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City-Product Service System: a Multi-scale Intelligent Engineering Design Approach

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Abstract. There is a grown interest to smart cities of the future with natural interaction between the body of the city and the different product using this body. This paper proposes a new approach that seeks to bridge and integrate the Product Service System and City Service System. Product service system engineering approaches driven by the performance criterion can deliver the right services of the product all the time. However, in the context of the city, the product service engineering should consider the body of the city and city service engineering should consider the product which uses the body of the city. Therefore, a new system service emerges: City-Product Service System engineering. It opens a new emergent area of intelligent sustainable engineering design.

Keywords. City design, Service Engineering, Product Service System, City Service System

Introduction

The industrial urbanization of the society has transformed cities into the most complex and most dynamic man-made systems. This undo transformation has created a new economic paradigm, the sustainable development [1, 2, 3, 4]. The new paradigm is spreading new knowledge, values, and practices [5]. Sustainable development should offer a holistic way of resolution of three main sharp objective conflicting goals of the life of the city: promoting economic development of city, environmental protection of city, and advocating social justice in city [1]. Sustainability has been also defined as the opposite of crisis. If crisis is defined as the inability of a system to reproduce itself, then sustainability is the opposite: the long-term ability of a system to reproduce. This

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criterion is quite interesting. It is the essential criterion of the life. This criterion applies to natural ecosystems, to economic and to social systems.

Designers can engage the current challenge of sustainable development applying also the “the long-term ability of a system to reproduce” criterion. Multi-scale engineering design of sustainable of cities integrating sustainable products and resolving multidimensional conflicts for finding creative engineering design solutions can be identified as a research engineering design problem. City-Product Service Systems (CPSS) can be considered as new emergent area of intelligent sustainable engineering design.

This paper proposes a new method for the multi-scale intelligent engineering design of city-product service system. City is considered and conceived as an evolving living body in complex interaction with its citizens, its artificial physical environment, and its natural physical environment. Products belong to artificial physical environment of city.

Firstly the paper analyzes the issue of product service system engineering design. Secondly, the paper extends the concept of the service engineering to the city. The product service system engineering and city service system engineering should be capable of adapting themselves to the new situations: from city to the product and from the product to the city. It is an important characteristic of intelligent models. Adaptive services are much more likely to emerge if they are composed of elements whose existence, by itself, enhances the probability of success, survival and growth of their population in the future. Likewise, these complex adaptive services themselves are more likely to survive if they self-sustain. Self-sustain is the long-term ability of a service to reproduce. City-product service systems should be self-sustained objects. Finally the paper shows how the city-product service system needs to be designed such that they are both self-sustain, self-stand and suited for integration.

1. Product Service System Engineering

The word “service” has a great richness and diversity of meaning [6]. Many existent concepts, definitions and properties of services given from the marketing perspective, consider the service as a production-consumption process or activity.

The definition of the concept of service directly conducts service engineering research. In value engineering design, the concept of service has been considered as equivalent to the concept of function [7]. From user point of view, functions are services to be provided by the artifact fulfilling user's needs. For instance, a manufacturer of engines is marketing energy conversion artifacts. These are core artifacts related to core services. Overall, the concept of function is central in engineering design. It bridges the user’s need with the design parameters of the artifact, which in its turn, should be bridged with manufacturing and production process [8]. It means that the artifact manufactured according to our design should always deliver services to the user which it is supposed to deliver. The goal is deliver the right services and deliver the services right all the time. This challenge goal is inherent in the service paradigm.

Delivering the services right all the time means low variation in service performance. It is also a matter of survival for an organization. Thus, competitive pressures force organizations to offer or to integrate additional services to the core services. The fundamental objective of the additional services is to support the core services, i.e. artifact functions. Table 1 shows a proposed taxonomy of artifact service engineering.

The design of superior integrated services, making it possible to deliver core services right all the time and which can perform highly consistently despite external disturbances and uncertainties, is the goal of integrated service engineering.

