: manufacturing service interface, four encapsulation strategies for manufacturing resources and dynamic provisioning of manufacturing service. Section 4 gives the conclusions.

2. Selection of Service-Oriented Architecture

In order to provision service resources for cloud manufacturing, a service-oriented architecture (SOA) is needed as the underlying service architecture. SOA is a software architecture using loosely coupled software services that integrates them into a distributed computing system by means of service-oriented programming [13], and it has three elements: service provider, service requestor and service registry. According to whether the communication protocol between service provider and service requestor is fixed or not, SOA can be classified into service protocol-oriented architecture (SPOA) and service object-oriented architecture (SOOA) as shown in Fig. 1.

In SPOA, the service provider publishes the service description to the service registry, and the service requestor looks up the service in the service registry then gets the service description. By the service description, the service requestor constructs a service proxy to communicate with the service provider, and the communication protocol in SPOA is fixed like SOAP (Simple Object Access Protocol) in Web Services and IIOP (Internet Inter-ORB Protocol) in CORBA. In SOOA, the service provider publishes the service proxy to the service registry, and the service requestor looks up the service in the service registry then gets the service proxy. The service requestor can communicate with the service provider by the service proxy without knowledge of the communication protocol, and the service provider can use any communication protocol according to its particular distributed application.

Most of manufacturing resources especially the manufacturing equipment uses exclusive communication protocol, because the manufacturer may not foresee that all the manufacturing resources will be connected in the future, or they want to maintain the key customers' share. So the SOOA which is protocol neutral is more suitable than the SPOA which uses fixed protocol for manufacturing resources.

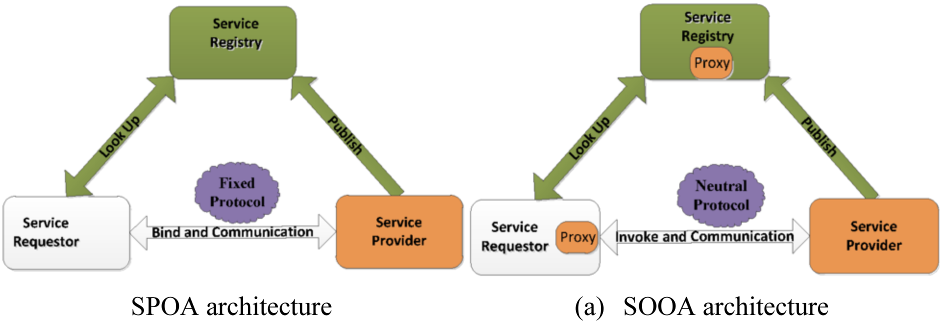

Figure 1. Comparison between SPOA and SOOA.

3. Provisioning Method of Manufacturing Services

Based on SOOA, a three-step provisioning method of manufacturing services is proposed: (i) Interface defining: to define manufacturing service interface which needs to be implemented by the manufacturing resources, so the service resources can be recognized and invoked correctly in SOOA; (ii) Resource encapsulation: according to the characteristics of manufacturing resources, to encapsulate different manufacturing resources as services and implement the interface in the service program; (iii) Dynamic provisioning: to deploy the service program into the service container, and then register the service in the service registry.

3.1. Manufacturing Service Interface

Crucial to the success of SOOA is interface standardization [13]. Service providers can publish their services and also be identified by the standardized interface. In order to define standardized interface for manufacturing resources, a manufacturing service interface is proposed based on the function classification as shown in Fig. 2.

Manufacturing service interface has two parts: manufacturing function tree and service interface. The manufacturing function tree is a classification system of manufacturing functions, and its basic element is manufacturing function (MF). Each MF node can be divided into sub MF classifications, e.g. a manufacturing function can be divided into design function, processing function, assembling function, transportation function, etc., and the design function can be divided into requirement analysis, conceptual design, structure design, etc., and the structure design can be divided into geometric modeling, structure analysis, digital simulation, etc. Thus a multi-dimensional and multi-level manufacturing domain-oriented tree can be constructed.

