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New Trends in Manufacturing: Converging to Service and Intelligent Systems

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Abstract: Manufacturing processes and models have been influenced by the linear approach, called Fordism, for almost a century, since the first automated devices and discrete control systems were introduced. At the same time, new ideas to organize manufacturing process have appeared that question the absolute dominance of gain in scale. More recently, new criteria invaded the scenario of manufacturing where quality led manufacturing process to a phase based on accurate supply chain and surrounded by ubiquitous computer and robotic devices. A very precise manufacturing processes can now be designed and implemented in almost all sectors of industry, where special sub-processes can be delivered by other players. In this new scenario, a new paradigm for manufacturing design emerged, based on a set of very specialized services that could be arranged to provide new creative and sustainable processes. In this paper we go into this new paradigm for manufacturing (process) design comparing it with the classic approach that relies on layers classified as production plant, control (software oriented) and supervisory.

Keywords: manufacturing design, service design, manufacturing service, AI planning.

1. INTRODUCTION

It is possible to devise two different phases for manufacturing systems: the one called classic, characterized by the important role played by humans in concentrating the "intelligence" of the process and all flexibility it could contain; and the digital manufacturing era, where the manufacturing process is ubiquitously permeated by computer and robotic devices (and linked by network connections). In the abstract of the book Fundaments of Digital Manufacturing Science, Zhou et al (2012) make a clear statement concerning the current status of manufacturing that could be also intriguing if we foresee in it the potential for a paradigm shift:

"… Originally manufacturing was accomplished by hand, but most modern manufacturing operations today are highly mechanized and automated. The history of manufacturing is as long as the history of human civilization, and it has become the basis of human being's existence and development. We cannot imagine how the world would be without manufacturing, so manufacturing develops with the progress of human beings, and manufacturing technology progresses alongside the progress of human society."

Manufacturing, and especially industrial manufacturing gave an enormous contribution to the development of human kind in the last two centuries. In fact, manufacturing influenced the whole design processes, and, in the beginning of the last century launched a reference process to create artifacts that could be classified as "goods" or manufacturing pieces. This reference process generated a paradigm that could be named as good-dominant (Lusch et al 2008).

Actually, the good-oriented approach was spread in Engineering Design in general, and specially in manufacturing since almost a century up to the last decade of the 20th century when a different paradigm appear: the service-dominant approach (Lusch et al 2008)(Vargo and Lusch 2006)(Spohrer et al 2007). In the light of this new influence, several attempts were made to preserve the current status of manufacturing and the good-oriented approach as the most appropriated to discrete and tangible artifacts, leaving the novel design to immaterial artifacts. However, there is a great possibility that the "continuity of the evolution" anticipated by Zhou et al (2012) points to a convergence between manufacturing and service, instead of a detached (Ettlie and Rosenthal 2011) situation, mainly inspired in products (good-dominant). If we look at this change as one from good-dominant to service-dominant and as a social-economic paradigm shift, this certainly will change the way we deal with manufacturing technology. The proposal of this paper is to analyze this possibility and propose a fusion of these two concepts (service and manufacturing) into a real paradigm shift that stands behind intelligent manufacturing systems. A natural consequence is to change the way we design manufacturing processes, which is the main contribution of the paper.

2. MANUFACTURING SERVICE EVOLUTION

Manufacturing service started with turn up of OEMs (Original Enterprise Manufacturers), where companies go into the business process of others breaking the rigid production process inherited from "Fordism". Since them, the number of services available has evolved and diversified in a list that includes: EMS (Electronic Manufacturing Services), or ECM (Electronic Control Manufacturing), MAS (Manufacturing Advisory Service) and a broad set of different services that become crucial to new demanding and innovative market. Therefore, it is not surprising that Electronic Industry has took a lead in this process, while improving the demand for new products. The introduction of manufacturing service became a consequence and also a stimulus for this high-speed evolution of products. It is an answer to the demand for quality in components, sub-processes, special material, planning and resource control, efficient supply chain management, etc.