Table 1: Artifact Service Engineering Taxonomy

Artefact	Service Fonctions	Generated Value	Ownership	Physical characteristics	Example
Product	Services to be provided by the product fulfilling a user's needs. They are Product Services.	New value emerges from: - the need of customers to find PRODUCT in the market, - the need of vendors to access new target market.	Customer buys the Services of the Product. Customer is the ownership of the product.	Material, bodied, tangible, corporeal.	Car
Integrated Product-Process	Product Services which integrates Process Services to enhance Product Services.	New value emerges from: - the need of customers to find integrated PRODUCT-PROCESS in the market; - the need of vendors to access new target market.	Customer buys the Services of the Product and the services of the Process. Customer is the ownership of the product and is not the ownership of the process.	Integrated Material, bodied, tangible, corporeal artifacts, with immaterial, bodiless, intangible, disembodied objects.	Car and Maintainability.
Integrated Process-Product	Process Services in relation with Product Services	New value emerges from: - the need of customers to find PROCESS to satisfy their need for a PRODUCT in the market, therefore to find suppliers; - the need of vendors to access new target market.	Customer buys the Services of the Process and the Services of the Product. Customer is not the ownership of the product and is not the ownership of the process.	Immaterial, bodiless, intangible, disembodied artefacts in relationship with material, bodied, tangible, corporeal artifacts.	Car hire, Electrical Energy Subcontracting
Process, Activity	Services to be provided by PROCESS fulfilling a user's needs. They are Process Services.	New value emerges from: - the need of customers to find PROCESS in the market, therefore to find suppliers, - the need of vendors to access new target market.	Customer buys the Services of the Process. Customer is not the ownership of the process.	Immaterial, bodiless, intangible, disembodied artefacts.	Consulting

2. City Service System Engineering

The city phenomenon meets the concept of level and scale. The reading and the interpretation of the city phenomenon is certainly multidisciplinary. In this paper, we adopted the city phenomenon analysis from three levels [9]: *global, mixed* and *private*.

The global level, at the same time social, logic and strategic, is that of the political functions of the space of the city in time. Physically, the global level is the place of the governance. The private level is the one of the *inhabit* function. Physically, the private level concerns the *dwelling*. It is the place of the primary relations. The *mixed* level is the one of double functions: function of the city with regard to the surrounding territories and internal function of the city. Physically, the concerned space represents what stays in the city after removing the global space and the private space. It is the place of interactions of the functions of the global level with the functions of the private level.

It means that city should consider the needs of different users, which often are in conflict. It means also that the city should always deliver services to the different users which it is supposed to deliver. It should support a fairer more inclusive society. The goal is deliver the right services and deliver the services right all the time to all users by the same artifact: city. This is the challenge goal of City Service Engineering paradigm.

For instance, listening and understanding the transport and mobility needs of all users, defining the services to be provided by artifact fulfilling different user's needs can change the strategic focus of artifact design and development, for instance multiple types of roads. Integrated-distributed city services produce the city into city structures characterized by global, mixed, private functional levels (Figure 1).

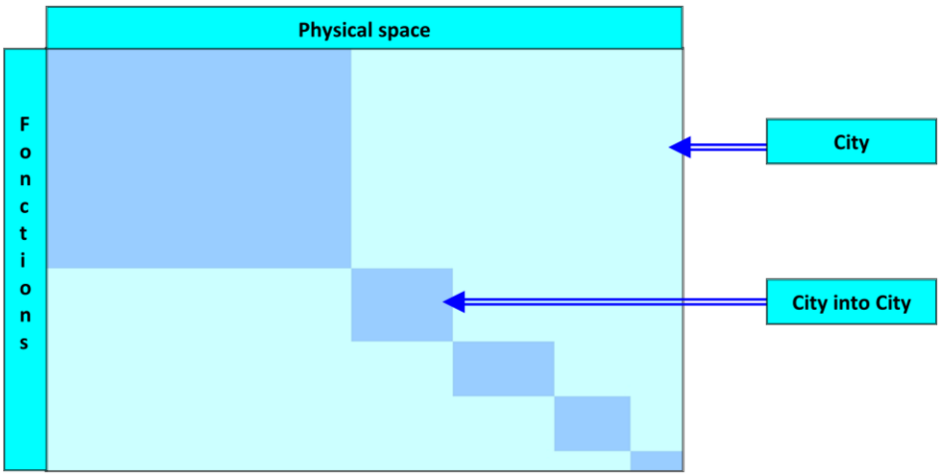

Figure 1: City into City: each city is characterized by global, mixed, private functional levels.

3. City-Product Service System: a conceptual framework

Today, there is a grown interest to smart cities of the future with natural interaction between the body of the city and the different products using this body. But it lack of a systematic engineering approach [11] which can consider in the same time the dynamic service relationship between the city and the product.

Product service system engineering approaches driven by the performance criterion [10] can deliver the right services of the product all the time. However, in the context of the city, the product service engineering should consider the body of the city and city service engineering should consider the product which uses the body of the city. Therefore, a new system service emerges: City-Product Service System engineering. The proposed approach uses the mapping [11] as principle for designing successful city-product system services. The approach then can be divided into following domains:

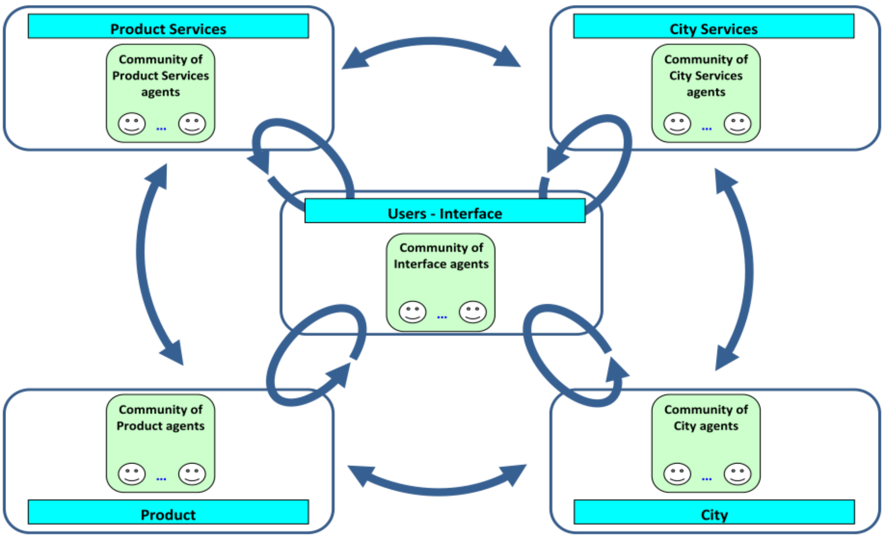

Figure 2. Architectural of City-Product Service System.

Identification of long term patterns of needs: The daily needs of the users are provided by products in *global, mixed or private* spaces of the city. In order to design a city-product system, designer should understand on the long rather than short term: the interaction between the user and the space of the city; the interaction between the user and the product and interaction between product and the space of the city. From these interactions can be discovered the services relationship between the *user* and the *city–product service system*. This implies the designer should design simultaneously the space city-product service system.

City-Product System: The interaction of the products with the body of the city can be conceptualized in the three levels of the space: *global*, *mixed* and *private*. Here, we are concerned with the co-design of the spaces and the products. The design should consider also the question of self-adaptive systems.

Intelligent interaction in City-Product System: It requires new ways of interacting with computation between city and the products, which can use or use already its body. The agent paradigm can be quite straightforwardly applied to handle uncertain problems where global knowledge is inherently distributed and shared by a number of agents, aiming to achieve a consensual solution [12] in a collaborative way [13]. Agents are autonomous and distributed entities capable of developing tasks either by themselves or by collaborating with other agents [14]. An agent is a computer entity, located in an environment that it can observe, in which it can decide and act, possibly composed of other agents with which it can interact in an independent way [15].

The literal definition of the interaction is « reciprocal action of two or more phenomena ». In multi-agent systems, as in human organizations, actions, interactions and communications, are closely linked and interdependent. Interaction is an exchange between agents and their environment. We can distinguish the following interactions (Figure 2): a) community of agents embedded in product, called *product behaviour-agents*, and the product, b) agents embedded in city, called *city behaviour-agents*, and the city, c) product process agents (for instance, maintainability), called *product service agents*, and the product, d) city process agents, *city service agents* and the city, e) between *interface agents* and user and f) between the communities. These exchanges depend on the intrinsic properties of the product and the city in which agents are active. The perception of agents may be passive when receiving messages / signals, or active, when it is the result of voluntary actions. Communication is an exchange between the agents themselves, using a language.

Communication in an agent-based system can be performed in two modes: 1) addressed communication to which a sender agent sends a message to one or more agents recipients (which corresponds to the model of Shannon), the basic unit in this communication is the speech act; 2) unaddressed communication in which a sender agent sends a message to all agents available to the applicant in the environment (without recipients named). Diagrammatic representation of concepts of actions, interactions and communications is given in Figure 3.

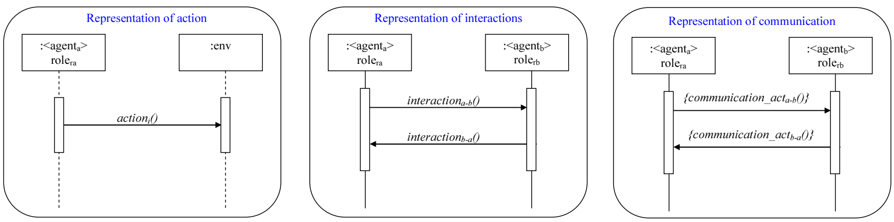

Figure 3. Diagrammatic representation of concepts of actions, interactions and communications

If the interactions between agents are frequently communicative, they involve cooperation and coordination of actions. The agent-oriented coordination models focus on the behaviour of agents in order to achieve a coordinated system. In a City-Product Service System, these interactions can be fuzzy (uncertain, incomplete, ambiguous and random). A fuzzy interaction $\tilde{\iota}_i \in \tilde{I}$ between two fuzzy agents $\tilde{\alpha}_s$ *and* $\tilde{\alpha}_r$ is defined by the following tuple (3):

$$\tilde{\iota}_i = < \tilde{\alpha}_s, \tilde{\alpha}_r, \tilde{\gamma}_c > \tag{1}$$

where $\tilde{\alpha}_s$ is the fuzzy agent source of the fuzzy interaction, $\tilde{\alpha}_r$ is the fuzzy agent destination of the fuzzy interaction, and $\tilde{\gamma}_c$ is a fuzzy act of cooperation. A cooperative act is consistent with the model of *5Co* defined in [16]: it belongs to the set {*Communication, Coordination, Co-production, Co-memory, Control-Process*} and has a goal.

