Research Article

Digital Transformation Path for Manufacturing Enterprises Using Internet of Things and Data Encryption Technology

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Innovation in products or services is crucial for industrial manufacturing businesses in countries that prioritize exports. A plethora of advancements based on the internet of things (IoT) applications has been made possible by the falling prices of processing power, communication, and electrical components. Only a small number of industrial manufacturing enterprise-specific IoT applications have been effective yet. The present literature does not fully explain this scenario, which is very necessary for taking the advantage of IoT in manufacturing enterprises. In order to adapt to the change in digital market demand and enhance the market competitiveness of manufacturing enterprises, this paper aims to study the digital transformation path of manufacturing enterprises based on the internet of things (IoT) and data encryption technology. A digital transformation service system is built for manufacturing enterprises based on the IoT and data encryption technology to help manufacturing enterprises fully understand their own digital degree, provide effective suggestions for the digital transformation, and introduce the overall architecture and functional structure of the service system in detail. A distributed intelligent recommendation method is proposed that is based on personalized customization and recommends transformation schemes for businesses in order to better direct users’ product customization and decision-making and allow the users to accurately describe their own needs, improve customization efficiency, introduce intelligent recommendation methods, and strengthen the basis of collaborative filtering methods based on items. The simulation result demonstrates that the service system proposed in this study performed really well in terms of both accuracy and time consumption. It is anticipated that the suggested approach will successfully raise the digital maturity of manufacturing companies and will help them in increasing their ability to compete in the current market.

1. Introduction

The manufacturing industry is the pillar industry of a country, which directly reflects the overall production level of a country. With the gradual convergence of industrialization and information technology (IT), a new strategic direction is brought for the rapid development of the manufacturing industry. In the current era of digitization, IoT and big data technologies have been gradually applied to various manufacturing industries. As a result, personalization and the change in digital product and service modes have been initiated. The drive mode of some traditional elements, such as capital investment will inevitably be replaced by the digitized innovation-driven development mode. Digitizing can drive productivity and production relationships. Digitization is the dynamic basis and source of energy for the transformation of manufacturing enterprises. Research on the transformation path of digitization of manufacturing enterprises has become the focus of current problem-solving techniques. Digitization transformation mainly takes digital industry and industrial digitization as the direction of the development of manufacturing enterprises. Enterprise integration and enterprise digital platform are built as the supporting mechanism inside and outside enterprises, which can better adapt to the changes in digital market demand.

IoT is an infrastructure that embeds electronics, circuitry, software, sensors, and network connectivity into physical objects including machines, instruments, buildings, cars, and other things for the purpose of data collection and sharing. Through the use of the current network infrastructure, IoT enables us to detect and control things...
remotely. This allows for a closer connection between the real world and computer-based systems, which boosts efficiency and accuracy [1]. IoT opens a door not only for smart homes but also for the smart industry where things are either entirely or partially managed by machines. Production sites and factories are two examples of the primary categories of smart industry. The first one is the setting for discrete manufacturing, while the second one is technologically specialized production. The use of IoT on “production sites” to improve operations and fine-tune processes would minimize losses from the ineffectiveness of the decisions taken by 5–12.5%. In addition, to enable continuous production process monitoring, IoT deployment in factories also facilitates better inventory management [2].

Under the background of the rapid development of IT, every country has put forward a transformation strategy for manufacturing enterprises. Accelerating the integration of industrialization and IT as well as digitizing the transformation of manufacturing companies are crucial for China to become a powerful manufacturing nation. However, currently, manufacturing enterprises are not fully utilizing the potential of IT. Therefore, it is very crucial to pay attention to the fact that how to digitally transform industrial businesses on the basis of IT development. For this reason, the digitized transformation path of manufacturing enterprises based on the IoT and digital encryption technology is deeply studied so that manufacturing enterprise can improve their digitization level and realize the practical value of digitized transformation of manufacturing enterprises on the basis of their own development.

The innovations of this paper are as follows: (1) firstly, a digital transformation service system for manufacturing enterprises based on the IoT and data encryption technology is built, and the overall structure and functional structure of the service system are described in detail. (2) Secondly, a distributed intelligent recommendation method based on customization is proposed, and the specific path of digitized transformation of manufacturing enterprises is analyzed. (3) Compared with other research methods, the overall performance of the service system proposed in this paper is better, and the methods can effectively improve the digitization level of manufacturing enterprises, thereby enhancing the market competitiveness of enterprises.