Historically, the early introduction of service in manufacturing received the name of servitization (of production) focusing on a process that combined an arrangement of services and components (eventually products as well) to compose the manufacturing of a target (product) artifact. Naturally, the main challenge was (and still is) the shift from an exclusively product-dominant approach to this new one, where value creation is added in the moment of the product delivery. That means that once manufacturing process is affected, the whole business process must change, in the sense the deliverable is now a combination of product and services.

Today the service approach is present in all sectors of the economy and met ICT (Information and Communication Technology) and finally reach cloud computing. With this surrounding technology, services can now face ACP Theory (Wang & Shen 2011, Wen at al. 2013), where innovation is supposed to follow a process that puts together artificial (intelligence) components (agents), with which is possible to do computational experiments for their collaborative actions resulting in intelligent supervision and control systems that work in parallel with the physical system.

All these tendencies converge to new productive arrangements where manufacturing processes still preserve a link to a specific artifact, while relies on a diversity of manufacturing services to compose its business process. However, this arrangement is very dependent on service design and demand new and sound approaches from service design to properly associate different artificial manufacturing services in a computational and collaborative network (Nof, 2013).

3. SERVICE DESIGN

There are several examples of manufacturing services that appeared during the last twenty years (not necessarily known by this name), but among all of them logistic processes reached the best performance. We can see logistic applications as a network involving suppliers (OEM contractors included), manufacturing plants, warehouses, and customers.

In some academic works, the management of suppliers was envisaged throughout some Internet-based clusters and called virtual enterprises arrangements, emphasizing a client-server approach between suppliers and manufacturers (Ferrada et al. 2013). However, that kind of service does not involve a (human) costumer, and the definition of value creation is different from what have been proposed by Moussa at al. (2010), and Goldstein at al. (2002). Current definitions based on agents (human or not) are not so strict and allow that a service could be provided to a generic agent (eventually called “user”), opening the possibility for a more generic approach.

Other important application can be devised as warehouse storing and retrieval, or emergence supply, a necessary management decision that could fit strategic changes or even important adjustments in manufacturing plan. Guettinger at al. (2011) showed that a good service-oriented software approach, based on the Simulate Annealing algorithm could reduce the lost in 10% by applying such strategy to emergence supply.

Other important application is the shared warehouse service that could serve several different enterprises. That is a creative approach, which benefits specially the computer manufacturing industry. This sector experienced a reduction in profit in the last five years and seeks for new ideas to improve its business process. Selling services - were products are components (informatics service) - is an idea that has being explored for big computer dealers, at least those who use to deal with big consumers.

The key point is exactly how to compose service and products in the same business process, and how to design, control, and supervise these new manufacturing processes. New service design methods are the key issue to enhance processes in manufacturing, composing new arrangements of products and services that should reach end users (humans or not).

Service Design is responsible for the modeling, analysis and specification of design processes that effectively covers a set of objectives called service requirements. In other words, the target service is modeled from a set of requirements that must be satisfied by a generic process that uses both (manufacturing) services and product components, besides resource material. The challenge is to find the best solution, or the best set of sub-processes satisfying requirements that fit an optimized design condition. Strategic needs could also demand some flexibility, that is, the set of suppliers, components and agents could be open, in the sense that their cardinality could change. Strategy is also a requirement that should be reflected in the way interaction and collaboration among people, machines, resources, inputs, and outputs are organized.

Such design process should have some different characteristics:

1. Treat people, devices components and activities as agents of the overall service/artifact, which compose the domain of the system;
2. Organize these discrete elements to achieve sub-goals (intermediary states) that leads to a finite set of states called final states;
3. Define a unique initial state;
4. Organize external elements (people, components, etc.) to set a proper time to attend needs from internal processes (as in timed resource allocation problem).

Another important issue in the design process of service/products is the value creation. This value creation should occur exactly when the service is provided, that is, in the exact moment it occurs the coupling between the system, composed by services and products, and the end user. This fact leads to a more precise validation/verification, which includes a model of the end user expectations. A more familiar issue is co-design, where end-users should anticipate their intentions and expectations to achieve a good design for a service-oriented system.

