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Fuzzy consensus model for governance in smart service systems

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Abstract

Service Systems are means of value-co-creation and are considered “Smart” if they are supported by IT and react to external changes for the satisfaction of the whole. The co-production of value occurs by processes coordinating the participants, which exchange services, and including decision-making activities, such as the choice of a specific Service Provider. Making decisions is a matter of Governance that often conciliate the expectations of everyone. For the selection of Service Providers among a set of suitable ones, it is possible to consider a Fuzzy Consensus Model for a Group Decision Making (GDM) situation within a service scenario. We have a set of Service Providers (possible alternatives), and decision makers, who examine the choices to reach a common decision. The model considers fuzzy preference relations and an advice generation mechanism to support the decision makers. A case study, where heterogeneous experts have to evaluate a research project, is considered. The results indicate that the “most important” expert influence deeply the final decisions.

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1. Introduction and motivations

Nowadays, there is a contingent necessity in adopting suitable choices in different contexts and for many purposes. This is a direct result of globalization, which allowed connections among technical, social and economic factors, leading to the aggregation of various products and services for the final user. For this reason, discussing

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about the "service" has become important to create benefits ([19], [22]), as shown in developments of theoretical models, strategies in enterprises and decision-making processes. The concept of "service" as an "intangible good" has transformed itself to include a wider meaning, described by the so-called "Service Science" (SS), see [14].

In this framework, Service Systems ([1], [15]) have gained momentum in recent years. They are dynamic sets of resources, such as people and technologies, which interact with other service systems through shared information, with the aim of creating and delivering value together with customers, providers and other stakeholders (see [20] for a theoretical analysis and [23] for a possible application). Moreover, because of a continuous development of technologies and rules, Service Systems have become "Smart" ([2], [8], [21]), namely they are supported by Information Technology (IT) and able to react to external changes through an appropriate use of available resources by adapting its organization, and the use of knowledge to self-reconfigure. Examples of possible Smart Service Systems include nations, cities, non-governmental organizations, people, and enterprises.

In particular, the enterprises ([5], [10], [16]) face ongoing challenges to remain competitive, providing convenient services to its customers via necessary actions and analyzing different business domains. Connections between enterprises and SS are evident: enterprises can offer IT solutions for all types of organizations, either of traditional or service-oriented type. On the other hand, SS as a discipline can suggest different engineering solutions where, e.g., enterprise could give potentials for supporting activities of service management, with a particular emphasis on services' exchanges for the value co-creation ([9]). Hence, the enterprise represents an ecosystem of services, which have to be carefully chosen in order to achieve innovation results for both the enterprise itself and the final customers. Benefits are the best way to guide the enterprise and often represent occasions for decision-making activities, with consequent exploitation of all possible resources and services, which allow obtaining meaningful results. Such aspects are better understandable using the following example: suppose that a generic enterprise, which deals with fruit juice production, should choose among different flavors (i.e. different services) for the production. The final decision is fundamental, as it involves either profits of the enterprise or the satisfaction of final customers. In our case, the leadership could decide the sale of only two flavors among the available ones, discriminating other possible decisions only for market strategies. The customers, who receive the offered services, could redirect the leadership's choices according to some feedbacks given to the enterprise. Therefore, the leadership's decisions become dynamic due to a continuous exchange of services between the enterprises and the customers. This allows co-creating value, with consequent advantages for all the participants in the ecosystem of services. Indeed, the key factor of such phenomena is a matter of decisions, which occur initially inside the enterprise and involve either automatic or human factors. A good organization of these last ones gives the real success, as automatic processes are not always able to capture all the possible tones for the evaluation and the choice of a given service. Human decisions can impose constraints among all the involved participants inside service scenarios. In this case, the Governance assumes an important role.

The Governance is a mechanism that, inside the Enterprise contexts, establishes limits, gives orders, advices, and conciliates eventual conflicts among all its entities for the interest of the whole ([24]). Its primary aim is always to equalize the subsidies and overcome the opportunism. The logic by which this occurs is extremely complicated, especially in phases of conflicts' resolutions, because the Governance consists of a Group Decision Making (GDM), i.e. experts who, as for the possible services to choose, are heterogeneous in terms of ideas and knowledge ([18]). This situation creates obvious difficulties, as the heterogeneity of members of GDM often implies disagreements in the choice of Service Providers. Moreover, the different decision weights of the experts could create serious problems of opinion's convergence in other members of GDM.

