Exploring the Impact of Structural Holes on the Value Creation in Service Ecosystems

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Abstract. A service ecosystem (SE) is essentially a value creation system, and changes in the organizational structure of services affect the value change of SE. No research work has been found on the impact of structural holes (SH) on the value creation of SE. Existing works on the value creation of SE have been carried out from the perspective of service ecology, ignoring the consideration of individual services. Therefore, we firstly construct a SE value creation model. Secondly, we propose an analysis method to explore the impact of SH on SE value creation from the level of both individual service and SE. In addition, we construct a computational experiment for experimental comparison and analysis, which reveals how changes in SH affect the value creation of SE. The findings of this paper can be used to induce the evolution of SE and promote its value maximization.

Keywords: Service ecosystem · Structural holes · Value creation · Analysis method · Computational experiment

1 Introduction

The constant development of big data, the Internet of Things, and other technologies have brought in new prospects for traditional services. Service is gradually penetrating various industries, e.g., education, healthcare, and transportation. The number and variety of services available are increasing. Complex correlations are developed between different services in the process of long-term competition and collaboration, and a service ecosystem (SE) is gradually formed to satisfy diversified, dynamic, and individualized user demands.

SE is essentially a value creation system, and value is created by the process of service interaction between many participants (e.g., users, and service providers) [20]. The socio-economic participants in SE are users and service providers [14]. If the services provided by providers can satisfy the demands

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proposed by users, the services will obtain value. In summary, around diverse user demands, different participants in SE integrate resources and create value based on the service network [4,19], which can achieve mutual integration and interconnection between value chains.

It is important to study the value creation of SE for the sustainable development of SE. The value creation of SE is the result of the joint action of many participants (e.g., users, services, and service providers), and the factors affecting the value creation of SE are also multi-level and multi-perspective. At present, there have been some studies on the factors influencing the value creation of SE. Maglio et al. [15] argue that a service system is a configuration of people, technologies, and other resources that interact with others. Thus, people, technologies, and resources influence value creation in a SE. Akaka et al. [2] argue that the embeddedness of social networks and the multiplicity of institutions within a SE influence the complexity of context, and that value (co-)creation interacts with and influences the environment at different levels. However, current research on the factors influencing value creation in SE is still coarse-grained, and there are many limitations in terms of the scope of the research objects and how each factor influences value creation in SE.

In SE, the competitive advantage of the service is mostly based on its quality and the complementary resources brought by cooperation with other services. Therefore, the value of services is closely related to the competitive and cooperative relationships among services, and changes in the organizational structure of services affect the value evolution of SE. Structural holes (SH) is an important characteristic that can reflect the organizational relationship between services. In 1992, Burt [3] first proposed the concept of SH, which is "SH refers to a non-repetitive relationship between two persons", i.e., SH is a non-redundant connection between two actors. From the perspective of the network, SH is a "cave"-like structure, where a node occupying the location of SH can connect two nodes or communities that are not directly connected. SH plays an important role in identifying the important nodes in complex networks [5,11] and controlling the public opinion dissemination in social networks [7,12].

In response to the current problems in the study of factors influencing the value creation of SE, we focus on exploring the impact of the SH on the value creation of SE and propose a value creation model of SE. Then, the impact analysis method is studied from two levels: individual service and SE. Finally, the paper constructs a computational experimental system for experimental validation. The main contributions of this paper are as follows:

1. A value creation model of SE is constructed, which helps us better understand the process of SE value creation.
2. We propose an impact analysis method, and research it from two levels of individual services and SE, which effectively extends the traditional research.
3. We design and construct a computational experiment system, which effectively reveals how the changes of SH affect the value creation of SE through experimental comparison and analysis.

The rest of the paper is organized as follows. Section 2 presents the value creation model of the SE. Section 3 proposes the methodology of this paper. Section 4 designs the computational experiment system and analyzes the experimental results. Section 5 introduces the related works, and Sect. 6 concludes the paper.

2 Value Creation Model of SE

In *Competitive Advantage*, Porter believed that value was the amount customers are willing to pay for what a company provides [17]. In this paper, value in a SE is the revenue generated during the complex and dynamic interaction between developers, providers, users, and many other actors, i.e., the revenue generated when developers provide services to users that satisfy their demands.