Some authors even claim that service design is better defined than the service concept itself (Goldstein et al 2002). However, we must also take in account that there is another important issue in service-oriented systems: artificial planning and scheduling (Vaquero et al 2011). Some process are not just workflow of items and messages but involve also people and a selection of admissible actions, therefore, they fall into the category of problems that should be solved using techniques of Artificial Planning and Scheduling, including the possibility to verify the resulting plan, called post-design (Vaquero et al. 2013).

Anyway, it is clear that service design is a complex problem that requires a fusion between traditional (engineering) design theory and some concepts of cybernetic and artificial intelligence.

If manufacturing is the result of a proper arrangement of processes and activities (Xun 2012)(Zhao 2012)(Ettlie and Rosenthal 2011), requiring human and machine resources to satisfy a human and/or machine demand, then, it could be treated as a service oriented problem and demands a service-oriented design.

The point now is how to formally define service design or at least how to identify its constituents. Following a very sensible method, we propose to investigate, first of all, the relationship between demands for new design service approaches (and manufacturing service in particular) and those that could be satisfied by conventional methods (rational methods, structured, objet-oriented, axiomatic, using reference models, model driven, etc.). At the same time, we investigate new demands that push us to go further in the investigation about service issues.

The hypothesis is that to achieve good manufacturing service design we should first define a domain, composed by sets of issues such as resources, human agents, machine agents, process actions and restrictions (timed or not). Over this domain, relations could be defined as well as workflow processes, and flow of information. All these artificial (and human) agents could be linked by a computational information system (including a supervisory system). Such system would work in parallel with the physical system (main assembler or manufacturing plant, shared warehouse, etc.), and some contact checkpoints should also be defined as part of the design process connecting information system and plant.

This process should be analyzed and simulated using a formal approach based on automaton and/or Petri Nets (including Time Automaton and Time Petri Nets) before putting both to work in parallel.

In the current hypothesis we avoid going deep in cognitive and intelligent methods but will be back to them as a future work. Thus, the framework we have so far is a set of classic design methods and a informal method to collapse viewpoints.

4. SOFTDISS: A FRAMEWORK ENVIRONMENT TO SERVICE DESIG

Our proposal is based on two assumptions: *i*) the design of a large and complex (service) system should be model driven (Kent 2002); *ii*) such design must follow a design discipline implemented in a framework, eventually using special tools to support innovation. Following that we choose a commercial environment to provide the basic approach: the Enterprise Architecture – EA, designed by Sparx (http://www.sparxsystems.com.au/).

EA environment uses MDG (Model Driven Generation) technologies, which allow the designer to extend the domain of EA to include knowledge from sub-domains, notations, etc. Also, EA already has a service-oriented extension: SOMF (Service Oriented Model Framework) proposed by Michael Bell (2008). This framework is directed to the design of service-oriented software systems. Therefore, we also included SOMF in our solution.

The proposed framework is called SoftDiss (Service Oriented Framework to the Design of Information System Service) and extends SOMF method to design information management systems to a wider approach supporting requirements analysis based on viewpoints and in a formal modeling. Thus, in the early phases, it is included a basic processes of elicitation, modeling and requirement analysis using a dynamic and cognitive configuration of technologies (and external tools). In this phase the process is semi-formal (as it is in all representations used, such as UML) and could not count on the automation of verification/validation process.

After the modeling of the domain (described above) requirements will be divided in business process (BP) and basic requirements (Oliveira and Silva 2011)(Khadraoui and Feltus 2012), covering all distinct functionalities, associated with different classes of agents. Requirements are also arranged in blocks to compose models of the service system in different levels of abstraction and in different levels of formalization, ranging from informal specifications in a semi-formal stage, until a formal requirement specification in a formal language, such as, for instance, SysML, or re-using a developed component. BP are strictly linked to stakeholder viewpoints, while all remaining requirements meet viewpoints for other classes of agents, including final users, managers, operators, etc.

Four different environments compose SoftDiss: Requirement Environment, Design Environment, Formal Environment and Managerial Environment. All environments are service-oriented and contribute to compose the main service goal, which is to provide the design of a new service system. Fig. 1 shows the basic composition of SoftDiss.