The rest of the paper is organized as follows: Section 2 discusses the work done in the literature on the digital transformation of manufacturing enterprises. Section 3 is about the digital transformation service system for manufacturing enterprises based on IoT and data encryption technology. This section further discusses the overall architecture of the digital transformation service system for manufacturing enterprises and the system’s functional architecture. Section 4 describes the distributed intelligent recommendation algorithm based on personalized customization by explaining the computing similarity of attribute values of articles in manufacturing enterprises, measuring the interests and interests of target users in manufacturing enterprises, and auxiliary customization to generate recommended results. Section 5 sheds light on the result of the experiment conducted in the study. Section 6 finally concludes the overall theme of the paper.

2. Related Work

In terms of the research on business transformation and the theory of digital transformation, certain developed nations are relatively young. These nations serve as a source of inspiration for the study of the digital transformation route taken by manufacturing firms in China. In view of the opportunities and challenges that the digital economy brings to the development of enterprises, especially, the digital transformation of manufacturing enterprises in China has important practical significance. With some manufacturing enterprises as the object of study, based on some theories such as path dependence on the technological trajectory, this paper uses the fuzzy set comparative analysis method to discuss the effect mechanism of some factors such as the property rights of enterprises, the size of enterprises, and the years of establishment on the selection of the digitized transformation path of enterprises. The results show that enterprise scale is the core condition in the enterprise transformation path before, during, and after the process. Small-scale businesses with medium or low technological development will pick the digital transformation, the nature of the property rights, the enterprise scale, and the inventive environment to be replaced during the process of digitization. Manufacturing enterprises with low and medium technological development tend to select the transformation path of product service types. The analysis conclusion shows that it can provide practical guidance for manufacturing enterprises to achieve digital transformation, but it does not improve the overall strength of enterprises [3]. Shi et al. [4] claim that as the world has progressed into the digital age, the relationship between manufacturing and digital technology is increasingly closing. The digital transformation of manufacturing companies is a crucial necessity to effectively improve the core competitiveness of organizations and achieve rapid development given the shift in technology innovation, production demand inside the firm, and external environmental variables. According to the author’s claim, his proposed study examines the digitization level status of manufacturing enterprises in a region using sample data analysis of more than 100 manufacturing enterprises on the integration platform of digitization. It also evaluates the level of digitization of manufacturing enterprises comprehensively from the dimensions of the enterprise’s infrastructure, product life cycle, and production management control and highlights the weak links in the process of digitization transformation of manufacturing enterprises. Effectively promote the integration of digital technology and manufacturing enterprises to provide data support, but this method does not reduce the production costs of enterprises. In conjunction with the acceleration of manufacturing digitization in recent years, Wang et al. [5] highlight some issues existing in the daily operation of traditional manufacturing enterprises, such as the lack of automation in settlement and the low transparency of business data, which cannot be trusted as evidence. Blockchain technology has the
characteristics of transparency and trustworthiness, and combined with IoT technology, it can help manufacturing enterprises take targeted solutions to the problems in the digital transformation. To this end, the matching system of service automation in manufacturing enterprises is designed based on the ant colony algorithm to provide tracking services using blockchain and the IoT. The simulation results show that the enterprise digital transformation scheme is feasible that can effectively reduce the cost of enterprise operation and settlement and can effectively enhance the transparency and reliability of enterprise business information. However, it does not improve the overall competitiveness of manufacturing enterprises. According to Zheng et al. [6], the digitized transformation opens up opportunities for the economic development of manufacturing enterprises and has a significant impact on that development. This is because the current market economy has gradually transitioned into the era of the digitized economy. The state proposes corresponding policies, takes standardization as the background, employs the hierarchical analysis method, and starts with the development status of manufacturing enterprises. It then conducts an extensive analysis of the influencing factors of digitized transformation of manufacturing enterprises, combines it with reality, and proposes the counter-matter. Finally, from the perspective of high-quality development goals for manufacturing enterprises [7], it is suggested to work together from many aspects, such as standardization methods, enterprises themselves, and consumer theory, to effectively achieve the digital transformation of manufacturing enterprises; however, this method does not improve the overall competitiveness of enterprises themselves.