Service interface is the description model of MF node, it has three parts: description, signature, and method. Description is an extensible node which can describe the function information. The signature is the identifier of the service interface. The method represents the invoking information of the service interface, it can has multiple operate, and each operate can have more than zero input and output. Service interface is the model of manufacturing function and is not related to the manufacturing resources. Each service interface can be implanted by multiple manufacturing resources. And the service interface is connected to the MF tree by the function path. The manu-

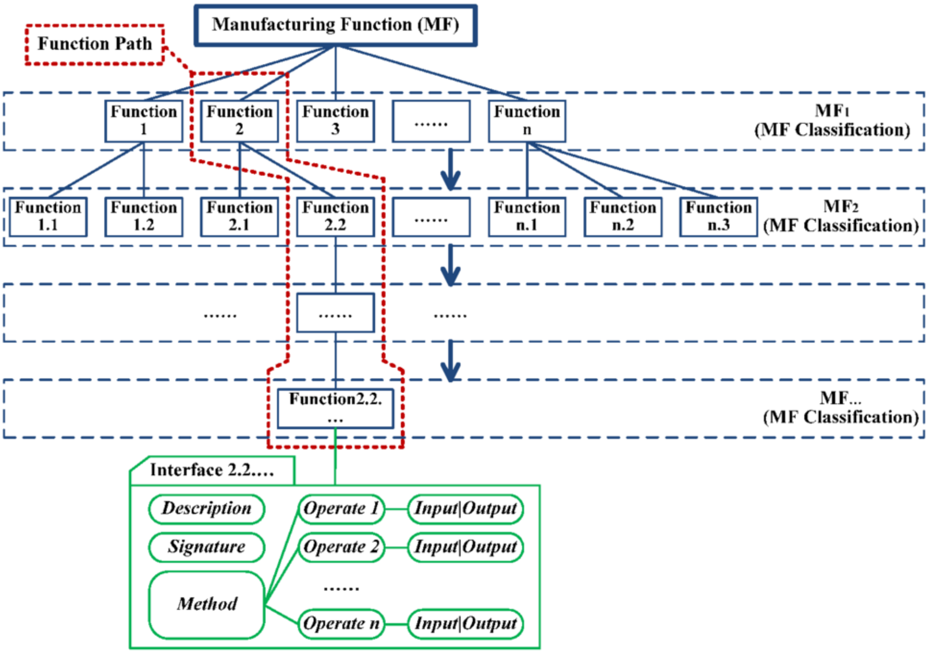

Figure 2. Structure of manufacture service interface.

facturing interface needs to be implemented by the resource provider according to the resource function, so the manufacturing service can be identified and invoked correctly.

3.2. Encapsulation Strategies for Manufacturing Resources

According to the formational relations between manufacturing resources, the manufacturing resources are classified into four categories: intelligence resource, knowledge resource, tool resource and manufacturing capacity. Because the content of each category is very rich and has many types of resources, it is infeasible to study the encapsulation method of every type of manufacturing resource. So the encapsulation strategies for the four categories of manufacturing resources are proposed below. When encapsulating a specific type of manufacturing resource, the corresponding encapsulation strategy can be extended to achieve the encapsulation of the specific resource.

3.2.1. Encapsulation Strategy for Intelligence Resource

Intelligence resource (IR) is a kind of manufacturing resource which has human wisdom behavior, and has the features of dynamic, mobility and autonomy. IR includes domain engineer, expert advisor, manufacturing activity coordinator, manufacturing requestor, product customer, etc. Generally speaking, intelligence resource is a kind of offline resource, for example, the domain engineer might not be online all the time, it might be working in the workshop or on a regular rest schedule, the IR needs to be notified to work online on time when the task arrives. If the IR has intelligent terminal, such as smart phone, PDA or tablet computer, the manufacturing task can be directly