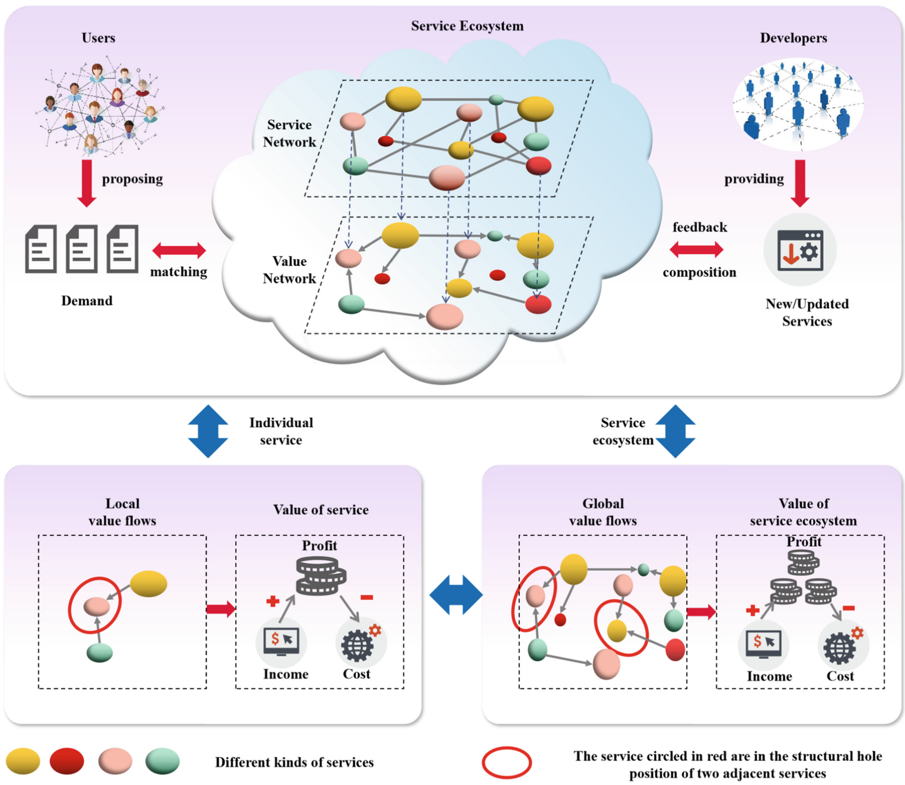


Fig. 1. Value creation model of SE.

The value creation process of the SE is shown in Fig. 1. In the figure, the circles represent service nodes, and the different colors of the circles represent the different types of service nodes. The size of the circle represents the capability and attributes of the service node, and the larger the size of the service node, the stronger the service capability. The services framed by the red circles occupy the position of the SH formed between neighboring nodes. Only some of the services occupying the SH positions are exemplified in the figure, and not all the services occupying the SH positions are labeled. The SE mainly includes three types of roles: users, developers, and services. To match the diverse and personalized demands of users, developers continuously improve or provide new services. At the same time, the competitive and collaborative relationships between services continue to evolve. In this dynamic process, value is also generated and flows, forming a value network. A value network is a topological mapping of a service network. The nodes in the value network are the service nodes, and the edges in the value network represent the value flow and transfer relationship between the service nodes.

In the dynamic process of value creation, the value of service nodes changes dynamically in real-time, but not every node can create value in real-time. Therefore, the edges of the value network are not the same as those in the service network, and they will change with the value flow. Changes in services (e.g., usage frequency decreases, service function changes) can affect the value creation of service nodes or even the whole SE.

We focus on the impact of SH on the value creation of the SE. The value creation of individual services is influenced by the organizational relationship between individual services and their neighbors. SE value is also subject to the constraints of its structure. Therefore, the influence of SH on SE value creation is researched at the levels of both individual services and SE.

3 Methodology

3.1 Research Questions

To explore the impact of SH on value creation in SE, we propose the following two research questions.

RQ1: How does the SH of an individual service affect its value creation?
RQ2: How does the SH of a SE affect its value creation?

3.2 Impact Analysis Method

To investigate the impact of SH on the value creation of SE, we propose an impact analysis method. It can be studied from two levels: the individual service level and the SE level. The method is shown in Fig. 2.

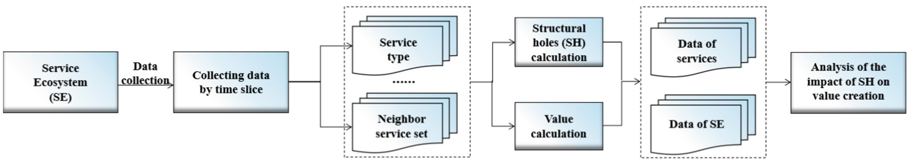


Fig. 2. Impact analysis method.

The impact analysis method is carried out in four main steps. Firstly, the rules and strategies of the computational experimental environment are designed to construct a simulated SE that matches the characteristics of the real SE. The construction method is described in the next section. Secondly, the data of SE at different times are collected separately according to the time slice. The data mainly includes the number of services in SE, the set of neighboring nodes, the value of each service node, etc. Thirdly, SH and values of service nodes and SE are calculated separately. The calculation method is described in the next subsection. Finally, the impact of SH on value creation in SE is analyzed and answered by comparing changes in SH and value at the individual service level and SE level through statistical and visual methods of data.

3.3 Concepts and Definitions

We provide a formal description of the service network and value network, and then define the relevant concepts and computational methods for individual services and SE, respectively.