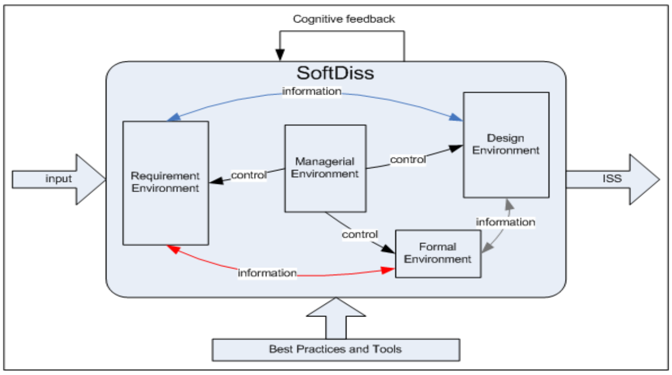

Fig. 1: Basic Structure of SoftDiss

Working with the Requirement Environment (ReqEnv) implies in organizing (structuring) requirements for all components, resources and (manufacturing) services in the domain definition. That means developing some of this components and services or just assembling (or reusing) them according to the requirements and documentation they already have from a previous design. However it is important to detach that during this process the Business Model (BP), the User Requirement (UR), and some reference model of the general product to be manufactured must be combined and checked for consistence. That is what is called Requirement Analysis.

Once a specification model is available, the Design Environment (DesEnv) identifies and analyzes all processes to produce the target service/product. That could be done informally, or going to a formalization procedure in the Formal Environment (ForEnv). Formalization would lead to formal verification or some validation based on a semi-formal approach. Formal representation is now carried by SysML and by classic and High Level (Timed) Petri Nets. As we said before, no AI or cognitive treatment was included.

The development process does not separate between design and management process. Thus, a Management Environment (ManEnv) provides a proper supervision for the whole design activity since project planning and supervision that follow domain definition up to resource allocation, warehousing and logistics. We claim that especially in what concerns service design, this management activities must be done in parallel with design activities, which brings another difference from the current classic approach.

Fig. 2 shows a more detailed view of SoftDiss with all internal element environments. The information flow among them is also represented, as well as methods, techniques and tools that compose the framework. Notice that such set of tools is open and can be changed or improved, by adding (or removing) more services or components. That is exactly what makes the proposal an interesting exploratory investigation environment to study service design.

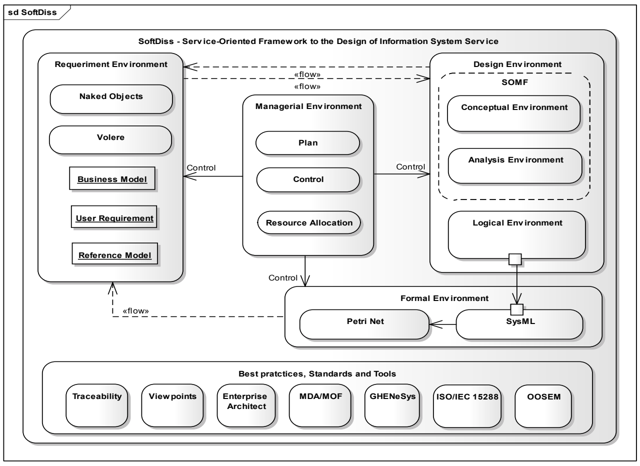

Fig. 2 SoftDiss detailed architecture

Fig. 2 shows the relationship between SoftDiss modules and those derived from the original proposal of Michel Bell (Bell 2008). All original modules are inserted in the Design Environment were a Logic Module were also included. The main idea is to transform the semi-formal model provided by SOMF modules in a formal model based on SysML (OMGSysML 2012). This is the first step to start a verification cycle to the new design. In the near future we will also include a time based analysis and verification relying in an object-oriented net system proposed by some of the authors called GHENeSys (General Hierarchical Enhanced Net System)(Silva 2008). Such inclusion would allow the system to be applied to real time (service) applications.