3. Digital Transformation Service System for Manufacturing Enterprises Based on IoT and Data Encryption Technology

This system is for manufacturing enterprises that need digitizing transformation. Its primary goals are to fully assist manufacturing companies in understanding their degree of digitization, to offer practical suggestions for their digitization transformation, to assess their level of digitization, to clearly understand their issues and gaps, and to assist the government, businesses, and industrial organization systems in promoting digitization work [8, 9]. In order to provide scientific decision-making basis for manufacturing enterprises, this system not only needs to have an information display function but also needs to provide an evaluation diagnostic model to support automated diagnosis and expert evaluation diagnostic function. The specific business architecture of the proposed system is illustrated in Figure 1.

In Figure 1, the system divides users into visitors as well as demanders, service providers, diagnostics experts, and platform administrators. Visitors who are not registered on the system can only browse the system display. Manufacturing enterprises need to authenticate after they register on the system. Demanders can publish their own requirements and view solutions; service providers can publish solutions and view the needs of demanders; and platforms provide docking capabilities [10, 11]. Experts are assigned by system administrators and are specifically responsible for docking manufacturing enterprise consultation and customized diagnostics. Administrators are primarily responsible for system security and portal information content maintenance, as well as diagnostic evaluation of the creation and maintenance of diagnostic templates in subsystems.

3.1. Overall Architecture of Digital Transformation Service System for Manufacturing Enterprises. The system is being developed using a front- and back-end split architecture mode, which is a novel architectural method for IoT application development. Traditional and most of the existing Web development is based on the model view controller (MVC) model. During the process of development, the front-end pages of the system are prone to generate a large amount of back-end code. As a result, the front-end development of the system will rely heavily on the back-end, which is not conducive to the later debugging and maintenance of the system, resulting in some problems such as low development efficiency and high maintenance costs [12, 13]. When the front end and back end of a system are operated separately, the front end only concentrates on the impact and user experience of the system pages. The back-end of the system no longer focuses only on the page display of the front-end of the system but also on the issues of high performance and high concurrency. The front end and back end of the system make use of the RESTful style API interface, which is the interface communication for transferring JSON data API. The front end and back end of the system are independent projects, and different servers are deployed, which improves the overall performance of the system and the user experience. The technical framework of a digitized transformation system in a manufacturing enterprise is represented in Figure 2.

In Figure 2, the front end of the digital transformation service system in manufacturing enterprises is the Vue framework, which is a progressive framework for building the user interface, can be applied from the bottom to the top, and has rich class library support. The data access layer (DAL) uses a JPA framework, provides a simple programming model, supports advanced object-oriented features, supports container-level transactions such as large datasets and concurrency, and simplifies the code for the DAL [14, 15].

3.2. System Functional Architecture. The main purpose of the digital transformation service system development is to provide specialized services for the digital transformation of manufacturing enterprises, including diagnostic evaluation, transformation solutions, and other functions. Based on the business process of Figure 1, the modular design of system functions is carried out, and the system function block diagram is provided as shown in Figure 3. According to different user roles, the system is divided into three
subsystems: portal system, enterprise management system, and background management system [16, 17].

In Figure 3, (1) the portal system is mainly open to all users and is the entry point for the digital transformation service system of manufacturing enterprises. Users can browse the latest policy information, industry trends, national enterprise digitization development, and enterprise publishing requirements and provide users with relevant content and information about digital transformation. (2) Enterprise management system is for certified manufacturing enterprises, providing the docking of supply and demand, diagnostic evaluation, and expert consultation functions for suppliers and service providers. In this system, the demander may post the enterprise’s own needs; the service provider can submit answers; and once the requirements or solutions are posted, all users can access them in the portal system [18, 19]. Provide functional support for manufacturing enterprises in the diagnostic evaluation module. After a manufacturing enterprise has been certified, the digitization level of its own
enterprise can be understood by filling in the system questionnaire, obtaining digitized transformation path suggestions and recommended solutions, and contacting experts to provide customized diagnostic consulting services. (3) Background management system is mainly open to administrators and experts. The functions of administrators include diagnosis management, template management, expert management, news dynamic management, and right management. System administrators can use the background system to develop configuration templates and questionnaires, assign expert accounts, manage registered enterprises, and so on. A diagnostic expert consists of a review of the diagnostic process and an expert response. Experts can review the status of questions and answers issued by manufacturing enterprises in the system, reply to enterprise customized consultations, and upload corresponding reports of customized evaluation.

