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A Service Pattern-Oriented Computing Architecture for Service Ecosystems

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A service ecosystem is an increasingly popular service organization form, where participants, services, data, resources, and capital of different domains are integrated. It can empower business systems to consider the exchanged values and creations in a certain context. How to manage the participants' cooperation and arrange the elements in the service ecosystem, namely service pattern, have become an important factor to influence the competitiveness of enterprises. However, at present, most of the relevant researches stay in the description of business model and qualitative analysis stage. The design and application of service pattern is still blind and risky. In this article, a service pattern-oriented computing architecture is proposed. It can systematically design and innovate new service patterns and comprehensively assess and simulate them.

Service ecosystems are self-contained, self-adjusting systems of resource-integrating actors connected by shared institutional arrangements and mutual value creation through service exchange.[1] With that, the value exchange and creation in a specific environment and context could be taken into consideration.[2] As service ecosystems are becoming increasingly popular, how to manage the participants' cooperation from different domains and arrange the exchange of data, resources, and capital intuitively and effectively, have become an essential issue. The overall choreography of the participants, services, data, resources, and capital is named as *service pattern*.

The service pattern is the overall description of service coordination mechanism, participant interaction mode, and data/resource/capital allocation scheme in business services. In short, a service pattern is the extension of a business model in the context of Internet. In order to integrate resources and services in different fields, achieve upstream–downstream integration, and clarify the direction of capital flow, service patterns are usually the first and most important part of business service design.

However, due to the lack of theory, method, and framework on service patterns, how to systematically design, effectively simulate, comprehensively assess, and efficiently innovate service patterns have become important issues. The service pattern research could reduce the blindness of service ecological development and the confusion of investment market to a large extent.

At present, most of the research works on service pattern are qualitative analysis, lacking systematical and comprehensive quantitative theory. The existing methods focus more on the analysis, reflection, and remedy to service patterns afterward, and lacks the means of simulation and prediction in advance, which makes the innovation of service pattern simple, risky, and unpredictable. Thus, how to orchestrate the multi-domain business services, model the interaction among participants, and quantify the service patterns has already been an urgent issue. Some tried to transform the traditional industry processes into digital business processes to help with service design and analysis. However, the existing business process modeling methods like BPMN and BPEL mainly focus on the workflow and lack the ability to depict the panorama of service patterns. Significant manpower and long-term testing were

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TABLE 1. Comparison Between Business Process Management and Service Pattern Computing.

	Business Process Management	Service Pattern Computing
Modeling	describe business processes with activities, gateways, and events	describe service ecosystems with participants, services, data, resources, and capital
Execution	enact business processes manually or automatically from the perspective of workflow	enact service ecosystems manually or automatically from the perspective of workflow, data flow, resource flow, capital flow
Monitoring	encompass the tracking to QoS indices	encompass the tracking to QoS indices and pattern quality indices
Optimization	optimize the business logic to improve the business process	optimize the business logic, data transit logic, resource exchange logic, and capital trade logic to improve the service ecosystem

the necessity of pattern innovation in the past. And the comparison between business process management and service pattern computing are shown in Table 1.

For instance, Rural Taobao of Alibaba, one of the biggest rural E-commerce platforms in China, was initiated based on an idea to stretch E-commerce business to suburbs. When designing the rural E-commerce pattern, the start-up team tried to figure out the business process which includes the modifications on traditional processes and extensions about stakeholders (shown in Figure 1). However, it was really difficult to speculate on the effect of each modification and almost impossible to forecast the performance of the pattern designed. Taking rural E-commerce as an example, it is difficult to say whether introducing rural partners to help villagers conduct online operation is a better service pattern than allowing villagers to place orders on their own. To prove the effectiveness of the pattern, they had no way but testify in practice, which could take significant time and cost during iteration. The absence of pattern computing makes it directionless to do business melioration. And it could be better for a starting up business if it can design, simulate, and assess the service pattern on a sound computing platform in advance.

The challenges associated with service pattern computing are summarized below.

a) The service pattern cannot be *depicted* systematically. The existing methods mostly focus on describing the business model, which cannot systematically describe the service pattern in the context of Internet.
b) The service pattern cannot be *simulated* effectively. At present, the feasibility of a service pattern is mainly obtained through rough market research and analysis, and lack of effective simulation means.
c) The service pattern cannot be *assessed* comprehensively. Nowadays pattern assessment approaches such as due diligence, can only find out whether there are financial and legal problems in a company, yet the time, cost, efficiency, value, and reliability of the business are not comprehensively evaluated.
d) The service patterns cannot be *amalgamated* efficiently. New service patterns usually face a lot of iterations in the process of implementation and it is quite complicated to amalgamate service patterns with existing ones.

