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Service Systems Modeling and Simulation: The Sergeant Distributed Approach

Thècle Alix, Gregory Zacharewicz and Bruno Vallespir

Abstract The economy is dominated by the service sector. Citizens see services as a way to have access to basic or complex commodities, to address environmental problems while manufacturers consider them as a way to differentiate themselves from the competition, to be closer to their customers and to improve the shopper experience. Services are of a huge importance in the national and international economy and are discussed in many domains: human and social science, manufacturing science, business domain, IT domain, etc. Several concepts related to service have merged as well as new scientific disciplines. General issues linked to service design, service implementation, service operation management, service quality, service modeling and simulation, product-service system design are still under consideration and the multiplicity of the domains concerned failed to come up with unanimous answer. This paper proposes a contribution to service modeling and simulation that can potentially be used in any area. The proposed model is based on the most relevant concepts coming from a specialized literature review on services. A distributed simulation model of service is then proposed.

Keywords Service system Conceptual modelling Distributed simulation
G-DEVS

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23 1 Introduction

24 The service sector is particularly important in the current economy and is now
 25 between 70 and 80 % of the gross national product of the developed and devel-
 26 oping countries. The tertiary sector drove the recent job creation, contributing to
 27 more than 4 million of “full-time equivalents” between 1990 and 2009 in France
 28 while the other business sectors lost 1.4 millions over the same period. In 2009, it
 29 represented about three quarters of the value added and employed 89 % of the
 30 working population.

31 Today, the proportion of unsatisfied services demand lead to the creation of new
 32 companies belonging to the service sector and de facto to the increase in the
 33 number of employed persons in this sector. As a result is an increase of the
 34 competition in both market and non-market-services which rises many questions
 35 such as the management of the service production process, the service productivity
 36 measurement, the quality measurement of the services supplied and of the activ-
 37 ities contributing to provide them, as well as the measurement of the real service
 38 value-added for customers. Accordingly, it becomes imperative for those com-
 39 panies producing services to rationalize and to industrialize their practices and to
 40 position themselves clearly in the competition regarding their value-added.

41 To prepare this shift, obviously approaches from the secondary sector of pro-
 42 duction could be reuse. Unfortunately, optimization models stemming from
 43 industry do not allow to analyse the service value chains because of its specific
 44 characteristics: a fuzzy border between production and distribution, a context
 45 dependent value, a customer participation to the production even to the design of
 46 the service, only few physical movement of material and finally the impossibility
 47 to reduce the hand of work.

48 Before focusing on the rationalisation of service production activities, it is of
 49 vital importance to define the production ins and outs and to clarify upstream what
 50 a service is. On the later point, it must be noted that each domain interested in
 51 services proposes its own definition and characterization of the concept. Accord-
 52 ingly, the paper proposes a conceptual model of services as broad as possible,
 53 based on a multidisciplinary literature review on the service concept and on the
 54 service production as well as some approaches that directly or indirectly address
 55 service production. At the end, the model is simulated to verify dynamically the
 56 correctness of its behavior regarding a temporal sequence chaining.

57 2 A Multidisciplinary State of the Art of the Service 58 Concepts

59 Some disciplines such as the Management Sciences are being interested for a long
 60 time in services. Its contribution is multiple. Regarding definition, a service is
 61 defined at the same time by opposition to goods [1, 2], as an activity [3, 4] and as a

result [5, 6]. Each point of view leads to introduce specific notions: some works aims at characterizing the system producing the service often called service delivery system [7]; while others propose specific service characteristics called IHIP characteristics standing for immateriality, heterogeneity, inseparability, and perishability [8–11].

Computer sciences address the concept of service through the service oriented architectures (SOA) or the IT services. A functionality is decomposed into a set of functions or of services supplied by components. A business service is a company functionality that seems to be atomic from the service consumer point of view. In this frame, a service is a connection to an application offering an access to some of its functionalities [12]. It appoints an action executed by a “service provider” component to the attention of a “service consumer” component, possibly based on another system. A Service Broker enables to choose the service that fits the best the requirements among the available ones.