4. Distributed Intelligent Recommendation Algorithm Based on Personalized Customization

Personalized customization is the main way of digitized transformation of manufacturing enterprises. It is combined with the above-digitized transformation service system of manufacturing enterprises based on IoT and data encryption technology.

4.1. Computing Similarity of Attribute Values of Articles in Manufacturing Enterprises. Users- and item-based collaborative filtering algorithms are the two categories of collaborative filtering algorithms. An article-based collaborative filtering algorithm is chosen as the foundational method in this study before the enhancement. The similarity between two items is defined by the following formula based on item collaborative filtering:

$$w_{ij} = \frac{|N(i) \cap N(j)|}{|N(i)|}$$

where \( |N(i)| \) represents the number of users who like the i-item, while \( |N(i) \cap N(j)| \) represents the number of users who like not only the i item but also the j item. However, this calculation method will produce j items that are popular and may be liked by almost all users, so \( w_{ij} \) will approach 1 to some extent, but it cannot accurately reflect the strong similarity between item i and item j. For this reason, formula (1) is adjusted to reduce the weight of j items and prevent the most popular goods from being recommended:

$$w_{ij} = \frac{|N(i) \cap N(j)|}{\sqrt{|N(i)||N(j)|}}$$

In distributed intelligent recommendation algorithms, although the recommendation object becomes an attribute value of a manufacturer’s product, the recommendation principle is the same.

In order to reduce the sparsity of enterprise data and facilitate the production of manufacturing enterprises, the properties of product configuration content are considered in the recommendation, and the configuration scheme of user products is decomposed into a set of attribute values [20, 21]. Assuming \( A_i \) represents an attribute that needs to be customized, in establishing an enterprise product customization, it is possible to specify the number of characteristics a product consists of and their set value range. The \( a_{ij} \) is utilized to describe the attribute value of the \( j^{th} \) type of the \( i^{th} \) custom attribute, and there are also differences in the range of values for different i and j.
4.2. Measuring the Interests of Target Users in Manufacturing Enterprises. Considering how closely related the gathered attribute values are, the product attribute values of interest to the target users of the manufacturing enterprise are measured. In the article collaborative filtering algorithm, the interest of the enterprise target user $u$ in the item $j$ is calculated by using the following formula:

$$ P_{uj} = \sum_{i \in N(u) \cap S(j,K)} w_{ji} r_{ui} $$  \hspace{1cm} (3) $$

Equation (3) is also applied to the proposed distributed intelligent recommendation algorithms. Among them, $S(j,K)$ represents a set of $K$ attribute values with high similarity to enterprise product attribute value $j$. $N(u)$ represents a set of attribute values customized or interesting by manufacturing enterprise user $u$. $w_{ji}$ represents the similarity between attribute value $j$ and $i$ that can be calculated based on the similarity matrix between attribute values; and $r_{ui}$ represents the degree of interest of the user $u$ in item $i$. For data sets with implicit feedback, when the user $u$ behaves accordingly with an item $i$, then $r_{ui} = 1$.

4.3. Auxiliary Customization to Generate Recommended Results. Following the calculation of the user’s interest in the attribute values of the present attributes, the first $N$ attribute values of interest are recommended based on the user’s level

Table 1: Experimental configuration table.

<table>
<thead>
<tr>
<th>Environmental parameters</th>
<th>Server</th>
<th>General computer</th>
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<tbody>
<tr>
<td>CPU</td>
<td>Intel 4 Nuclear</td>
<td>AMD 4 core</td>
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<tr>
<td>RAM</td>
<td>64 GB</td>
<td>8 GB</td>
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<tr>
<td>Hard disk</td>
<td>1 TB SDD</td>
<td>500 GB machinery</td>
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<td>Operating system</td>
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<td>Database</td>
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Table 2: Comparison of recommended accuracy of different methods.

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Figure 5: Reliability comparison of different recommended methods.

Table 3: Comparison of the recommended time for different methods.