In such an ecosystem of services, a possible strategy is to model the Governance activities. From a technological point of view, although there are valid automatic processes, defined by workflows orchestrating services, the conflicts' resolution among experts can never be supported completely. The only alternative is an integration of mathematical models, which guarantee correctness and robustness, inside processes.

Among all possible solutions, which are suitable for decision problems, a valid alternative for our context is to reach the so-called "consensus", namely a situation of sufficient and acceptable decision harmony among the experts. Various mathematical models about consensus strategies arise from the scientific literature, see [3], [4], [6], [7], [17], [25]. Indeed, as we consider the heterogeneity of experts inside GDM in service scenarios, in this paper we focus on a Fuzzy Consensus Model (see [11] and [12] for possible uses of fuzzy logic), which deals with Fuzzy Preference Relations ([13]) and a moderator process that understands if a consensus state occurs. In particular, if the consensus is not reached, a feedback mechanism is useful to give advices to the experts in function of their importance degrees. A possible interpretation of the fuzzy consensus approach within the Enterprise is in Fig. 1: the Governance, consisting of a GDM with heterogeneous experts, expresses preferences among possible Service Providers. A consensus process allows establishing, also using a feedback mechanism on the experts, the correct service to choose. Such decision represents the best possible in the interest of the whole and achieves a sufficient agreement among all experts. A possible correct decision can imply positive feedbacks from the final customers. Hence, the advantages of a fuzzy consensus model within Smart Service Systems, such as the enterprise, is evident: services are chosen in the best way, reaching an acceptable consensus degree from all the possible participants of the ecosystem, and this allows creating a high value co-creation.

The paper is organized as follows. Section 2 describes the integration of consensus approaches with business processes within the SS context. Sections 3 and 4 show, respectively, the fuzzy consensus approach and the case study. Conclusions ends the paper in Section 5.

2. Integrating consensus approaches with business processes in the service science perspective

As already emphasized in the previous section, SS represents, as for studies and researches, an emerging field that deals with value creation through services from technical, behavioral and social perspectives, [9]. Moreover, this discipline is the application of services management and engineering sciences to work tasks that are performed by an Organization for and with customers. Hence, Enterprises can be also seen under the SS perspective. In particular, we will consider a technological point of view: the Enterprise System (ES).

The various connections between SS and ESs are described in [16]: ESs are general or universal IT solutions for all kinds of Organizations, while SS often proposes many kinds of engineering tools for supporting service management in Organizations.

An ES is an integrated part of the business operations and it is embedded with the business services in companies, [1]. In particular, in [16], the authors state that ESs work at three different stages. In the first one, that is also the main one, ESs are used to increase the efficiency of different functions or activities in organizations, automating service jobs that earlier were carried out manually. In the second one, the cooperation between business processes and service operations inside companies is exploited. In this context, business persons are thinking more and more in terms of workflows or service processes for achieving expected results. Finally, the third (and last) stage focuses on the transformation of service operations in marketplaces, shared by different business actors (e.g. managers, workers, customers, suppliers), for creating competitive power of the ESs.

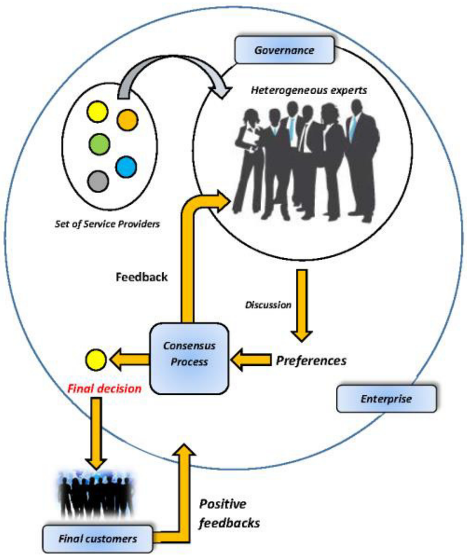

Fig. 1. Consensus reaching process within a service scenario.