The functional analysis or value engineering method used in product design does not evoke directly the concept of service but focuses on the concept of function that is similar to a certain extent to the concept of service. The functional analysis was firstly used to identify the needs within the frame of new products design [13]. The most known approach that joins the functional analysis into this frame is the value engineering method. It is characterized by a functional approach proposing to formulate the problem in terms of objectives rather than in terms of solutions. For that concern, the value engineering method rests on several fundamental concepts: the value [14], the need [15] and the function [16]. The functions of a product define what the product (or product subset) is doing or what it is going to do. That perspective is very close to the service concept.

The service science, management and engineering (SSME) addresses several concepts relative to services. It aims at a better understanding of design, evolution, and emergent properties of service systems and also how the innovation leads to productivity gains in this sector [17]. The SSME consider the services as processes, performances or else results that a person (company, organization) realizes for the profit of another company/organization. Several approaches such as “the triptych of technical criteria” [18] or the “triangle of services” are proposed [19].

3 Service System Modelling

This section presents a conceptual model of service based on the above-presented contributions. The objective is to embrace the main part of these contributions to be as generic as possible. The result is a conceptual model based on the fundamental concepts related to services [20–22].



Fig. 1 Basic principle and representation of a sergent

3.1 Basic Principles: The Sergent

The basic principle of the proposed approach is that a service is an interaction within a service provider/consumer couple oriented from the provider towards the consumer. The intensity of the service delivered grows in the same way than a parameter that characterises the provider/consumer coupling. A provider is identified with regard to its function and is noted P. A consumer is characterized by its need and is noted C (Fig. 1, left part).

Of course, an object cannot be limited to be a provider or a consumer. That is why objects are generally considered to be able to behave simultaneously as both.

The initial principle presents an object as a one service provider or consumer. Obviously, a complex object is able to provide several services and/or to consume several ones. Accordingly, an object can be a provider/consumer of several services (Fig. 1, right part). Service delivery relations become then more complex i.e. each relation is defined for a given service. An object is then part of a service delivery series, linked to another upstream object as service consumer and a downstream object as service provider.

The “object” talked about up to now will be called an “agent of service” or a “service agent” or, in short, a “sergent”.

3.2 Service Delivery Process Dynamics

For realizing the service delivery process, a consumer and a provider require to be coupled. The coupling steps are illustrated in Fig. 2.

The abovementioned situations suppose that the service delivery process can only be led during the coupling. Obviously, the interaction between the service supplier/consumer is the main part of the service delivery process. However, in more complex cases both actors can require to be prepared in an upstream phase (pre-process) and to get free in a downstream phase (post-process) (Fig. 3).

The corresponding phases are the following ones:

- Initialization: this phase does not require the coupling to be established but requires to know that the service must be provided. Information on the service need is necessary to activate the phase.