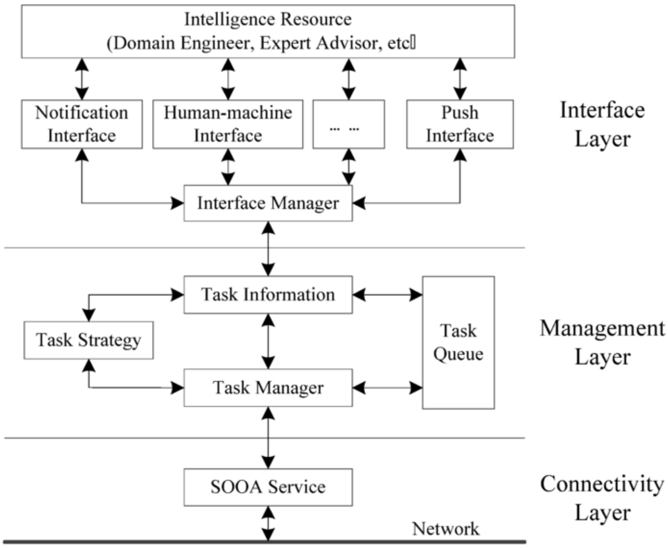

Figure 3. Encapsulation strategy for intelligence resource.

pushed to the intelligent terminal for IR. Meanwhile, the engineering background and knowledge structure of different IRs differs a lot, the customized human-computer interaction interfaces are needed to be constructed for different IRs.

According to the analysis above, the encapsulation strategy for IR is shown in Fig. 3 which has three layers: (i) Connectivity layer. The SOOA service connects to the network dynamically and is used as the connector of IR and IR service, when the IR service is requested, then it submits the request to the upper layer. (ii) Management layer. The task manager is responsible for the management of submitted service requests, forms the task queue according to the task strategy, and provides task information to the upper layer. (iii) Interface layer. The interface manager gets the task from the management layer and invokes suitable interface to communicate with IR according to the task status and IR features. If the task status is uninformed, the interface manager invokes the notification interface to ask the IR to work online on time, if the IR has intelligent terminal, the interface manager invokes the push interface to send the task directly to the terminal of IR and provides customized human-machine interaction interfaces to help IR finish manufacturing task successfully.

3.2.2. Encapsulation Strategy for Knowledge Resource

Knowledge resource (KR) is generated by intelligent activity of IR. KR is a kind of manufacturing resource which is knowledge-based and can be reused in the manufacturing process. KR can be classified into explicit knowledge and tacit knowledge. Explicit knowledge is a kind of KR which has physical form such as engineering case, working standard, simulation model and so on. Tacit knowledge is a kind of KR which still exists in IR, such as project experience, operation experience, individual method, etc. Assistant methods are needed to help the IR convert tacit knowledge to explicit knowledge in order to avoid repeated intelligent activity. For example, the knowledge engineer acquires domain knowledge from the domain engineer by means of meeting

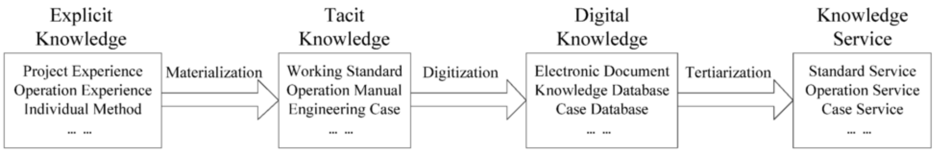

Figure 4. Encapsulation strategy for knowledge resource.

or questionnaire. The digitization is the precondition of service encapsulation of KR. Because the same KR can provide different KR services to different target users, the manufacturing function needs to be identified in order to confirm the manufacturing function interface, and the service process is the query and reasoning process of KR. Take the KR service of material property for instance, the service target user is the finite analysis element engineer, service input is the material name and analysis type, service output is the set of material properties, and the service process is the criteria query of material property database.