Definition 1. *(Service network, SN). SN is a complex network structure consisting of competing and collaborative relationships between services. It can be represented by the two-tuple SN(S, R).* $S = \{S_1, S_2, \cdots, S_n\}$ *represents the service set, which is a representation of the individual vertices in SN. and* $R = \{< S_i, S_j > | S_i, S_j \in S\}$ *represents edge set (i.e., coupling relationship between services), which represents the edge in SN.*

Definition 2. *(Value network, VN). VN is a mapping of value flow relationships between SN, with services as its nodes and the value flows between services represent its edges. Therefore, VN can be represented by the two-tuple VN(S, E).* $S = \{S_1, S_2, \cdots, S_n\}$ *represents the vertex set of VN.* $E = \{< S_i, S_j > | S_i, S_j \in S\}$ *represents the edge set of VN.*

Definition 3. *(Service, s). The service is expressed as follows.*

$$s_i = <R, S_t, E_t, V_t, Y_t> \quad (1)$$

R is the stable capability property of individual service, which remains unchanged for a relatively long time; S_t is the dynamic capability property of individual service, which will change with time; E_t is the perception capability of individual service; V_t is the response capability of individual service; Y_t is the learning capability of service, which allows it to promote itself by interacting with external events and other services.

Definition 4. *(Structural holes of service, SHS): SH is a social network characteristic that can reflect the non-redundant relationship between two persons. In this paper, it will be used to measure the organizational structure between services. SHS is the degree of SH occupied by the individual service. The closeness of the network environment in which an individual node is located can reflect its SHS to a certain extent. The closer the relationship between the node and the neighbor nodes, the fewer SH positions the individual service may occupy, i.e., the lower SHS of the individual service. The metric of SHS is constructed for* *reference to the calculation of clustering coefficients [13], while the formulae are divided into three categories based on the number of neighboring nodes and the degree of closure of nodes: 1) If there are two or more neighboring nodes of the service node and the service node is not completely closed, SHS is calculated as shown in Formula 2. 2) If the service node is completely closed, SHS is calculated as shown in Formula 4. 3) When the service node is independent and has no mutual relationship with other nodes or exists only with one service node, its SHS takes the value of 0.1. 0.05 and 0.1 was set empirically, and we also verified it by other structural hole calculation methods.*

$$SHS_{s_i} = \frac{|Neb\left(s_i\right)|}{\alpha} \times \left(1 - \frac{2E_i}{|Neb\left(s_i\right)|\left(|\mathrm{Neb}\left(s_i\right)| - 1\right)}\right) \tag{2}$$

Simplified as:

$$SHS_{s_i} = \frac{\mathrm{Neb}\left(s_i\right) \mid \left(|\mathrm{Neb}\left(s_i\right)| - 1\right) - 2E_i}{\alpha\left(|\mathrm{Neb}\left(s_i\right)| - 1\right)} \tag{3}$$

$$SHS_{s_i} = \frac{|Neb\left(s_i\right)|}{\alpha} \times 0.05 \tag{4}$$

$Neb(s_i)$ represents the neighbor service set, E_i represents the number of interconnection edges between neighboring nodes of S_i. α is the adjustment parameter, and it exists to control the value of SHS of individual services between 0 and 1. The value of α depends on the number of services in the SN, and its value is different for different SN.

Definition 5. *(Value of service, VS): VS is the value created by the individual service over a while minus its cost of value creating. The value created by the individual service includes the value created by the service and the value created by the interaction between the service and its neighbor services. The cost of individual service includes both the cost of the service itself and the cost of the service spent on interacting with neighboring services. Therefore, the calculation formula of VS is as follows.*

$$VS_i = g_i - c_i \tag{5}$$

$$g_i = vsel_i + vcol_i \tag{6}$$

$$c_i = csel_i + \sum_{s_j \in Neb(s_i)} cs_{ij} \tag{7}$$

g_i is the value created by the individual service, c_i is the cost of the individual service, $vsel_i$ is the value created by the individual service itself, $vcol_i$ is the value created by the interaction between the service and the neighbor services, $csel_i$ is the cost of the individual service itself, cs_{ij} is the cost of maintaining the relationship between the service and its neighbors.

Definition 6. *(SH of SE, SHSE): SHSE is the mean value of SHS in SE, so the calculation formula for SHSE is as follows:*

$$SHSE = \frac{\sum_{i=1}^{N} SHS_{s_i}}{N} \tag{8}$$

N is the number of services in SE.

Definition 7. *(Value of SE, VSE): We ignore some external factors that affect the operation of SE, and only consider the interaction between services. Therefore, VSE is the sum of VS in SE.*

$$VSE = \sum_{i=1}^{N} VS_i \tag{9}$$

4 Experimental Design and Analysis

4.1 Construction of Computational Experiment

There are many inconveniences in using a real environment for experimental validation. On the one hand, the research content of this paper involves specific service values. Due to the security and confidentiality demands of data, real data are not available in this paper. On the other hand, the value creation of services in the real environment may be disturbed by various internal and external factors, e.g., QoS and the market environment. This prevents us from intuitively discovering the impact of SH on service value creation, and the economic and time costs are too large. Computational experiments are one of the mainstream methods to analyze complex systems. It can be used to simulate the evolution process of complex systems under different rules. Therefore, to verify the impact of SH on value creation in SE, we use computational experimental [16,21] to simulate the dynamic evolution of services and user demands in SE. At the same time, we achieve a comparative analysis through the design of different parameters and evolutionary strategies.