In this work, we aim to propose a set of service pattern-oriented computing tools. On the one hand, it should be able to help start-ups to design and simulate service patterns of which the prediction and prospect could be provided. On the other hand, it should be able to evaluate and innovate existing patterns, so as to obtain feasible solutions for service pattern evolution.

To that end, a service pattern-oriented computing architecture is proposed to solve the problems above. And a prototype system named JTangDubhe is developed along with that as well. JTang is an open source community supported by Zhejiang University, and Dubhe is the first and most glorious star of the Big Dipper and implies the origin of all services and businesses with bright future. JTangDubhe consists of service pattern design module, simulation module, assessment module, and innovation module. The design module describes the service pattern through four layers: entity layer, service layer, application layer, and exchange layer. The simulation module can rehearse possible conditions and preview a formerly designed service pattern through multiagent simulation after a certain number of further configurations. The assessment module can assess service patterns through time, cost, reliability, efficiency, and value based on the simulation results. The concept of pattern entropy is proposed to evaluate the service pattern as a whole and facilitate comparison and further optimization. The innovation module provides algorithms for pattern convergence and pattern optimization, which can automatically generate new patterns from existing ones.

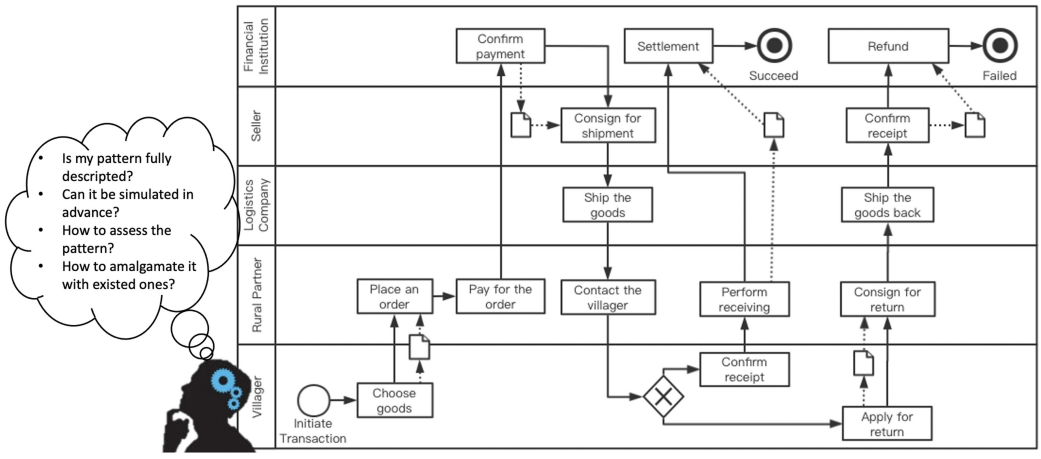

FIGURE 1. Business process depiction of Rural Taobao, where there are extensions on participants compared to traditional E-commerce like the rural partner to operate online on substitute of the villager.

RELATED WORK

As traditional industries are increasingly operated through the Internet, participants from different domains are able to interact and realize the exchange of data, resources, and capital more complicatedly and directly ever.[3] Researchers begin to analyze and discuss the resources and values transformed and exchanged in service ecosystems.[4] And the service pattern, as the overall choreography of the participants, services, data, resources, and capital in a service ecosystem, has become an essential study point.

Since service patterns are becoming increasingly important with the development of the information technology industry, a pattern-centered formalization language named service pattern description language was proposed to support the pattern designing and reconstructing.[5] The service pattern modeling approach was also provided and used to bridge the gap between the business process model and the enterprise economic model.[6] In addition, the service pattern could also be used to evaluate the service's profitability.[7] However, these studies only describe a single aspect of the service pattern like profit or service configuration. We need to survey the service modeling and business model area since the service pattern, which consists of service coordination mechanism, participant interaction mode, and resource allocation scheme, is the extension of business model in the context of Internet.