The challenge of the proposed conceptual framework is the intelligent interaction between users, products and spaces of city. Discovering the long term needs of the people and the reoccurring services in interaction user-product-city system should allow identifying the functional requirements of the smart city-product system.

4. A scenario of a prototype: City-Car System Service engineering

The need of different users for safe, effective and efficient movement has been identified. Priority should be given to the *maintaining* and *managing* of the *city–car system*. The maintaining and managing should deliver the right services and deliver the services right all the time. This is typically a *City-Car System Service* engineering scenario (Figure 4).

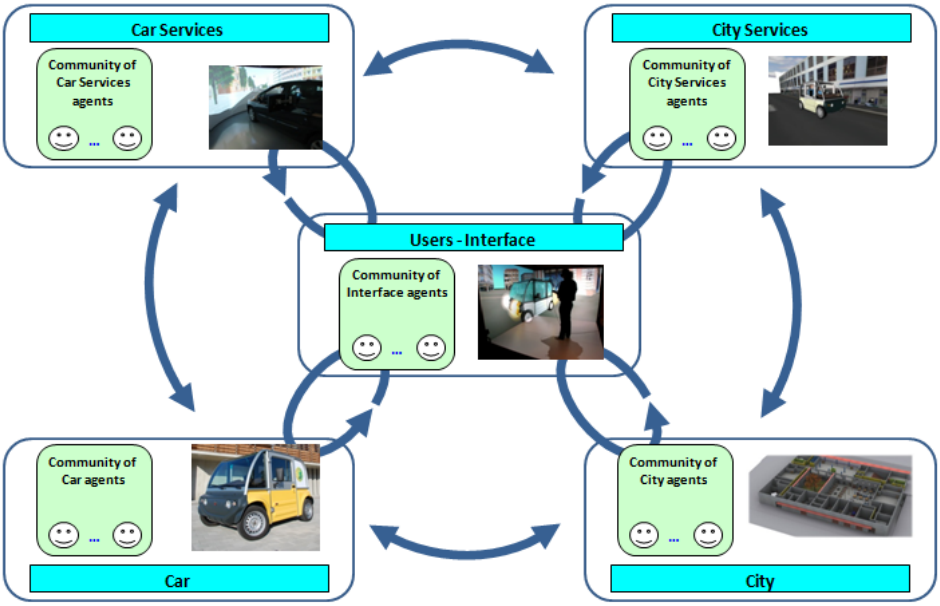

Figure 4. Architecture City-Car Service System

The interaction between the user and *mixed space* of the city (for instance: circulating space, intelligent road), the interaction between the artefact (for instance: non motor vehicles, motor vehicles, etc.) and user, and the interaction between the mixed space and the artefact can been identified (Figure 5). The purpose is then to co-design the *city – car system*.

Figure 5. A view of virtual simulation of the City-Car Service System

The intelligent decision of what is acceptable by the *city–car system* involves striking a balance between traffic capacity, the environment, speed, safety and *city-car* user comfort. The *city–car system* should resolve conflicts and accommodate the competing demands made upon it.

5. Discussion and Conclusion

In this paper, we present a new concept in service engineering paradigm. It is City-Product Service System Engineering. In terms of conceptual framework, we can see an emerging vision of the future of the architectural computing in City-Product integrated environment.

City, a living body, should be considered not only in the design of the products that uses its body, but it should be active in the interactions with these products. The most important claim is that city should be designed to have the decisional capabilities during these interactions. It implies that the users should understand that fulfilling their needs should strongly be related with the fulfilling of city “needs”, i.e. the “needs” of a living body.

City-Product Service System Engineering can improve the sustainability and the eco-efficiency. It can enable new ways of designing what we call the "City-Product-Service" that satisfy users needs and also city’s needs. The knowledge of City-Product Service System can make possible both governments to formulate policy with respect to sustainable City-Products, and companies to discover directions for innovation. The knowledge City-Product Service System also opens new area for engineering education.

Moreover, specific implementing strategies and methods, knowledge mining and management system and detailed case study and original application scenario will be discussed in the further study.

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