The operation and evolution of SE can be seen as the process of the service continuously satisfying the demand of users. Therefore, as shown in Fig. 3, the computational experiment system is designed from both the service-side and the demand-side, including two types of agents: service and demand. The computational experiment system operates and evolves according to both a natural evolution and controlled evolution, respectively. The difference between natural and controlled evolution is how newly joined service nodes in the SE select cooperative nodes. During natural evolution, the newly joined nodes freely choose the cooperating nodes. During controlled evolution, newly joined nodes choose to cooperate with nodes that have greater connectivity. We believe that these two types of collaboration are already representative of what is possible in most SEs. The properties and behavior rules of the service-side and demand-side agents are designed based on the characteristics of the services and user requirements in real SEs, e.g. the demise of services and the increase in demand. The computational experiments are designed to satisfy the characteristics of SE, e.g., complexity and autonomy.

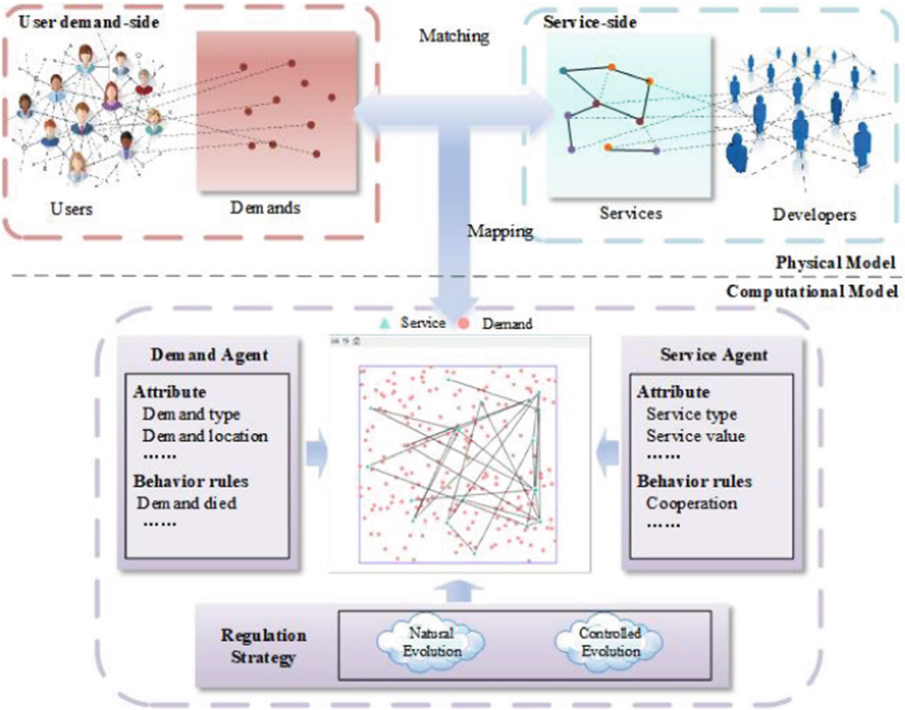


Fig. 3. Design of computational experiment system.

In the computational experiment system, the service-side agent represents the service node, which has the characteristics of autonomy and self-evolution. All agents can perceive the surrounding demands, and if they cannot satisfy the demands, they will seek cooperation from neighboring agents. The benefit distribution is carried out according to the capacity ratio of the service agent. The characteristics of the service agent are represented as shown in Formula 10.

$$SA = <Styp, Scap_t, Sval_t, Ssh_t> \tag{10}$$

$Styp$ represents the type of service, and different types of services have different functions. $Scap_t$ represents the capability of service. $Sval_t$ represents VS. Ssh_t represents SHS. In addition, $Scap_t$, $Sval_t$, Ssh_t are constantly changing with time.

In the computational experiment system, the demand-side agent represents user demands, and user demands are constantly changing. In the experiment, the complexity of demands is different. When the complexity of the demand is large, a single service cannot satisfy the demand. The cooperation of neighboring nodes needs to be sought for a win-win situation.

$$DA = <Dtyp, Dval_t, Dlif_t> \tag{11}$$

Dtyp represents the type of demand. It is mainly divided into primary and secondary demands. Primary demands are of low complexity and can be satisfied by a single service or cooperation services of low capability. Secondary demands are of higher complexity and cannot be satisfied by a single service and need to rely on the synergy between services. $Dval_t$ represents the profit that can be obtained by processing the demand. $Dlif_t$ represents the life cycle of the demand. In addition, $Dval_t$ and $Dlif_t$ are constantly changing over time.

To ensure the reliability of the experimental results, we set the experimental parameters regarding the operation of real SE, e.g., we set the probability of service evolution based on the update time and frequency of apps in the application store. The specific parameter settings are shown in Table 1.