Many researchers have studied service modeling and business process management and made profound progress. BPMN 2.0 can be used to model distributed information system from different perspectives through structures like collaboration and choreography.[8] To create cross-organizational business processes, the service choreography was proposed as a standard to combine web services and model the interactions.[9] Besides, a framework was proposed to monitor and analyze the performance and quality metrics of business processes based on runtime data.[10] Skopik *et al.* proposed an interpretative rule-based approach to enable trust foundation among services and participants with context and perceptions considered.[11] To support automatic reasoning, Autili *et al.* introduced additional software entities to the enforce the choreography realizability.[12] In addition, a design method and a formal framework, which could check the conformance of choreographies, were proposed to promote practitioners to adopt choreography more widely.[13] Nevertheless, those methods concentrate on choreography to service elements and lack of panoramic view on participants collaboration and pattern description.

The business models were also analyzed to define how companies create, deliver, and capture value.[14] Lüdeke-Freund *et al.* proposed major business models to support the closing of resource flows.[15] Besides, to suit circular economy or sustainability principles, various business model innovation approaches were proposed.[16] And the system dynamics were applied to business model innovation to enhance managerial understanding and decision-making.[17] Ghezzi *et al.* studied three digital multisided platform startups and proposed a unified framework to make business model innovation methods more practical.[18] However, these studies only reveal the management of participants and value flow, lacking quantitative description and comprehensive calculation support to service patterns.

To support quantitative analysis and to solve the computational problem on service patterns, we

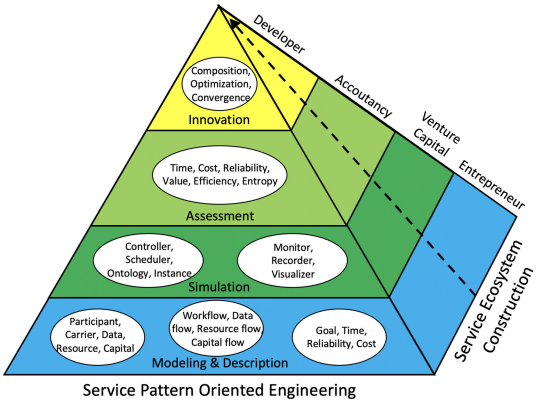

FIGURE 2. Service pattern-oriented architecture.

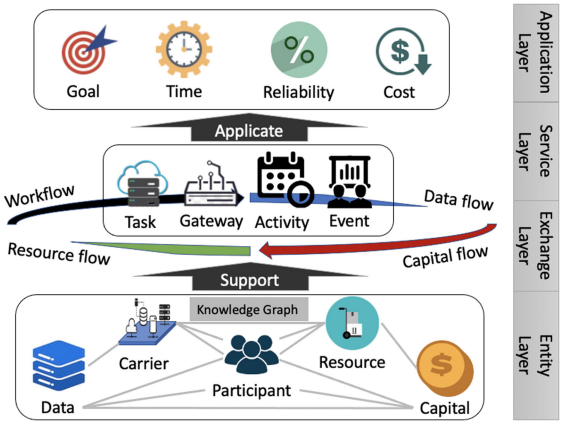

FIGURE 3. Key elements in service pattern design.

designed and developed a service pattern oriented computing framework named JTangDubhe to empower the stakeholders in service ecosystems to design, simulate, assess, and innovate their service patterns.

THE SERVICE PATTERN-ORIENTED ARCHITECTURE

The service pattern-oriented architecture introduces a stratified engineering roadmap to create an efficient and feasible service ecosystem. As shown in Figure 2, the architecture has four planes with the bottom plane describing entities, flows, and attributes, while the service simulation, assessment, and innovation planes are layered on top of it. The perpendicular axis indicates service ecosystem construction procedure with actors marked on the side including entrepreneur, venture, accountancy, and developer. Its objective is to provide facilities not only for start-ups to depict their service patterns systematically and to generate a prospect in advance, but also to provide feasible solutions to service pattern evolutions for existing service ecosystems. And we shall introduce each plane in detail below.

Service Pattern Modeling

The service pattern model is divided into four layers: entity layer, service layer, application layer, and exchange layer (see Figure 3).

The entity layer is constructed on the basis of knowledge graph and used to describe the underlying entities that make up the service pattern, including carriers, participants, data entities, resources entities, and capital entities. The carrier is a physical or virtual platform to support the normal operation of services, and it is also a medium for data, resources, and capital interaction among participants, including service platform, intelligent tools, systems, etc. The participants refer to people, organizations, programs, or intelligent systems that provide or use services in the service pattern. The data entity is a collection of information used for collaborative interaction between services in a pattern. Resource entity refers to the entity resource or virtual resource that can generate capital through transaction. The capital entity is mainly composed of currency or capital objects that can directly exchange with currency.