5. SOME PROMISING RESULTS

In order to evaluate the capacity of the framework to solve real problems, three different service systems were used as case studies: *i*) a customized Smart Grid system where manufacturing (of components) stay more in the components than in the final product/service; *ii*) an application of supply chain in agribusiness, directly linked to providing products to support automation in agriculture; *iii*) a consulting and research service, which is a pure service system and matches the servitization design occurring in several manufacturing environments, specially in the automotive industry.

The Smart Grid system was modeled, based on a reference model developed by EPRI (Energy Power Research Institute), and customized to emerging countries, especially to Brazil. With this application we could face the complexity of a system that combines services (supervision, maintenance, accounting, Internet business, etc.) and manufactured products[1] (smart meters, automated transformers, etc.) to provide a better service to the end-user. The final (social) service includes a lot of human agents (technicians, engineers, managers, help desk, etc.) that act in collaboration with machines to provide service. However, a real co-design process was not launched, what was expected when a reference model is used. For these reason other case

[1] Some of this products also had their manufacturing process designed, but not using SoftDISS.

studies were considered to explore requirements analysis for a different kind of process.

A formal workflow model of the process can be seen from Fig. 3, where an enhanced hierarchical model of the classic Place/Transition net is used. However, the supporting tool used, GHENeSys (General Hierarchical Enhanced Net System) (Silva 2012) (Silva 2008) could also support Time Petri Nets or High Level models that follow ISO/IEC 15.909 standard.

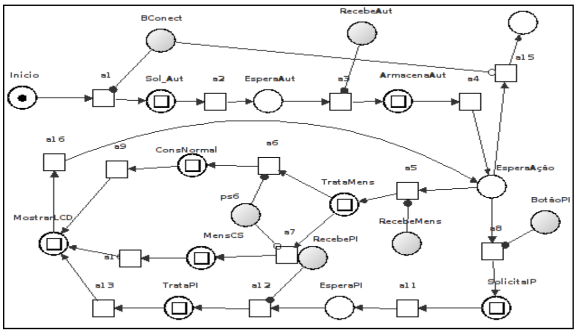

Fig. 3 Net model for the Smart Grid approach

Service applied to agribusiness shows a different case study where there is no reference model. Thus, design must be more creative and innovative and the importance requirement analysis grows up. On the other hand, it is a (real) process and therefore difficult to formalize, due to its nature and because it involves diversified classes of users which could not be modeled using any classic tool available.

Thus, agribusiness application is a good case where a diversity of viewpoints (Fig. 4) (more then in manufacture business) should be considered. It is a case that deals with the growing demand for automation, process innovation, and new equipment, launched by the fast growing in the demand for aliment. Such combination makes this integrated project for precision agriculture difficult challenge to face without SoftDISS Management Environment (ManEnv).

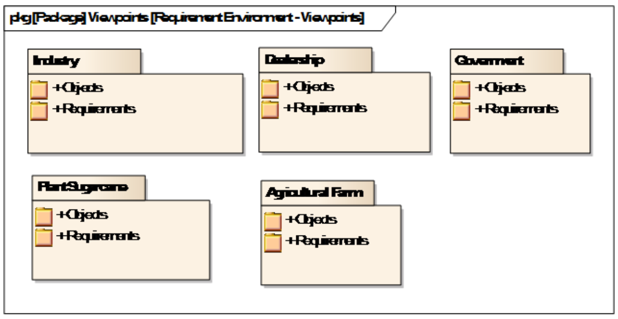

Fig. 4 Dealership requirement viewpoints

Finally, in an attempt to provide a good metaphor for manufacturing services, we used SoftDISS to design a service for a consulting design group (our own Design Lab).

Design groups (companies) are today the most detached manufacturing service in automotive business, or to fulfill the demand for specific or personalized equipment (motors, sensors, robots, etc.). In the present case we select our own Lab, which is a research lab and also works with the design of industrial processes, sometimes requiring the redesign or reuse of legacy systems.