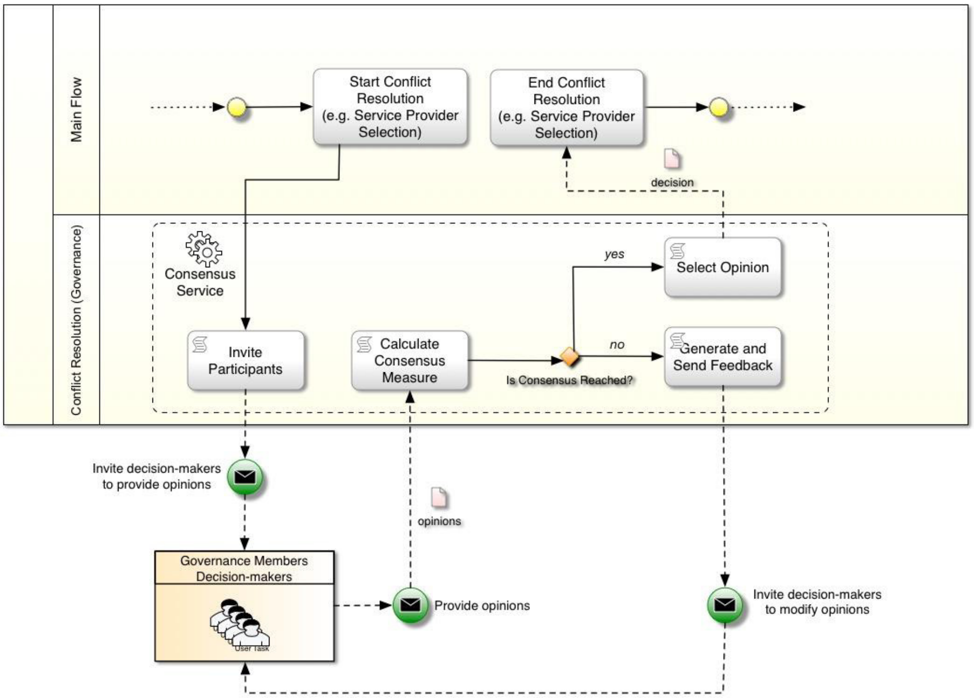

Fig. 2. Describing and integrating the Consensus Service.

Now, consider a technological environment consisting of several ESs, deployed at a Service-Oriented Ecosystem. In this context, it is fully realistic that business analysts adopt BPMN (http://www.bpmn.org) to design business processes, which can be instantiated by means of workflows and executed by a workflow engine, with the aim of realizing the second stage of the ESs. Within business processes, business operations can be realized by requesting and invoking specific services. Specific operations need to accomplish decision-making tasks that can range from fully automatic to human-based. Notations like BPMN support human-based tasks, as well as the chance to evaluate conditions, follow a branch rather than another. Although the above-mentioned notation is expressive enough to represent complex processes, the lack of a solid framework to support decision makers emerges. Governance activities are typical examples for the aforementioned tasks.

The goal of this work is to provide a mathematical framework able to guide fairly Governance activities (e.g. conflict resolution, etc.) in a service-oriented Enterprise Ecosystem. The proposed framework, namely a Fuzzy Consensus Model, is able to support all the three stages, briefly described before, of ESs.

The framework can be implemented as a service and smoothly included into the Enterprise Ecosystem at the first stage. Moreover, at the second stage, the sub process concerning a Governance activity can be agilely designed using BPMN and executed by a workflow engine. Finally, at the third stage, Governance can include different and heterogeneous actors who could be modelled as heterogeneous decision makers in the Fuzzy Consensus Model.

An additional benefit of the proposed framework is its capability to enable the tracing of single steps of the Governance activities.