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of interest in various attribute values \( P \). Measuring the similarity and distribution of item attribute values, enterprises can calculate the distribution of target users interest in attribute values to form a complete intelligent recommendation outcome, which is a custom solution set \( D_n \). This scenario set is specifically formed by the combination of different attribute customization results. On the basis of receiving each recommended result, the user completes attribute customization [22, 23]. Figure 4 shows the specific flow of the distributed intelligent recommendation algorithm. Based on the recommendation results, the digitized transformation path of manufacturing enterprises based on the IoT and data encryption technology is completed.

5. Experimental Result

In order to prove the validity of the research on the digital path of manufacturing enterprises based on IoT and data encryption technology, this paper conducts simulation experiments. This experimental platform contains five nodes, one server, and four general computers. Table 1 is the experimental configuration table.

The accuracy of recommendation based on distributed intelligent recommendation algorithm proposed in this paper is compared with that in references [5, 6] through five experiments, which is represented by Table 2.

From the analysis of Table 2, we can see that the overall recommendation accuracy of the methods mentioned in [5] has a small fluctuation and has been stable between 80% and 90%. The overall recommendation accuracy is higher. The overall recommendation accuracy of the methods mentioned in [6] has a large fluctuation, but at the highest time, it has not exceeded 80%. In the five experiments, the methods mentioned in this paper have been kept above 90% because distributed intelligent recommendation is used. Produce products based on attribute values of interest to users, thereby enhancing the overall competitiveness of the enterprise and enabling the manufacturing enterprise to complete the digital transformation. Figure 5 shows the method presented in this paper and the reliability comparison of the methods in [5, 6].

Analysis of Figure 5 shows that the recommendation reliability based on distributed intelligent recommendation algorithm proposed in this paper has been stable at over 90% when recommending product attributes, reaching 98% in the fifth experiment. Although the reliability of the method proposed in the literature [5] may reach 80% in the first experiment, the reliability of the recommendation gradually
decreases with the increase of the number of experiments. Although the overall stability of the method proposed in the literature [6] is good, the reliability of the recommendation is only 40%, which shows that the method mentioned in this paper can ensure the reliability of the product attributes recommendation of manufacturing enterprises. Table 3 shows the method proposed in this paper and the recommended time comparison between the methods in [5, 6].

As can be seen from Figure 6, in the five experiments, the average recommendation time of the methods proposed in this paper is 14.6 s; the average recommendation time of the methods mentioned in [5] is 26.2 s; and the average recommendation time of the methods mentioned in [6] is 41 s. It is concluded that the proposed methods can effectively improve the efficiency of product recommendation, thus speeding up the transformation of manufacturing enterprises to digital as shown in Figure 7.

Figures 8 and 9 show the overall performance comparison between the digital transformation service system and the traditional system for manufacturing enterprises with the internet of things and data encryption technologies mentioned in this paper.

From the comparison of Figures 8 and 9, it can be seen that in several experiments, the overall performance of the traditional digital transformation service system of manufacturing enterprises is not up to 50%. However, the overall performance of the digital transformation service system of manufacturing enterprises based on IoT and data encryption technology mentioned in this paper is significantly better, which is above 70%. This is due to the employment of data encryption technologies and the IoT. An important way to effectively enhance the competitiveness of the manufacturing enterprise market and achieve high-quality development.

6. Conclusion

With the gradual advancement and integration of informatization and industrialization, digital transformation has become the key strategy of manufacturing enterprises in each country. Chinese manufacturing companies are concentrating their efforts on figuring out how to become digital under the presumption of their own development. Digital transformation is a long-term development process, and it is impossible to succeed in one go. At present, manufacturing enterprises are in an environment of high-speed development of IT. The level of an enterprise’s own IT is especially important for the development of digitized transformation. Studying the digitized transformation path of manufacturing enterprises based on the IoT and data encryption technology is of great significance to the successful progress of the digitized transformation of manufacturing enterprises on the basis of the development of information technology. Therefore, in this study, a digital transformation service system for manufacturing enterprises based on IoT and data encryption technology is built, and the overall structure and functional structure of the service system are described in detail. Apart from this, we also proposed a distributed intelligent recommendation method based on customization and analyzed the specific path of digitized transformation of manufacturing enterprises. Our proposed method is of great significance as its overall accuracy is greater compared to the
existing methods. In addition, the average recommendation time of the proposed system is also the lowest among the present approaches, which shows the significance of the proposed system.

**Data Availability**

All the data are included within the article.

**Conflicts of Interest**

The author declares that there are no conflicts of interest.

**References**