Table 1. Parameter setting

System variable	Experiment setting
Environmental scale	50 ∗ 50
Initial number of services	20
Initial capability of service	Random value in [1, 4]. If we need to set the initial service with the same conditions, its capability is 3
Initial type of service	6
Initial value of service	Random value in [130, 180]. If we need to set the initial service with the same conditions, its initial value is 150
Moving cost	Y = k ∗ x (x is the moving distance, x > 0), k = 1.3
Operation cost	Random value in [2, 6]
Cooperation cost	Random value in [3, 8]
Service evolution probability	Random value in [1.4%, 1.7%]
Service evolution capability	Random value in [0, 1]
Service types increase cycle	90 tick
Initial number of demands	200, and the ratio of the primary demand to the secondary demand is 4:6
Demand value	Primary demand: random value in [20, 70), Secondary demand: random value in [70, 110]
The growth trend of demand value	N(60,100)

4.2 Experimental Design

Scenario Design. We simulated four experimental scenarios to answer RQ1 and RQ2 using a computational experimental system with the configurations shown in Table 2.

To verify the impact of the SH of the individual service on value creation, we do two types of comparison experiments: 1) In Scenario 1 and Scenario 2, we compare the changes of SHS and VS of any two initial services at different ticks,

Table 2. Scenario design

Scenario	Environment configuration
Scenario 1	Natural evolution: All properties of the initial services are identical
Scenario 2	Controlled evolution: All properties of the initial services are identical
Scenario 3	Natural evolution: All properties of the initial service are set randomly
Scenario 4	Controlled evolution: All properties of the initial service are set randomly

respectively. 2) In Scenario 3 and Scenario 4, we compare the changes of SHS and average VS at different ticks, respectively.

To verify the impact of the SH of SE on value creation, we compare the changes of SHSE and VSE under Scenario 3 and Scenario 4 with different ticks, respectively.

Experimental Data. On the one hand, we obtain the data of all the initial services in Scenario1 and Scenario 2 from tick 1 to tick 320. On the other hand, based on the above scenarios and experimental design, we obtain two runs data of Scenario 3 and Scenario 4, and 4 different ticks are selected for each run: 80, 160, 240, and 320. The data for each scenario were obtained twice to reduce the effect of accidental factors. The specific data descriptions are shown in Table 3.

Table 3. Data description

Dataset	Descriptions
Data 1	This dataset contains the SH and VS of all initial nodes under all ticks during the Scenario 1 run
Data 2	This dataset contains the SH and VS of all initial nodes under all ticks during the Scenario 2 run
Data 3-1	This dataset contains the SH and VS of all nodes in
Data 3-2	the Scenario 3 run under 4 different ticks
Data 4-1	This dataset contains the SH and VS of all nodes in
Data 4-2	the Scenario 4 run under 4 different ticks

4.3 Analysis on Individual Services Level (RQ1)

The data of two initial service nodes are randomly selected from Data 1 and Data 2, respectively. Comparing the relationship between SHS and VS with the same initial conditions in the same scenario, the results are shown in Fig. 4. VS is much larger than SHS, and it is reduced in equal proportion to facilitate the comparison of the two indicators in the same graph. According to VS of different ticks and the graph display under different reduction ratios, the reduction ratio of VS is finally set to 500.

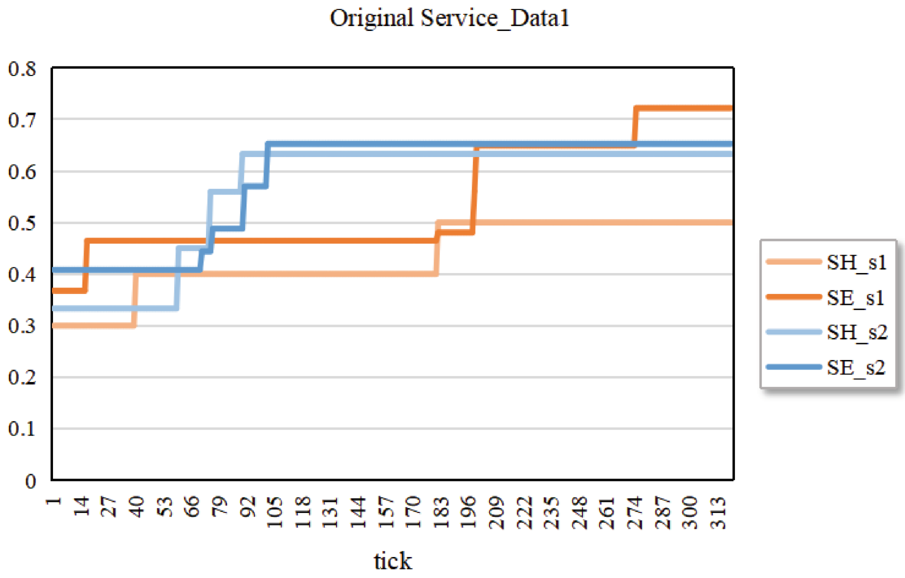
From Fig. 4, it can be seen that: 1) In both Scenario 1 and Scenario 2, the comparison between individual services yields that the larger the SHS, the higher its corresponding VS. 2) In different scenarios, for any service, when its SHS grows, the VS also grows. 3) In both Fig. 4(a) and Fig. 4(b), it can be found that the VS grows faster when the SHS is between 0.3 and 0.5. 4) In both Fig. 4(a) and Fig. 4(b), there is a phenomenon that the VS sometimes grows when the SHS does not change. This is because the VS is not influenced only by SH. The occasional growth may be influenced by the environment in which it is located, functional attributes, and other factors.