The exchange layer is used to describe the workflow and the exchange of resources, capital, and data between different entities in the application process. Workflow is an abstract and general description of the business rules among the service units in the service pattern. Data flow, resource flow, and capital flow respectively represent the transmission of data entity, resource entity, and capital entity between service units in workflow.

The service layer is used to describe the service units in the business processes involved in the service pattern built based on the entities in the entity layer, including activities, gateways, and events. Activity is the basic service unit in business process, with definite input and output, including web service, microservice, restful API, etc. Gateway can control the business process trend according to different situations, including parallel gateway, inclusive gateway, exclusive gateway, complex gateway, etc. Events are used to mark status milestones of business processes, including start events, intermediate events, and end events.

The application layer is used to describe the specific instances and related attributes of service units and entities in the application process in the service layer, including dependence, time, cost, reliability, and goal. Dependence refers to the dependence between entities or between service units and entities. For example, a service unit must depend on a certain carrier to deploy and run. Time and cost refer to the time and cost consumed by the service unit when it is

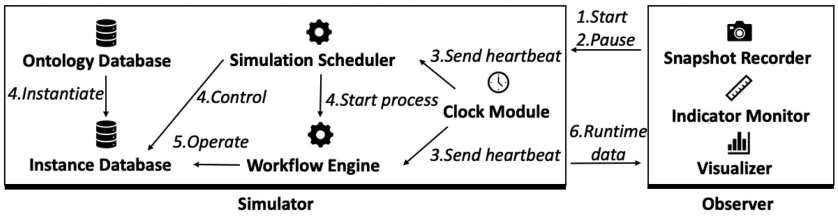

FIGURE 4. Framework of service pattern simulation.

actually running on a specific carrier. Reliability refers to the ratio of normal response of a specific carrier during operation. Goal refers to the goal to be achieved through a specific service pattern.

Service Pattern Simulation

Based on the general description of the service pattern proposed above, a scenario-oriented service pattern simulation framework is proposed. Service pattern simulation consists of a simulator and an observer (see Figure 4). The observer takes charges of start, pause, and stop the simulator, and get and process the runtime data generated.

The observer contains three parts including a snapshot recorder, an indicator monitor, and a visualizer. The snapshot recorder can save all runtime data step by step in sake of further analysis. The indicator monitor can be used to track the trends of certain values. The monitored values can be customized through insert python codes through a graphic interface. And the visualizer can visualize all the values monitored through various formats like histogram and line graph.

The simulator is formed by a clock module, a workflow engine, a simulation scheduler, an instance database, and an ontology database. The clock module is used to schedule the order received from observer and send heartbeat to simulation scheduler and workflow engine. The simulation scheduler is used to start the processes in the workflow engine and control the change of agent number and object volume in the simulation environment. Then, the workflow engine would operate the instances in the database on the basis of process logic and attribute values designed in advance. And the instances are all instantiated from the ontology database.

Service Pattern Assessment

The service pattern assessment plane is to evaluate service patterns through analyzing their simulation results. By simulation, we have determined all the variables or distribution of the environment model in the service pattern, so we can evaluate the time, cost, reliability, value, and efficiency of the service pattern by the way of statistics and get the expectations. After that, the assessment plane could generate an overall score, named pattern entropy. The assessment metrics are shown as below:

- The time consists of execution time and interaction time. The execution time indicates the service runtime, and the interaction time indicate the time lost in the interaction between different participants.
- The cost consists of execution cost and waiting cost. The execution cost indicates the cost of service operation, and the waiting cost indicates the cost of keeping a running environment available when a service is idle, such as server costs.
- The reliability indicates the probability of the service pattern run successfully.
- The value of the service pattern refers to the expectation that the sum of all resources and capital is different from the original after the service pattern has completed simulation.
- The efficiency of service pattern refers to the mean of delivery efficiency of capital objects, resource objects, and data objects in the service pattern.

Pattern entropy is a comprehensive score defined in the system to evaluate the integrity of service patterns. Pattern entropy refers to the time needed to transfer unit value when the workflow in this service pattern runs successfully once. Generally, the pattern entropy is negatively correlated with the mass of the pattern itself. The lower the pattern entropy, the shorter the consumption time, the lower the cost, the higher the efficiency, the higher the value, and the higher the reliability.