The encapsulation strategy for KR has three steps as shown in Fig. 4: (i) Materialization. By the methods of knowledge engineering, convert the tacit knowledge such as project experience, operation experience, individual method, etc. to explicit knowledge such as working standard, operation manual, engineering case, etc. (ii) Digitization. Convert the explicit knowledge to digital knowledge resource such as electronic document, knowledge database, case database, etc., and the knowledge resource in this stage is a localized electronic resource or a networked information resource which can be accessed through a particular tool or interface. (iii) Tertiarization. Convert the digital knowledge resource to knowledge service by means of SOOA technology, implement the manufacturing service interface according to the resource function, implement the service execution process, the knowledge resource in this stage is a knowledge service which has well-defined service semantic on the network.

3.2.3. Encapsulation Strategy for Tool Resource

Tool resource (TR) is developed by IR according to specific aim, and it is a kind of manufacturing resource which has specific manufacturing functions, and can be classified into software tool and hardware tool. The software tool includes office software such as word processor, presentation software, etc., and engineering software such as CAx, PDM, PLM software, etc. The hardware tool includes computing resources such as computer, storage, network, and manufacturing equipment such as NC lathe, machining center, drill machine and etc. The service encapsulation of TR has two preconditions: (i) TR can connect to the network. The software tools which are installed in computer can get network connection through the resource host computer. Most hardware tools need to be network-connectable by adding network connection module, for instance, add the Zigbee wireless module to fatigue-testing machine; (ii) TR provides open interface. The open interface is needed as the encapsulation interface of TR, so TR can be invoked externally.

The encapsulation strategy for TR has three steps as shown in Fig. 5: (i) Connect TR to the network. According to the resource features, add the network connection module to TR; (ii) Choose resource function. Most TRs have multiple functions, such as the ANSYS software can execute geometric modeling, meshing and finite element analysis, the multifunctional NC machine can perform the operation of drill, mill, grind

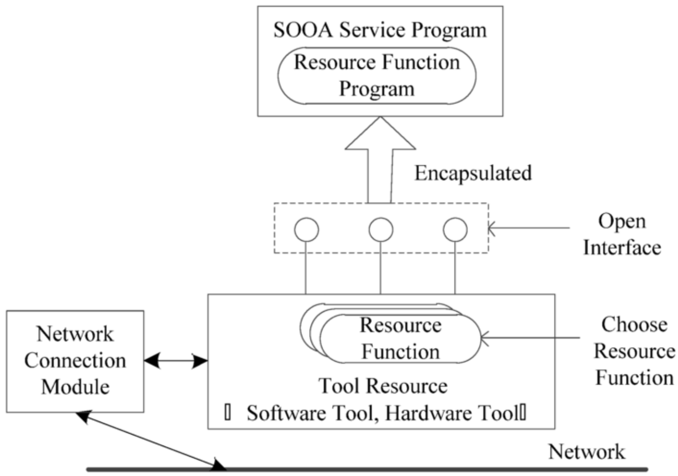

Figure 5. Encapsulation strategy for tool resource.

and laser processing, and thus the resource function needs to be chosen according to the application requirements; (iii) Build SOOA service program. Based on the open interface of TR such as application programming interface, command line interface, database interface, etc., develop the local program of the chosen resource function, then encapsulate the program by means of SOOA technology.

3.2.4. Encapsulation Strategy for Manufacturing Capacity

Manufacturing capacity (MC) is a kind of intangible resource which is composed by IR, KR and TR according to a certain logical relations and constraints. MC can provide a certain capacity to finish a type of manufacturing task, suck as design capacity, processing capacity, transportation capacity and so on. Organizing the resources of IR, KR and TR as MC has two benefits. The first benefit is the manufacturing enterprise can provide the overall solution of problem in the form of MC to attain high profits. The second benefit is the resources which are difficult to integrate by computers can be shared indirectly by the IR in MC.