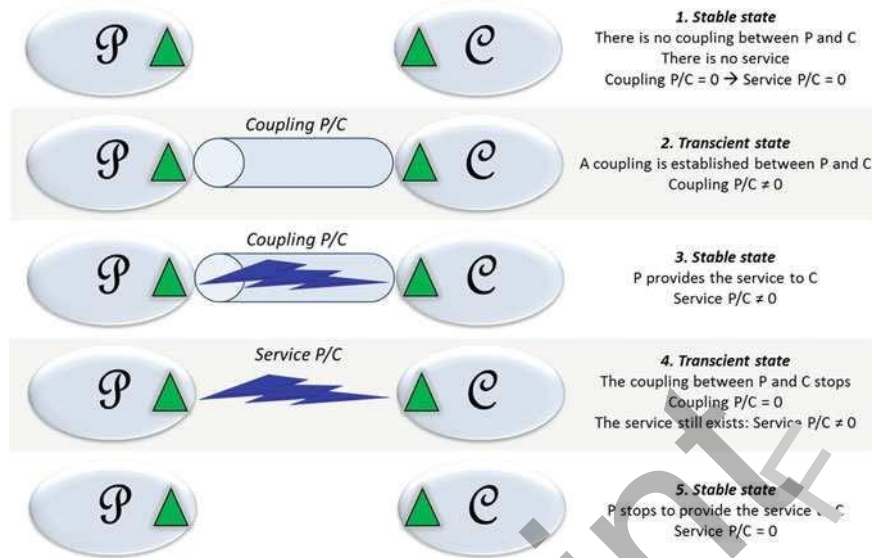


Fig. 2 Coupling dynamics

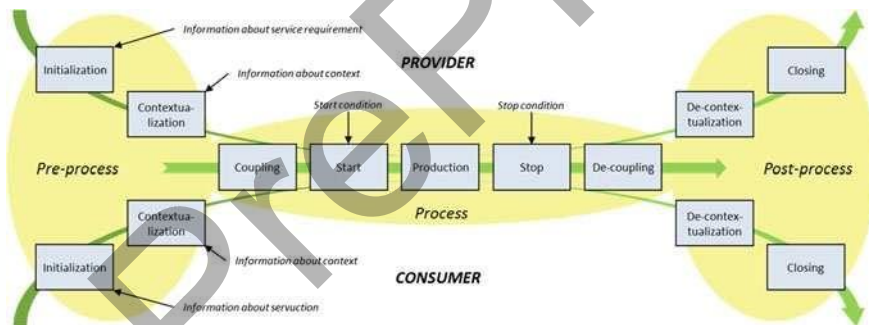


Fig. 3 The whole service delivery process

- Customization and contextualisation: in case the service is not standard, a phase of customization based on information coming from the consumer is to be envisaged. The contextualisation focuses on the adaptation to the context (consumer, surrounding conditions, etc.) of the service to be provided and of the service delivery process.
- Closing and de-contextualisation: phases exist when both actors require a process to close the activity. This process is similar to the initialization phase one but occurs after the service delivery.

137 3.3 Function Capacity and Need Load

138 A sergent may use its function in different ways: possibility to implement a
 139 function one or several times, in a successive or simultaneous way. These oper-
 140 ational situations differ according to the sergent capacity to implement a function.
 141 Conversely, a sergent need can lead to different load levels.

142 Valuation of capacity and load: the capacity is a variable belonging to an
 143 interval $[0, \text{Max}_c]$. When the capacity is lower than Max_c , the sergent is able to
 144 implement the function but not with its maximum potential. The function capacity
 145 and need load are time variables. In particular, the provider capacity can be low or
 146 non-existent because the sergent is occupied or not operational for example.

147 Capacity variability: several phenomena can lead to a temporary or long-
 148 lasting capacity variation of a sergent to provide a service. When a sergent pro-
 149 vides a service, its capacity decreases. Once the service provided and the service
 150 delivery process ended, two situations can occur: either the capacity provides to its
 151 initial value (long-lasting function) or the capacity maintains its new value (con-
 152 sumable function). The first case corresponds to non-perishable sergents while the
 153 second one corresponds to the consumption of not renewable resources.

154 In the case of long-lasting functions, several phenomena can appear: wear
 155 (capacity decreases each time the process is launched), learning (capacity
 156 increases each time the process is launched) and unlearning phenomenon (capacity
 157 decreases because the process is not launched as often as it should).

158 3.4 Provider/Consumer Matching

159 The provider/consumer matching is based on the following mechanism.

160 Function statement. A provider declares his functions in a “service directory”
 161 that indicates the precise nature of the proposed functions. The function statement
 162 is to be made according to a standard expressed in a “service repository”. The
 163 nature of the function is the static part of the statement while the capacity that can
 164 be used at a moment corresponds to the dynamic part (Fig. 4, left part).

165 Matching. The dynamic is the following (Fig. 4, right part): (1) expression of
 166 needs by the consumer, (2) comparison to functions reported in the service
 167 repository, (request), (3) choice among providers able to fulfil the need, (4) pro-
 168 vider selection.