Fig. 2 reports a fragment of a BPMN diagram. This diagram shows how to handle a conflict resolution by means of the approach proposed in this work, when several decision makers are supported by the Fuzzy Consensus Model (described in details in the next sections). Briefly, when a decision (for instance, when a specific Service Provider has to be selected among a set) has to be made, it is possible to activate the Consensus Service. This service is committed to invite the decision makers (taking part in the Governance) to express individual opinions. The aforementioned opinions are collected and processed in order to calculate a consensus measure that is compared with a threshold. If the consensus is reached then the final decision is selected and sent to the main process. If the consensus is not reached then some feedback is generated and sent to some decision makers (taking part in the

Governance). The decision makers who have received the feedback are invited to modify their opinions according to those of their neighbors, who are decision makers with similar opinions.

3. The proposed approach

Consider the Enterprise Ecosystem and, in particular, a GDM situation. For a given service to choose, there is a set of alternatives (the different Service Providers), $X = \{x_1, x_2, ..., x_n\}$, $n \geq 2$, and a group of experts (members of GDM), $E = \{e_1, e_2, ..., e_m\}$, $m \geq 2$, each one identified by his/her own ideas and knowledge.

The most interesting case is when experts have different backgrounds, attitudes, and levels of knowledge for the service to choose. In such a situation, different approaches have been considered (see [6] and [25]). In this paper we assume that an expert $e_i \in E$, $i = 1,...,m$, has a proper importance, defined as a fuzzy subset I^{e_i}, with a membership function $\mu_{I^{e_i}} : E \to [0,1]$. The interpretation is the following: $\mu_{I^{e_i}}(e_i) \in [0,1]$ represents the importance degree of the opinion provided by the expert e_i. Moreover, it is assumed that the experts provide their preferences using fuzzy preference relations (see [13] and [17]). Notice that a fuzzy preference P on X is a fuzzy set with a membership function $\mu_P : X \times X \to [0,1]$.

Consider now a consensus reaching problem in a GDM situation. We deal with an iterative process in which the experts can modify their choices according to the advices of a moderator. In order to automatize the moderator's activities, according to [3], a feedback mechanism is proposed, whose aim is to compute and send recommendations to the experts, also considering their importance degree.

After that experts have given their preferences, the level of agreement is computed. Consensus degrees are useful to measure the consensus level. They are obtained as follows: fix two different experts, $e_r \in E$ and $e_s \in E$, with $r = 1,...,m-1$, $s = r+1,...,m$, and for them define the Similarity Matrix (SM), $S^{rs} = \left(s_{ij}^{rs}\right)$, and a Consensus Matrix (CM), $C = \left(c_{ij}\right)$, where s_{ij}^{rs} and c_{ij} are defined as in [13] and [17]; using CM, obtain the following consensus degrees (see [17] for the formal definitions): consensus degree on pairs of alternatives, cp_{ij}; consensus degree on alternatives, ca_i; consensus degree on the relation, cr. Finally, compare cr with the minimum required consensus level, $cl \in [0,1]$, for the problem under discussion. If $cr \geq cl$, the consensus model finishes and the selection process is considered to obtain the solution. Otherwise, the feedback mechanism is activated and a new consensus iteration occurs.

As for the feedback mechanism, its aim is to guide the change of controversial experts' opinions, and is based on the assumption that the experts with lower knowledge level need more advices than others.

In order to identify the degree of agreement between each expert and the group, similarity measures are computed via a collective fuzzy preference matrix, P^c, see [13] and [17]. Once the matrix P^c has been obtained, the following similarity measures are computed (formulas are in [17]): similarity measures on pairs of alternatives, pp_{ij}^r; similarity measure on alternatives, pa_i^r; similarity measure on the relation, pr^r. Such measures are used by the feedback mechanism to generate advices for experts. This is achieved via two different phases: search for preferences; generation of advice.

Consider the search for preferences. All experts are divided into three different groups, according to their importance degrees $\mu_{I^{e_i}}(e_i)$, $i = 1,...,m$. Hence, we get that $E = E_{low} \cup E_{med} \cup E_{high}$, where E_{low}, E_{med} and E_{high} are, respectively, the sets of low-importance, medium-importance and high-importance experts. In particular, fix two threshold values, Φ_1 and Φ_2. We assume that $e_i \in E_{low}$, $i = 1,...,m$, if $\mu_{I^{e_i}}(e_i) < \Phi_1$; $e_i \in E_{med}$, $i = 1,...,m$, if $\Phi_1 \leq \mu_{I^{e_i}}(e_i) < \Phi_2$; $e_i \in E_{high}$, $i = 1,...,m$, if $\mu_{I^{e_i}}(e_i) \geq \Phi_2$. For each set, different advising strategies and search policies for controversial preferences are considered. As for the identification of Low/Medium/High-Importance Experts' Controversial Preferences, the sets of preferences to modify, PCH_{low}^r PCH_{med}^s and PCH_{high}^t, respectively, for experts $e_r \in E_{low}$, $e_s \in E_{med}$ and $e_t \in E_{high}$, are obtained as in [17].