Service Pattern Innovation

Service pattern innovation is a way to achieve new goals by decoupling, reorganizing, and combining existing service patterns. The innovation plane mainly includes pattern convergence and pattern optimization.

The pattern convergence includes participant convergence, resource convergence, and service

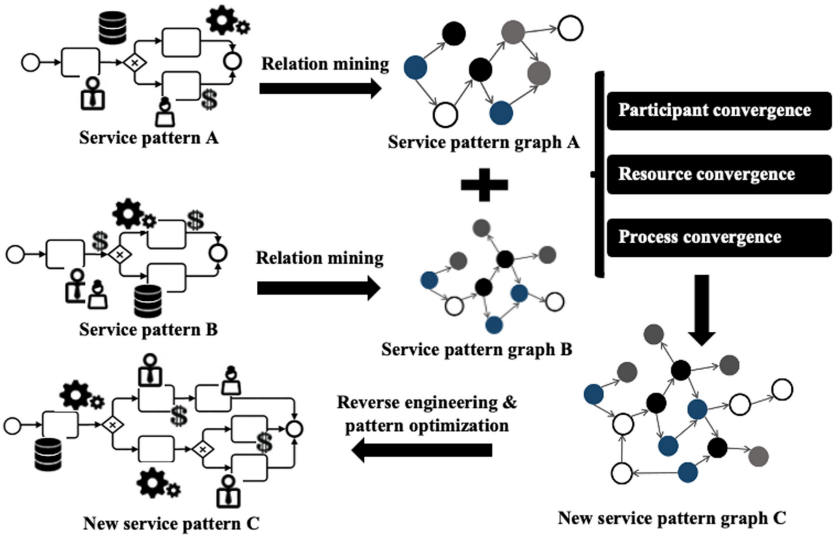

FIGURE 5. Illustration of innovation mechanism.

process convergence (see Figure 5). In the process of participant convergence, if there is injective mapping between the attributes and relationships of participants from different patterns, they can be merged into one participant in the new pattern. In the process of resource convergence, if the types and relationships of two resources from different patterns are the same, the volumes would be summed to get a merged resource. As for the service process convergence, tasks with the same input and output and the same participants and resources as the dependent will be considered as the same task and merged. So are the gateways and events.

In order to ensure the effectiveness and efficiency of the patterns generated by the convergence method, the pattern optimization methods are introduced. It is to optimize the business structure and task deployment by adjusting the execution order of the tasks in the workflow and exchanging the task deployment environments on the premise of not changing the data flow, resource flow, and capital flow of the service patterns. As a result, the optimized patterns can realize a lower service time and cost expectations, as well as improved efficiency and quality. The pattern optimization algorithm takes pattern entropy as the optimization goal and performs simulated annealing on the service pattern, thereby obtaining a set of noninferior solutions, that is, the Pareto solution set, for users to choose.

JTANGDUBHE CASE STUDY

As shown in Figure 6, JTangDubhe consists of a service pattern design module, simulation module, assessment module, and innovation module. The design module and simulation module are proposed to help start-ups to depict their service patterns systematically and to generate a prospect in advance. And the assessment module and innovation module aim to provide feasible solutions to service pattern evolutions. In this section, we first introduce how service patterns are designed and simulated, then the assessment metrics and the innovation method.

The Rural Taobao is a rural e-commerce project of Alibaba group. Based on the e-commerce platform, the Rural Taobao realizes the function of "online goods to the countryside" by building a village level service network. Rural Taobao allow farmers to enjoy the same convenience of online shopping as urban residents at home. At the same time, Rural Taobao hopes to use the Internet to promote the process of urban–rural integration and create more employment opportunities for rural areas.

Through JTangDubhe, we can first design the service pattern of Rural Taobao (as shown in the Figure 7). The service pattern of Rural Taobao mainly includes five types of agents: villager, rural partner, logistics company, seller, and financial institution. Through the system, additional pattern elements like carrier, capital, and resource can be depicted. Besides, the attributes of the elements are enriched to support to following quantitative pattern computing.