Compared with the behavior of individuals, the average behavior of similar nodes can more objectively reflect the characteristics of this class of nodes. So, we use the average value to represent the VS of a group of nodes with the same SHS. Based on Data3-1, Data 3-2, Data 4-1, and Data 4-2, we calculate the average VS corresponding to SHS at different ticks, and the obtained results of Data3-1 and Data3-2 show the same trend, as do Data4-1 and Data4-2, so only one set of results is shown in this paper (See Fig. 5). When SHS is equal to 0.1, SHS and its corresponding VS are represented by darker colored bars. When SHS is less than or greater than 0.1, SHS and its corresponding VS are represented by slightly lighter colored bars. Observing Fig. 5, we can see that: 1) When SHS is less than 0.1, VS gradually decreases as SHS increases. 2) When SHS is greater than 0.1, VS tends to increase and then decrease as SHS increases. 3) When SHS is greater than or equal to 0.7, VS increases abruptly as SHS increases. 4) When SHS is equal to 0.1, the VS increases compared to those nodes with SHS less than 0.1. This is because when the service node has many neighboring nodes but is completely closed, too much association with other services will increase the cost of relationship maintenance, and it will affect the efficiency of value creation.

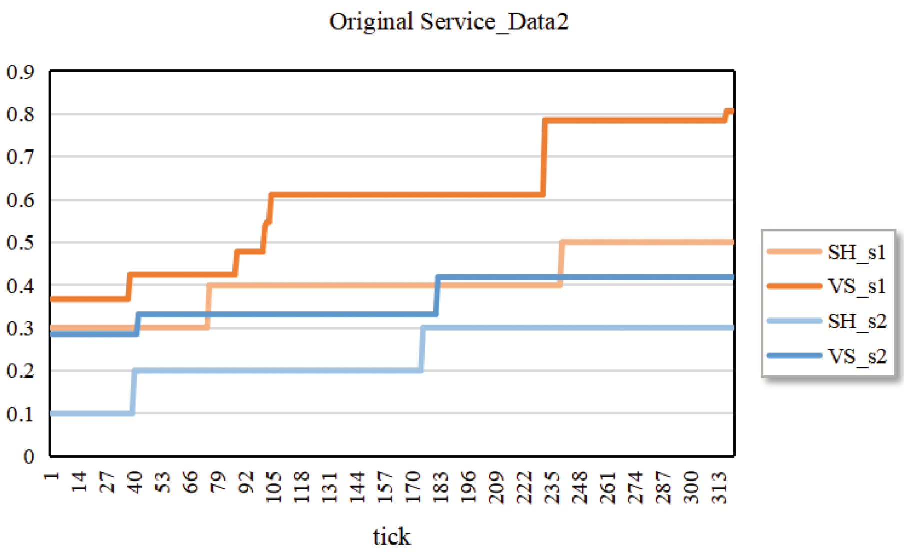
Integrating the above experiments and the actual SE operation and evolution process, we can conclude as follows: 1) when the individual service is completely closed (i.e., the individual service does not occupy SH), the value created by it gradually decreases as the number of its neighboring nodes increases. 2) When the individual service occupies SH, it has a better advantage in creating value when its SHS is between 0.3 and 0.5. 3) When SHS is greater than or equal to 0.7 (i.e., the individual service has an absolute positional advantage), the individual service is also able to create value better. 4) A service node with only a single neighbor has a higher ability to create value than a service with many neighbor nodes but closed.

4.4 Analysis on SE Level (RQ2)

Based on Data3-1, Data 3-2, Data 4-1, and Data 4-2, we calculate SHSE and VSE for different ticks under different scenarios. Different SEs in our computational experiments have the same service growth trend, and they have the same number



(a)



(b)

Fig. 4. The comparison of SHS and VS.