Consider now the generation of advice. For each preference value seen as controversial, the model suggests to increase the current assessment if $p_{ij}^r < p_{ij}^c$, and to decrease if $p_{ij}^r > p_{ij}^c$. Notice that the suggested changes are only recommendations to show the experts the most appropriate way to narrow their positions.

4. Case study

We present a case of consensus process for the ex-ante evaluation of a research project, that has to be considered according to three criteria, that correspond to different offered services: excellence; impact; quality/efficiency.
There are four experts, represented by the set $E = \{e_1, e_2, e_3, e_4\}$ $(m = 4)$. They are heterogeneous and their importance degrees, $\mu_{I^{e_i}}(e_i) \in [0,1]$, $i = 1,...,4$, are established through their experience: $\mu_{I^{e_1}}(e_1) = 0.2$, $\mu_{I^{e_2}}(e_2) = 0.25$, $\mu_{I^{e_3}}(e_3) = 0.5$ and $\mu_{I^{e_4}}(e_4) = 0.05$. Moreover, as for each different evaluation criterion, there is the set of alternatives $X = \{x_1, x_2, x_3, x_4, x_5, x_6\}$ $(n = 6)$, with the following meaning: x_1 (score 1), the proposal does not match the acceptance criteria; x_2 (score 2), weak proposal; x_3 (score 3), discrete proposal; x_4 (score 4), good proposal; x_5 (score 5), very good proposal; x_6 (score 6), excellent proposal. It follows that the maximum score for the project is 18, namely evaluation 6 for excellence, impact, quality/efficiency. Notice that the experts give their opinions indicating a possible evaluation for each alternative, according to a soft logic. This guarantees that higher information is explicit and allows creating a real negotiation among all the experts, with consequent advantages in terms of a suitable agreement of the whole.

We consider in detail only the case of the criterion "excellence", as the other cases are similar. Assume $cl = 0.9$. Initially, the experts provide some preference relations, giving a value in $[0,1]$ for each alternative (see Table 1).

Table 1. Preferences of experts.

	x_1	x_2	x_3	x_4	x_5	x_6
e_1	0.1	0.7	0.1	0.4	0.1	0.4
e_2	0.1	0.4	0.5	0.9	0.4	0.1
e_3	0	0.2	0.1	0	0.1	0.9
e_4	0.2	0.8	0.5	0.4	0.1	0.1

From Table 1, we obtain, for each expert k, $k = 1,...,4$, the fuzzy preference relations P^k, that indicate the preference of x_i, $i = 1,...,6$, on x_j, $j \neq i$. In what follows, we report only P^1 and P^2, where 0.5 indicates indifference between two alternatives:

$$P^1 = \begin{pmatrix} 0.5 & 0.2 & 0.5 & 0.35 & 0.5 & 0.35 \\ 0.8 & 0.5 & 0.8 & 0.65 & 0.8 & 0.65 \\ 0.5 & 0.2 & 0.5 & 0.35 & 0.5 & 0.35 \\ 0.65 & 0.35 & 0.65 & 0.5 & 0.65 & 0.5 \\ 0.5 & 0.2 & 0.5 & 0.35 & 0.5 & 0.35 \\ 0.65 & 0.35 & 0.65 & 0.5 & 0.65 & 0.5 \end{pmatrix}, \quad P^2 = \begin{pmatrix} 0.5 & 0.35 & 0.3 & 0.1 & 0.35 & 0.5 \\ 0.65 & 0.5 & 0.45 & 0.25 & 0.5 & 0.65 \\ 0.7 & 0.55 & 0.5 & 0.3 & 0.55 & 0.7 \\ 0.9 & 0.75 & 0.7 & 0.5 & 0.75 & 0.9 \\ 0.65 & 0.5 & 0.45 & 0.25 & 0.5 & 0.65 \\ 0.5 & 0.35 & 0.3 & 0.1 & 0.35 & 0.5 \end{pmatrix}.$$