The encapsulation strategy for MC has two steps as shown in Fig. 6: (i) Inner encapsulation. Based on the encapsulation strategies for KR and TR, encapsulate the easy encapsulation resources of the interior of MC as services to improve the operation efficiency of MC. (ii) Outer encapsulation. Based on the encapsulation strategies of IR, encapsulate the IR of the interior of MC as IR service. The IR service is taken as the service agent. The requestor can submit task to the IR service, then the IR service will inform the representative IR to coordinate the resources in the interior of MC to finish the task collaboratively.

3.3. Dynamic Provisioning of Manufacturing Services

After the encapsulation of manufacturing resources, the SOOA service programs need to be deployed into the SOOA service container and be provisioned as manufacturing services on the network. The SOOA service container is a light-weight service contain-

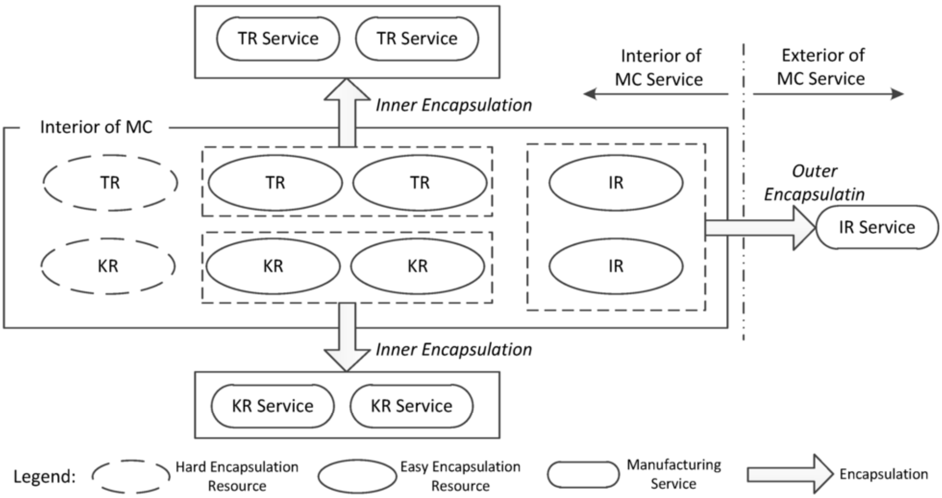

Figure 6. Encapsulation strategy for manufacturing capacity.

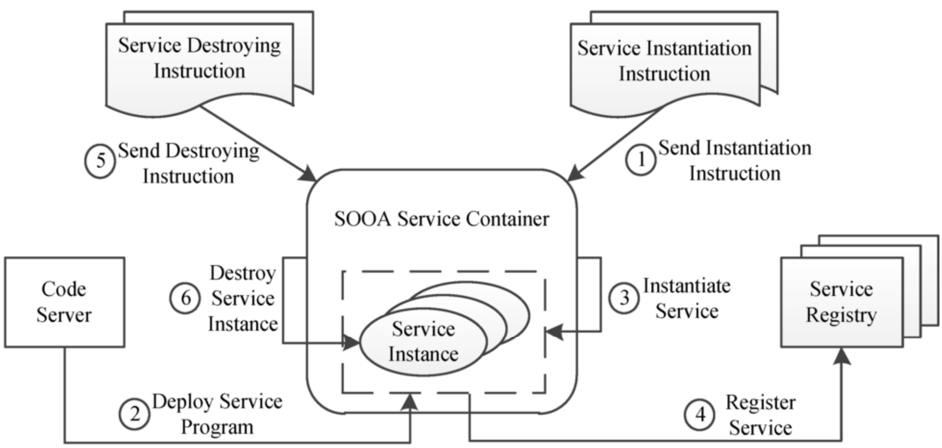

Figure 7. Provision process of manufacturing service.

er for SOOA services, and it supports distributable hot deployment, e.g. Cybernode service in RIO [14]. The provisioning process of manufacturing service has six steps as shown in Fig. 7: (i) Send instantiation instruction with the location information of code server and the service interface to the SOOA service container; (ii) SOOA service container deploy the service program by downloading the service program from the code server according to the service interface; (iii) SOOA service container startups the deployed service program; (iv) The started service program registers its service proxy in the service registry; (v) After the invoking of the service, the destroying instruction is sent to the SOOA service container; (vi) The service container destroys the service instance, and the service is unregistered by the service registry.