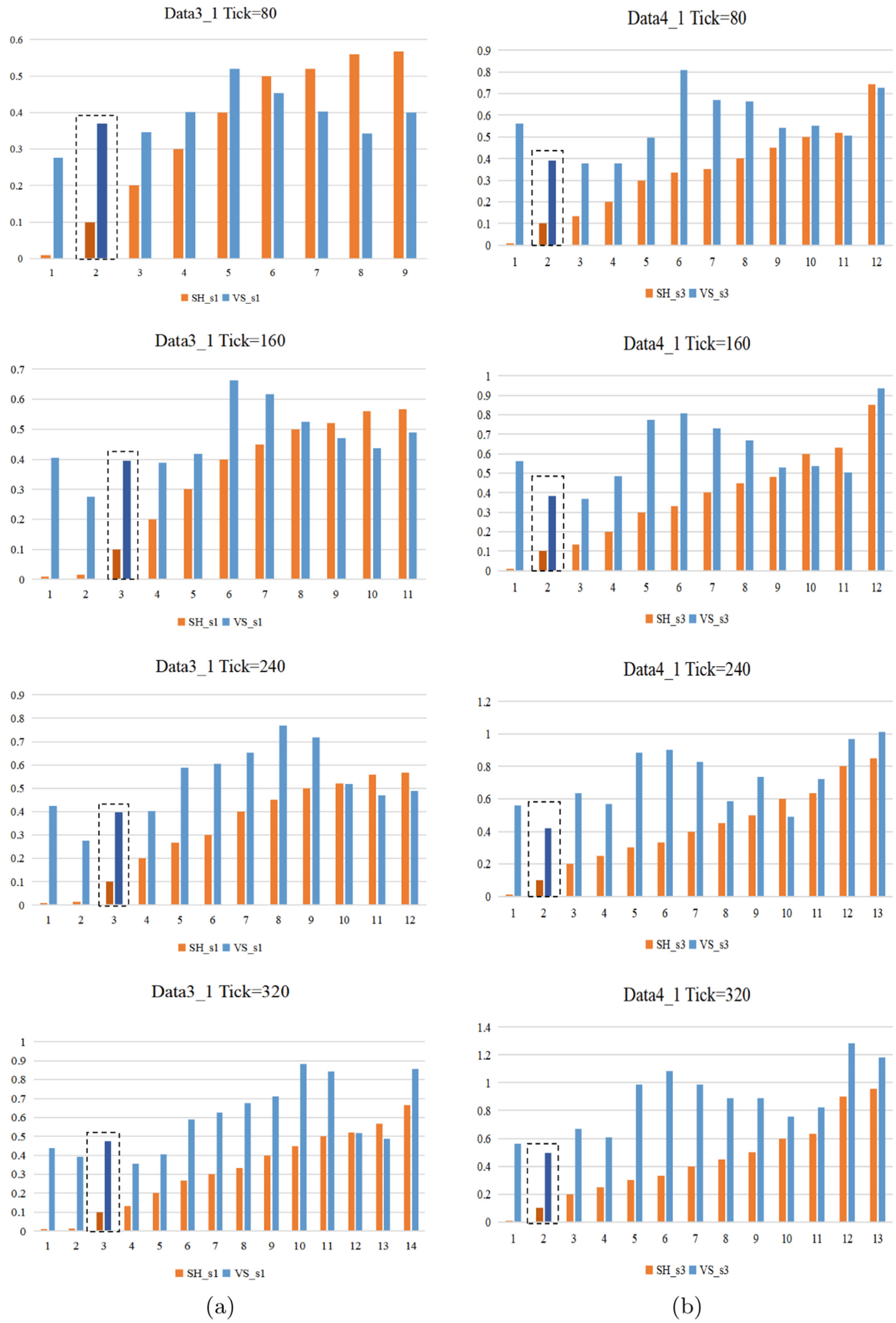


Fig. 5. The comparison of SHS and average VS.

of services under the same tick. The SHSE and VSE of the four datasets with different ticks were compared separately, and the results are shown in Fig. 6. VSE is also much larger than SHSE, so the reduction ratio of VSE is finally set to 20000.

From Fig. 6, it can be seen that: 1) The SHSE is consistently between 0.15 and 0.25 under five different ticks. It is not possible for all services in a SE to have a high SHS, so a low SHSE is a result of averaging the SHS. In real SEs, SHSE will not take high values either. 2) The comparison between SHSE and VSE under five different ticks all show the same phenomenon, i.e., the larger the SHSE, the greater its VSE.

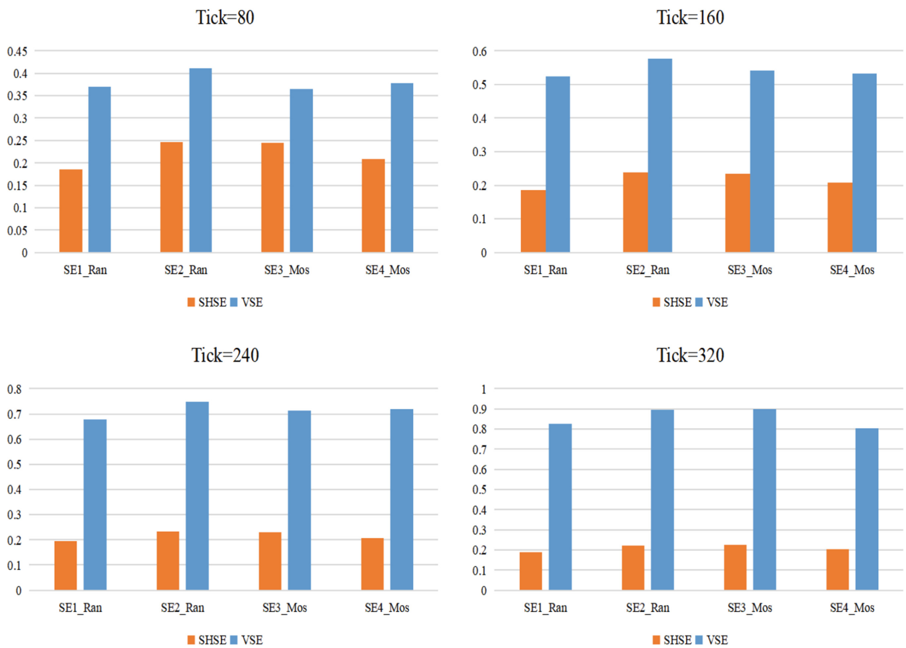


Fig. 6. The comparison of SHSE and VSE.