From all possible SMs and CM, we have that $cr = 0.776 < cl$, hence the feedback mechanism occurs. As for similarity measures, we get that $pr^1 = 0.8965, pr^2 = 0.7955, pr^3 = 0.8751, pr^4 = 0.8155$. As for the search of preferences, the experts are divided into the different subsets $E_{low} = \{e_4\}$, $E_{med} = \{e_1, e_2\}$ and $E_{high} = \{e_3\}$, obtained assuming $\Phi_1 = 0.1$ and $\Phi_2 = 0.3$. We have that:

$$PCH_{med}^{1} = \varnothing,\ \ PCH_{med}^{2} = \{(4,2),(4,6),(6,1),(6,2),(6,3),(6,4),(6,5)\}.$$

$$PCH_{high}^{3} = \varnothing,\ PCH_{low}^{4} = \left\{\begin{matrix}(1,6),(2,4),(2,6),(3,6),(4,2),(4,6),\\ (5,6),(6,1),(6,2),(6,3),(6,4),(6,5)\end{matrix}\right\}.$$

Hence, for instance, the expert 1, who has an importance degree lower than the one of the expert 2 and preference values similar to the expert 3, is not advised to modify his/her opinions.

Consider the generation of advice. For experts 1 and 3, preferences are advised to be the same. For experts 2 and 4, instead, they are required to modify their preferences receiving the following recommendations:

$$R^2 = \begin{pmatrix} = & = & = & = & = & = \\ = & = & = & = & = & = \\ = & = & = & = & = & = \\ = & - & = & = & = & - \\ = & = & = & = & = & = \\ + & + & + & + & + & = \end{pmatrix},\ R^4 = \begin{pmatrix} = & = & = & = & = & - \\ = & = & = & - & = & - \\ = & = & = & = & = & - \\ = & + & = & = & = & - \\ = & = & = & = & = & - \\ + & + & + & + & + & = \end{pmatrix}.$$

where $R_{ij}^{r} = +/-,\ \ r \in \{2,4\}$, expresses the recommendation to the expert e_r to increase/decrease his/her preferences p_{ij}^{r}. For example, the expert 4 is suggested to increase the preference of x_4 with respect to x_2 and to decrease the preference of x_2 with respect to x_4. In order to understand the dynamics of the consensus mechanism, we simulate a change of opinions for experts 2 and 4 (see Table 2):

Table 2. Modified preferences.

	x_2	x_3	x_4	x_6
e_2	0.4	0.5	0.6	0.4
e_4	0.3	0.1	0.4	0.6

In this last case, we get that $cr \approx 0.92 > cl$ and the consensus process leads the experts to consider the choice x_6, namely the criterion "excellence" should be evaluated with the highest score for the project under consideration. As for the other two criteria (quality and quality/efficiency), the consensus process shows that the alternatives to choose are, respectively, x_5 and x_6. Hence, for the considered project, the feedback mechanism guides the total evaluation to a score equal to 17. This means that the expert with higher importance degree has a fundamental role in evaluating the real consistency of the proposed project. Indeed, the underestimation of this aspect could lead to the possible exclusion of efficient project proposals.

5. Conclusions

In this paper, we considered a fuzzy consensus model for a typical GDM situation within a service scenario.

Such approach allowed modeling situations with heterogeneous experts, characterized by different viewpoints and decision weights, with consequent advantages in terms of correct choices within Smart Service Systems.

The proposed methodology has been applied to a case study, which deals with the evaluation of a research project. The obtained results proved that, in contexts in which many possible services should be considered for the best of the whole, the opinions of experts with higher importance represent a key factor for the decision success. In such sense, a consensus approach does not represent a mean that privileges eventual personal benefits, but a useful way to exalt importance, knowledge, opinions and attitudes of each expert who takes part to a decision table.

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