As we expected, using the framework proposed to support design of service raises the need to model (formally) some classes of human participants, not only the end user but engineers, consultants, managers, system managers, etc. In this particular case machines are important but not enough to determine the characteristic of these service components and the flow of information. That is what they are called a Cyber Physical Social Service system (in opposition to just a Cyber Physical Service, where the presence of humans are not so important). This experience was important to lead our investigation to innovative processes including human (agent) modeling and to proceeds to a new research line focusing on man-machine relationship and its impact in manufacturing services.

6. CONCLUSIONS

As many other areas (education, industrial agriculture, consulting, etc.), manufacturing is facing an agile and volatile market (Christopher 2000), characterized by a high variety of tools and great uncertainty in their life cycle. The first reflex of market pressure can be notice in new arrangements for supply chain, especially in automotive business. However it is possible also to follow this tendency in the computer and electronic market, were a shift for service could means a good way to improve revenue, as is happening in the personal computing Chinese industry.

By the end of the last century, robot manufacturers proposed a fully automated environment to build automobiles in a single room, instead of a huge (linear) industrial facility. Similar proposals appear in the pharmacy industry, where special drugs can be prepared on demand, instead of in a scaled production. The reason is that the only way to combine harmonically the bias for good quality, high production speed, fast innovation, and sustainability is to shift from good-dominant processes to a hybrid process composed of manufacturing services and components that result in a service, in a product or even in a combination of product and services.

Manufacturing in this new perspective is a complex and demanding process, where design is a key issue and probably the first challenge to be faced. A simple assembling of good practices, semi-formal and formal approaches are promising but not enough to all kind of productive arrangements or for all kind of manufacturing services as shown in this work. Therefore, some new challenges should be presented, such as the introduction of cognitive management and the introduction of planning and scheduling processes based in AI methods.

Besides, direct applications in manufacturing components (or services) - such as warehouse managing, logistic problems, shared storage, or direct control algorithms - AI (and a cognitive approach) should be applied to the whole conception of service, with the modeling of classes of human agents and its “intentions”. Thus, in our research a new tool (also developed in our lab) is being added to SoftDISS:

itSiMPLE (Vaquero at al. 2013) to provide some of this demand for AI planning and scheduling.

We are also improving SoftDISS to provide scalability and to cover a wide and diversified demand of problems and service arrangements. In the near future we expect to have a new cognitive framework available for manufacturing design.

REFERENCES

Agogué, M., F. Arnoux, I. Brown, S. Hooge. "Introduction à la conception innovante. Élementes théoriques et pratiques de la théorie C-K.". Paris: Presses des Mines, collection Économie et gestion, 2013.

Bell, M. 2008. *Service-Oriented Modeling: Service Analysis, Design, and Architecture*. 1st ed. New Jersey: John Wiley.

Dolgui, A., J-M. Proth. 2010. *Supply Chain Engineering: Useful Methods and Techniques*. Springer Verlag, London.

Dutra, D., Valter C. Oliveira, J. Reinaldo Silva. 2013. Proc. of IFAC IMS 2013, São Paulo, Brazil.

Ettlie, J.E., S. R. Rosenthal. 2011. Service Versus Manufacturing Innovation." Journal of Product Innovation Management, v. 28, no. 2, pp. 285-299.

Ferrada, F., L. M. Camarinha-Matos. 2013. Collective Emotions Supervision in the Product-Servicing Networks. In: Technological Innovation for the Internet of Things, IFIP, vol. 394, pp 32-42.

Fry,T. D. C. Steele, B. A. Saladin. 1994. "A Service-oriented Manufacturing Strategy", International Journal of Operations & Production Management, Vol. 14 Iss: 10 pp. 17 – 29.

Gao, J., Y. Yao, V. C. Y. Zhu, L. Sun, L. Lin. 2011."Service-oriented manufacturing: a new product pattern and manufacturing paradigm." Journal of Intelligent Manufacturing, 22: 435-446.

Goldstein, S.M., R. Jonhston, J. Duffy, J. Rao. 2002. "The service concept: the missing link in service design research?" Journal of Operations Management, vol. 20, no. 2, 121-134.

Guettinger, D., E. Godehardt, A. Zinnen. (2011). In: Online strategies for optimizing medical supply in disaster scenarios.