Therefore, we can get the conclusions as follows. Changes in the SH of a SE affect its ability to create value. The more SH exists in the organizational structure of a SE, the greater the ability of SE to create value.

4.5 Answers and Analysis to the Research Questions

Based on the process of value creation in SE and the above experimental analysis, it is possible to answer the 2 questions raised above.

1) Answer and analysis to RQ1. Changes in the SH of an individual service affect its ability to create value. When the individual service is completely closed, the value created by it decreases and then increases as its number of neighboring nodes increases. When the individual service occupies the SH, its value creation ability increases and then decreases with the enhancement of the SH. In addition, when the SH of the individual service has an absolute advantage, it is also able to create value better.
   From the level of individual services, the service that occupies the SH position has more competitive advantages compared with other services. Therefore, the value of services is higher when they have SH advantages. However, this does not mean that more SH occupied by an individual service is better. When the SH of an individual service is at an appropriate level, it is more beneficial to its value creation. When an individual service occupies many SH, the cost of synergy between the individual service and other services will lead to a reduction in the service value. Of course, there are exceptions. When an individual service occupies a particularly large SH, it has an absolute location advantage. At this time, the value creation ability of the individual service will also be strong.
2) Answer and analysis to RQ2. Changes in a SE's SH have an impact on its ability to create value. When there is more SH in the organizational structure of SE, the stronger its ability to create value.

From a SE level, the number of SH in a SE represents the closeness of the SE aggregation. When its aggregation is too high, it tends to cause a waste of resources and reduces the value-creating capacity of SE. Therefore, the more the SH of SE, the greater its value creation capacity.

5 Related Work

There is more literature on SE value creation in terms of stakeholders (e.g., users, service providers) and SE. To understand the positive value sources of platform-based SE, Haile et al. [8,9] studied the value creation process of the IT service platform ecosystem and software service platform ecosystem, respectively. In the IT service platform ecosystem, application service users, service developers, and service platform providers are the main market players. In the software service platform ecosystem, the value creation process mainly involves three types of stakeholders: application users, service developers, and platform providers, and the parameters affecting value are divided into four categories: service type, QoS, cost, and user base. Zahid et al. [18] analyzed the interrelationships among stakeholders in the cybersecurity information sharing ecosystem and determined the value parameters. Their work better coordinates the value of stakeholders (i.e., utility and profit) and assists business managers in making decisions related to business strategies.

There is only small literature that considers how it affects the value creation of SE in terms of other factors. Akaka et al. [1] used structural modeling techniques to analyze the role of technology in service systems and how it interacts with human practices and institutions. They argued that technology is a resource that can act on other resources to create value and is a key resource for value co-creation, service innovation, and system re-engineering. Selam et al. [6] constructed a value creation model for an IT service platform, and analyzed the impact of the degree of openness (i.e., interoperability, portability, and availability) of cloud computing platforms on the value creation of IT service platforms.

There is also little literature on the analysis of SE impact factors from different levels. Haile et al. [10] used an economic perspective to study the value creation of providers and users at different levels of interoperability. Based on this, platform providers can not only understand how investments in interoperability and portability affect costs, but also design new strategies to optimize their investments.

In summary, the research on the influencing factors of SE value creation has made certain achievements, which provides a good reference for SE value co-creation research. However, there are two deficiencies in this research work at present. On the one hand, in terms of the research scope, most of the current studies have been conducted from the perspective of SE, ignoring the influence of individual behaviors and lacking consideration of how each factor affects the value creation of SE. On the other hand, in terms of research objects, most of the current studies promote value co-creation in SE by studying the value creation mechanism among different stakeholders. In this paper, we considered how to promote the value maximization of SE from the aspect of the organizational structure of services. There is no relevant literature that studies the impact of SH on value creation in SE.

6 Conclusion

In this paper, we studied the impact of SH on the value creation of SE, which promotes the maximization of SE value. By constructing a SE value creation model, we analyzed the dynamic process of SE value creation. Then, we proposed an impact analysis method and studied it from two levels: individual service and SE. Finally, we designed a computational experimental environment based on the Repast platform and concluded how the SH of individual service and SE affect their value creation through experimental comparison and analysis. The above conclusions obtained in this paper can guide the development and evolution of SE.

The experimental data in this paper were obtained from a simulated environment, but the simulated environment was designed based on the operation of real SEs, and the data obtained from the simulated environment were random and multi-sampled. Therefore, the research results in this paper are credible. In the future, we will consider more about how to induce and intervene in the value creation process of SE through the indicator of SH.

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