169 4 Service System Simulation

170 Indeed, the service modelling requires also the modelling of the interactions
 171 between multiple services; this process can lead very quickly to a significant level
 172 of complexity from a static point of view and even more in a dynamic view. We

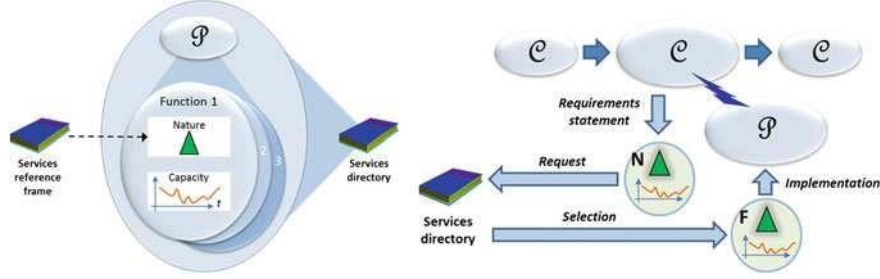


Fig. 4 Provider/consumer matching

proposed in previous works [23, 24] a first tentative to represent service in simulation. We therefore focus in this paper on the establishing operations for a single service coupling in the G-DEVS formalism [25]. This discrete formalism is selected because of its formal property and its time management capability. We propose to model each service component through a G-DEVS model based on attributes. The model attributes are described from a qualitative and quantitative point of view and all elements (actors and material) that interact within its environment are required. Once the description is complete, the described component can integrate a G-DEVS based library of service components: the service repository. The prospect of a break in service into four subsets then seemed obvious. These four models are:

- The sergent requesting the service (here sergent B is the consumer),
- The service provider (here sergent A),
- The coupling as the association between two sergents that will achieve the service delivery process, and
- The service delivery process ‘service providing’).

4.1 Coupled model

The coupled model (Fig. 5 shows the global architecture) presents the G-DEVS component required for the global simulation of the process. The components 1 and 2 are the A and B models. The component 3 is a coupling model used to connect the models paired for the service. The component 4 is used to orchestrate the process steps defined Sect. 3.2.

4.2 The Service Requester: Sergeant B

The G-DEVS atomic model corresponding to the sergent B is an applicant for a service and its operations are detailed. This model describes the sergent behavior during the process of service delivery coupling.

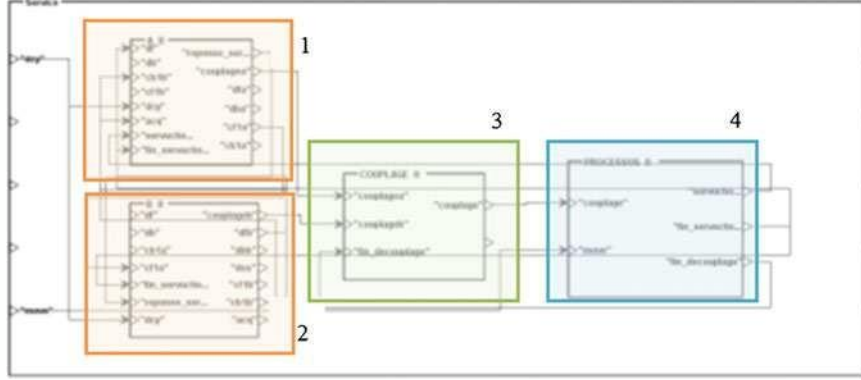


Fig. 5 Architecture of the coupled model of service **delivery**

The G-DEVS model follows the coupling steps described in §3. It communicates with the service delivery model. To assume the simulation execution, the states, event and temporal information have been added. These data are not related in this example to any information coming from a real system. The goal of the simulation is the verification of different correct communication sequences. Operations are as follow:

1. Every five time units (again; arbitrary chosen), the model B launches the comparison of its P/S potential intensity over a threshold value. This comparison is expressed as a condition on the internal transition.
2. The model function sends a request (DFb1) to the service provider (sergent A).
3. Positive response is received when sergent A is able to achieve this service.
4. Negative response is received when A is not available or not competent for this service achievement, a request will be send to another sergent.
5. Sending an acknowledgment to sergent A to tell them that the service can be achieved and to lock between them a delivery process.
6. Sending "ok_coupling" to external produce model.
7. Pending the external event "end_SD" meaning that the production of the service is completed.
8. Back to the waiting phase, the service was rendered, the intensity of sergent B to decrease the capacitance value function of sergent A demand. We note that some strategy can keep the value of the sergent B since some service potential is infinite.

4.3 The service provider: Sergent A

This section is introducing the G-DEVS atomic model of the service provider sergent A. An explanation of the model and its operations is detailed here.