Then on the basis of the systematical and quantitative design of the pattern, Rural Taobao is able to be simulated through JTangDubhe to obtain a comprehensive cognition on how the variables inside would change. The simulation module supports step by step

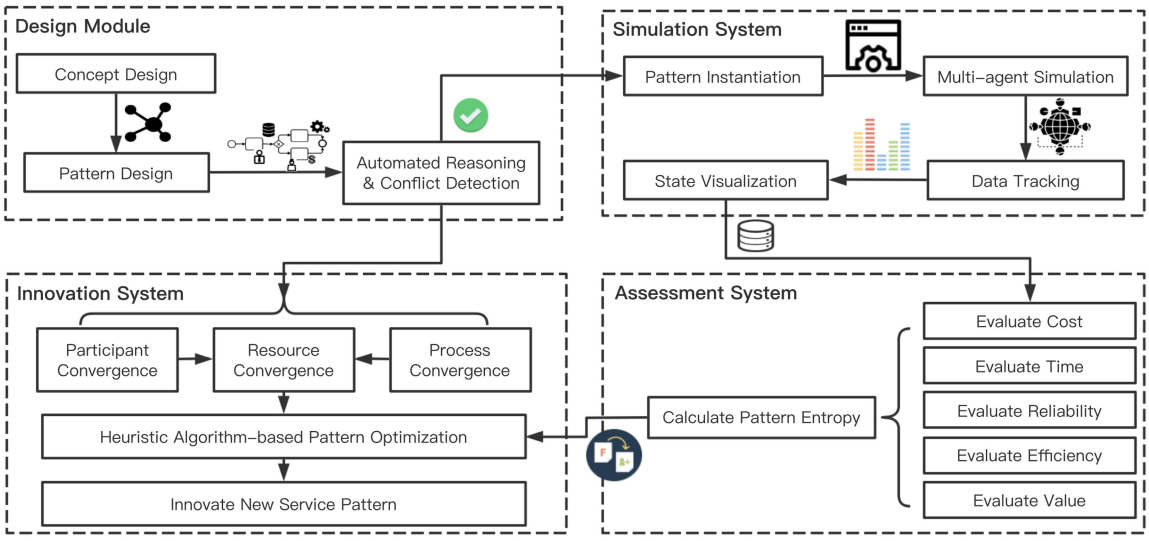

FIGURE 6. Overall framework of JTangDubhe.

simulation and keeps the snap shots for each step, and the variables concerned can be customized and traced. We simulate the Rural Taobao for 1833 steps (5 years), which each stands for one day, and traced the profit of logistics company and the satisfaction of the villager (see Figure 8). As shown in the Figure 8(a), the profit of the logistics company would increase linearly in the first 600 days as its capacity was gradually fully used. However, as the demand of villagers exceeded the capacity of the logistics company, the penalty for breach of contract made the profit decline (about days 600 to 1000). Finally, the profit gradually reached stability in the fluctuation. Accordingly, as shown in Figure 8(b), the villagers were almost completely satisfied for the first 600 days. Then, the satisfaction fell sharply because logistics could not meet their needs. In the end, it gradually tended to be stable.