4. Conclusions

Provisioning diversified service resources is the key to the implementation of cloud manufacturing. According to the exclusive characteristics of communication protocols of manufacturing resources, SOOA is selected as the underlying service architecture. An SOOA-based provisioning method of manufacturing services is proposed, by which the four categories of manufacturing resources including intelligence resource, knowledge resource, tool resource and manufacturing capacity can be encapsulated and dynamically provisioned as services with well-defined interface for cloud manufacturing. This work is the research basis for the following studies of CMfg in the future.

Acknowledgements

This research is supported by the National Natural Science Foundation of China (No.51175033).

References

[1] Y.S. Fan and G.Q. Huang. Networked manufacturing and mass customization in the ecommerce era: The Chinese perspective[J]. International Journal of Computer Integrated Manufacturing, 2007, 20(2–3): 107–114.
[2] G. Flammia. Application service providers: challenges and opportunities[J]. IEEE Intelligent Systems and Their Applications, 2001, 16(1): 22–23.
[3] F. Tao, L. Zhang and A.Y.C. Nee. A review of the application of grid technology in manufacturing[J]. International Journal of Production Research, 2010, 49(13): 4119–4155.
[4] Y.Y. Yusuf, M. Sarhadi and A. Gunasekaran. Agile manufacturing: The drivers, concepts and attributes[J]. International Journal of Production Economics, 1999, 62(1/2): 33–43.
[5] M. Ulieru, D. Norrie, R. Kremer et al. A multi-resolution collaborative architecture for Web-centric global manufacturing[J]. Information Sciences, 2000, 127(1/2): 3–21.
[6] B.H. Li, L. Zhang, S.L. Wang et al. Cloud manufacturing: A new service-oriented networked manufacturing model[J]. Computer Integrated Manufacturing Systems, 2010, 16(1): 1–7, 16 (In Chinese).
[7] X. Xu. From cloud computing to cloud manufacturing[J]. Robotics and Computer-Integrated Manufacturing, 2012, 28(1): 75–86.
[8] M. Armbrust, A. Fox, R. Griffith et al. A view of cloud computing[J]. Communications of the ACM, 2010, 53(4): 50–58.
[9] International Telecommunication Union. ITU Internet reports 2005: The Internet of things[EB/OL]. (2005-11)[2013-01-13]. http://www.itu.int/osg/spu/publications/internetofthings/InternetofThings_summary.pdf.
[10] E.A. Lee. Cyber physical systems: Design challenges[C]// Proceedings of the 11th IEEE International Symposium on Object/Component/Service-Oriented Real-time Distributed Computing, 2008, Orlando, USA, 2008: 363–369.
[11] B. Huang, C. Li, C. Yin et al. Cloud manufacturing service platform for small- and medium-sized enterprises[J]. International Journal of Advanced Manufacturing Technology, 2012, doi: 10.1007/s00170-012-4255-4.
[12] A. Szalavetz. 'Tertiarization' of manufacturing industry in the new economy: Experiences in Hungarian companies[R]. Budapest: Hungarian Academy of Sciences, 2003.
[13] M. Sobolewski. SORCER: Computing and metacomputing intergrid[C]// Proceedings of 10th International Conference on Enterprise Information Systems, Barcelona, Spain, 2008: 74–85.
[14] Rio Project[EB/OL]. (2012-12-31)[2013-01-13]. http://www.rio-project.org/.