- 224 1. The model A is expecting a request from sergeant B.
- 225 2. A tests the ability to get the function (FC1a) and the load required by sergeant B
- 226 (NL1b). If the ability and capacity of A is greater than or equal to the need and
- 227 load of B then the service is feasible.
- 228 3. Same as step 2; if the capacity is lower than the load of B then the service will
- 229 not be feasible.
- 230 4. The service is not feasible, the supplier is informed the consumer via a message
- 231 object "NOK".
- 232 5. The service can be done, A sends to B "OK".
- 233 6. The model waits for the acquittal of sergeant B to produce the service.
- 234 7. The model awaits a response from an external "process" models and indicating
- 235 that the service is in progress.
- 236 8. The model pends an external event "end_SD_OK" from the "process" model.
- 237 9. The process is over and the ability to provide the function of the particular
- 238 service A can be reduced (consumption) or increased (experience).
- 239 10. The service is completed. The ability of A can stay decreased or can recover
- 240 its initial value with a gain of experience that increases its ability (the
- 241 hypothesis can be to gain 10 % capacity acquired for each service delivery).

242 4.4 Coupling and Decoupling

243 This atomic model enables the coupling orchestration of two sergeants before the
 244 service delivery process and manages the notion of decoupling at the end of the
 245 service. This model is labelled 3 in Fig. 5. Its main operations are the followings.
 246 It starts by waiting an event from the sergeant A informing that it is ready and
 247 looking for a delivery process coupling. Then it is waiting for an event from the
 248 sergeant B answering that it is available and capable regarding the load and com-
 249 petence required by A. Then the coupling can be realized. Gathering the infor-
 250 mation, the model is informing both participants. Then it is waiting for an event
 251 informing of the end of the service delivery to return to the standby state. This last
 252 step is producing the end of the coupling.

253 4.5 The Service Delivery Process

254 A last G-DEVS atomic model is required to define the characteristics and simulate
 255 the service delivery process behaviour (service delivery model 4 in Fig. 5).

256 This model starts by waiting an event to be in-formed that a coupling is ok. At
 257 this time, it computes the characteristics of this service delivery including cou-
 258 pling, duration, quantity of load and experience acquired at the end. It informs by
 259 output sending the "SD" settings to the model participants and set them in pro-
 260 gress. When the service is ended, it informs the participants by sending to output
 261 "end_SD".

The simulation concludes and illustrates the choreography between the supplier sergeant and the receiver sergeant. It shows clearly the communication steps during the service delivery. Nevertheless, the question is still on quantities and values used to define the potential of the sergeant and the duration of the steps.

5 Conclusion

The paper presents a conceptual model of service and service delivery which takes into account notions and concepts stemming from disciplines initially remote but which become integrated rather naturally into a coherent set. The proposed concepts contribute to a first level of model that requires nevertheless to be completed. Others concepts need to be explored and some questions need to find response. For example, how to select a provider when the function capacity is similar from one to another? or else, in the case of service composition, how to decide the composition? and how to ensure its coherency?

Considering perspectives to that work, three concepts need to be explored.

At first, considering the fact that a way to approach the concept of service is to make the difference between buying a service and buying a product providing a service, it is necessary to take into account into the model all the elements focusing the transactional aspect around the sergeant or around its functions.

Then, the sergeant life cycle was not envisaged. Nevertheless, knowing in which phases of its life cycle a sergeant is really able to implement its functions, or knowing what it becomes in the other phases or identifying the phases when it will consumes a service are so many questions which have to find an answer within the framework of a model of life cycle.

On the simulation aspect, the paper has provided a preliminary work to define the root concepts that can be modelled and simulated. It has focused on splitting the service delivery into different steps used to couple a service provider and a consumer. It opens the research in this domain where few works considering quantitative and dynamic aspects already exist. As perspective the authors are considering the definition of a simulation platform running an open space populated by autonomous sergeants entities. Once a sergeant needs a service, it will try to connect to a service supplier in its neighbourhood (that needs to be defined).

Finally, the measure of a service remains a huge problem. In equal function, can the service of a provider be considered as upper to that of another one? This problem of the measure is certainly the most difficult to be settled. Nevertheless, it would enable to clear up some other aspects presented here.

Finally, this model has started to be tested on academic cases [20]. The tests on real cases have to be processed I the near future.

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