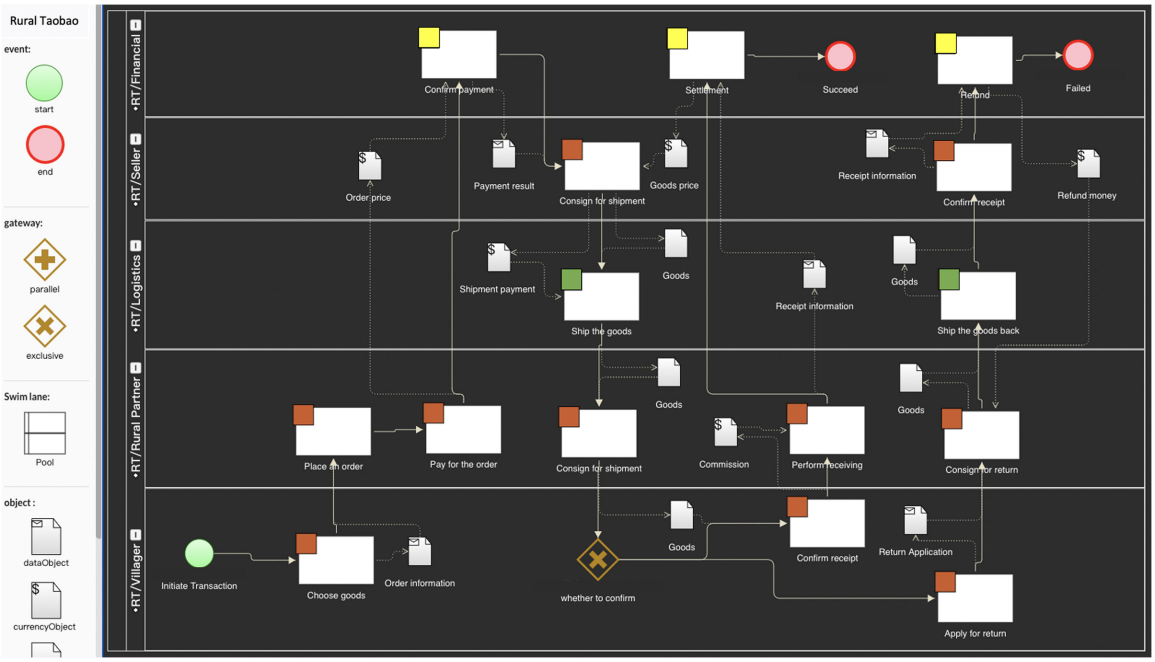

FIGURE 7. The service pattern of the Rural Taobao.

FIGURE 8. Simulation results for Rural Taobao pattern.

Besides, with the cost, time, reliability, efficiency, value, and pattern entropy calculated by assessment module, the service pattern of Rural Taobao can be comprehensively analyzed and compared with others. Because it is confusing that whether it is better to let the villagers operate by themselves or involve a rural partner instead, we implement a comparison between the two and get the corresponding metrics (see Figure 9). Due to space limitations, only time and cost results are shown and discussed. As shown in the box plots in Figure 9(a), the expected time of Rural Taobao with a rural partner is one-third day shorter than without. It is understandable because the rural partner's professional operation can accelerate the trade process. And the expected cost of the pattern with a rural partner is lower because the shortening of time reduces the running cost and waiting cost of the activities [see Figure 9(b)].

Finally, if there is a requirement to fuse some other ideas and businesses to Rural Taobao, the innovation module can efficiently implement the pattern-amalgamation. The innovation module could find out the possible amalgamation solutions and select the most appropriate one or several based on the assessment result and user preference.

JTangDubhe makes the service pattern design systematical, makes simulation effective, makes assessment comprehensive, and makes innovation efficient. All those can bring a more sober and rational market environment, increase the entrepreneurial success rate, and reduce investment failure.

CONCLUSION

In this article, a novel service pattern-oriented computing architecture was proposed to bridge the gap between business plans and service patterns of the service ecosystems. Along with that, a prototype system named JTangDubhe is developed. It combines business process modeling and analysis with business models to achieve a systematical and effective design and simulation. In addition, several key theories and techniques are proposed to make it more comprehensive and efficient to assessment and innovate the service patterns.

However, there are still works to be studied in the future. The valuation of the model and the mutual trust mechanism among the participants are important for the development of the service ecosystem and modern service industry. And those will be a valuable work in the near future.

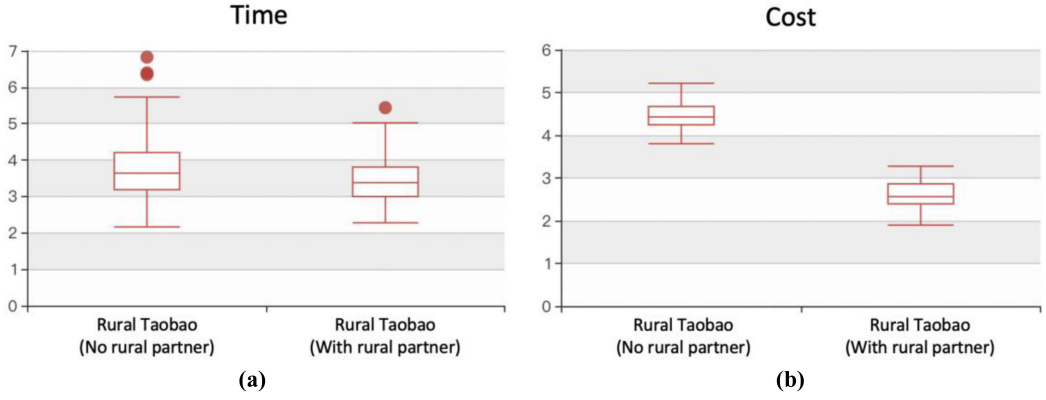

FIGURE 9. Assessment results of Rural Taobao with and without the rural partner.

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