Khadraoui, A., F. Christophe. 2012. "Service Specification and Service Compliance: How to Consider the Responsibility Dimension?" *Journal of Service Science Research* 4 (1) (June 30): 123–142.

Lusch, R., S. Vargo, and G. Wessels. 2008. "Towards a Conceptual Foundation for Service Science: Contributions from Service-dominant Logic." IBM Systems Journal: 1–9.

Moussa, S., M. Touzani. 2010. "A Literature Review of Service Research Since 1993". Journal of Service Science (2010) 2:173-212 .

Nof, S. Y. 2013. Research Advances in Manufacturing with Service-Oriented E-Work and Production. Proc. of IFAC IMS 2013, São Paulo, Brazil.

Oliveira, V. C., J. R. Silva. 2011. "Process Oriented Design Service: Case Study for Automated Information System." In *21st Brazilian Congress of Mechanical Engineering*, 10. Natal, RN, Brazil.

Silva, J.R., I. Benítez, L. Villafruela, O. Gomis, A. Sudrià. 2008. "Modeling Extended Petri Nets Compatible with GHENeSys IEC61131 for Industrial Automation." *The International Journal of Advanced Manufacturing Technology* 36 (11): 1180–1190.

Silva, J.R., del Foyo, P.M.G., 2012. "Timed Petri Nets". In Petri Nets: Manufacturing and Computer Science, Pawel Pawlewski (ed.), pp. 359-378, InTech.

Spohrer, Jim, Paul P Maglio, John Bailey, and Daniel Gruhl. 2007. "Steps Toward a Service Systems." IEEE Computer Society (January): 71–77.

Tao, F., L. Zhang , K. Lu & D. Zhao. 2012. "Research on manufacturing grid resource service optimal-selection and composition framework." Enterprise Information Systems, 6:2, 237-264.

Vaquero, T. S., J.R. Silva, J.C. Beck. 2011. A Brief Review of Tools and Methods for Knowledge Engineering for Planning & Scheduling. In: Int. Conference in Automated Planning and Scheduling, 2011, Freiburg, Germany. Proceedings of ICAPS 2011. Menlo Park: AAAI Press, 2011.

Vaquero, T.S., J. R. Silva, F. Tonidandel, J. C. Beck, 2013, itSIMPLE: Towards an Integrated Design System for Real Planning Applications, The Knowledge Engineering Review, vol. 28, no. 02, 215-230.

Vargo, S.L., and M.A. Akaka. 2009. "Service-Dominant Logic as a Foundation for Service Science: Clarifications." Service Science 1 (1): 32–41.

Vargo, S. L., and R. F Lusch. 2006. "Service-dominant Logic: What It Is, What It Is Not, What It Might Be." In The Service-dominant Logic of Marketing: Dialog, Debate, and Directions, ed. S. L. Vargo and R. F Lusch, 43–56. Armonk: M.E. Sharpe.

Vargo, S.L., and M.A. Akaka. 2009. "Service-Dominant Logic as a Foundation for Service Science: Clarifications." Service Science 1 (1): 32–41. http://sersci.com/magazine/V1N1.pdf#page=37.

Wang, K., Z. Shen. 2011. Artificial societies and GPU-based cloud computing for intelligent transportation management, IEEE Intelligent Systems, 26, 22-28.

Wen, D., Yong Yuan, Xia-Rong Li,. 2013. Artificial Societies, Computational Experiments, and Parallel Systems: An Investigation on a Computacional Theory for Complex Socioeconomic Systems, IEEE Trans. on Services Computing, vo. 6, no. 2.

Xiong, G., Z. Liu, Xi-Wei Liu, F. Zhu, D. Shen. 2012. Service Science Management and Engineering: Theory and Applications, Elsevier.

Xun, X. 2012. "From cloud computing to cloud manufacturing." Robotics and Computer Integrated Manufacturing, 28: 75-86.

Zhou, Z., X. D. Chen. 2012. *Fundamentals of Digital Manufacturing Science,* Springer Verlag, N.Y..