Design of a smart after-service system for sugarcane harvesters based on product lifecycle

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ABSTRACT. *To overcome the current defects in the after-service of sugarcane harvesters in China (e.g. lack of support, poor quality, low reliability and production delay), this paper creates a smart after-service system for sugarcane harvesters through smart service design, in light of the features and theories on product lifecycle. The mobile Internet and big data technologies were integrated into the system design. Firstly, the behaviors of service provider and recipient in the after-service were discussed, and the service requirements were analyzed in details. On this basis, a service model was established through user-centered design. Finally, a smart after-service system was set up for the maintenance, remote failure diagnosis, quick service response, failure detection and iterative optimization of sugarcane harvesters. The system sheds new light on the daily conservation and convenient maintenance of the agricultural equipment, and the collected failure and repair data lay a solid basis for improving the key parts in the equipment.*

RÉSUMÉ. *Afin de surmonter les défauts actuels du service après-vente des machines de découpe de canne à sucre en Chine (manque d'assistance, qualité médiocre, fiabilité assez faible, retard dans la production, etc.), cet article crée un système intelligent de service après-vente pour les machines de découpe par une conception de service intelligente en vertu des caractéristiques et des théories sur le cycle de vie du produit. Les technologies d'Internet mobile et des données massives ont été intégrées à la conception du système. Tout d'abord, les comportements du fournisseur et du destinataire de services dans le service après-vente ont été discutés, et les exigences de service ont été analysées en détail. Dans ce contexte, un modèle de service a été établi selon une conception centrée sur l'utilisateur. Enfin, un système intelligent de service après-vente a été mis en place pour la maintenance, le diagnostic de défaillance à distance, la réponse rapide au service, la détection de défaillance et l'optimisation itérative des machines de découpe de canne à sucre. Le système apporte un nouvel éclairage sur la conservation quotidienne et la maintenance pratique d'équipement agricole, et les données de défaillance et de réparation collectées constituent une base solide pour améliorer les composants clés d'équipement.*

KEYWORDS: *sugarcane harvester, service design, product lifecycle, after-service system.*

MOTS-CLÉS: machines de découpe de canne à sucre, conception du service, cycle de vie du produit, système de service après-vente.

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1. Introduction

The application of smart agricultural equipment is a notable mark of highly networked and intelligent modern agriculture, in that it greatly enhances the efficiency and reduces the labor intensity of traditional farming. With smart agricultural equipment, farmers can receive necessary agricultural information and services right at home. Recent years has seen a major shift in farmers' demand on agricultural equipment. Traditionally, farmers looked forward to replacing manual labor with specialized machines. Nowadays, high-quality and differentiated services have become the key to the popularity of agricultural equipment among farmers, owing to the growing similarity in functions between machines produced by different manufacturers.

Unlike their counterparts in developed countries, most Chinese farmers cannot afford to buy medium or large agricultural equipment on their own, or acquire the operation and maintenance skills of agricultural machines conveniently. At present, there are two ways for common Chinese farmers to access agricultural equipment services: (1) forming small cooperatives to jointly purchase agricultural equipment and share related services; (2) purchasing agricultural equipment services from manufacturers or special service providers. In this way, the farmers can save lots of maintenance cost, avoid the problems caused by their poor skills and achieve smooth operation in the short harvest season, while the manufacturers can win the trust of farmers and enhance market competitiveness through the provision of efficient and convenient services.

During the services, the data on the agricultural equipment can be acquired in a timely and accurate manner, laying the basis for quality improvement and innovation. For the agricultural equipment industry, the production resources should be allocated rationally according to the service demand, and the waste parts should be maintained and recycled efficiently. This calls for the service design based on the lifecycle of agricultural equipment. Therefore, this paper designs an Internet-based smart after-service system for sugarcane harvesters according to the theories of smart service design and product lifecycle. The proposed system enables its manufacturer to monitor product quality, detect failures and defects, and optimize the product and services. Thus, the system offers a viable solution to the biggest problem in the current use of agricultural equipment: the production delay resulted from mechanical failure.

Rather than the entire process of agricultural equipment services, our system only focuses on after-services like quality tracking, maintenance and conservation. This is because individual Chinese farmers tend to buy related services instead of agricultural equipment, some of whom may work as full-time providers of such services, while cooperatives are the main purchasers of agricultural equipment.

Hence, the proposed after-service system mainly targets the individual operators of the cooperatives engaged in harvest activities.

2. Theoretical framework

2.1. Smart service design of agricultural equipment

With the proliferation of smart Internet technology, some scholars have explored agricultural equipment services from the angle of smart Internet technology. For instance, Chen *et al.* (2002) studied the agricultural information service based on mobile devices. Yu *et al.* (2006) designed a distributed, mobile smart expert system, shedding new light on agricultural diagnosis. Song *et al.* (2010) built a common knowledge database of chicken flocks and developed an aided diagnosis system based on the smart phone platform. These systems are the firstlings of the smart system design in China's agricultural equipment services. Nowadays, the popularity of user-centric design and smart information technology has propelled the smart service design of agricultural equipment, which includes expert diagnosis, information supply and smart decision-making.

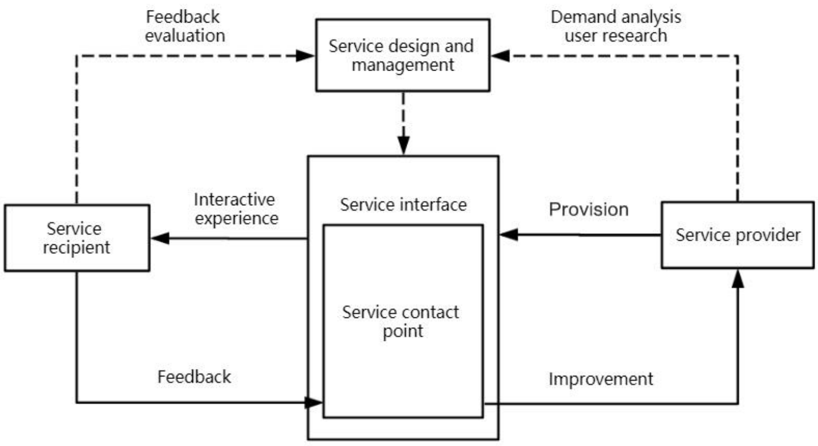

Figure 1. Service design process between service recipient and provider

Smart service design integrates theories on planning, management, identity, branding, and marketing into an organic whole. This approach can improve service usability and reliability, enhance customer satisfaction and loyalty, and ultimately create values to customer, service provider, and the entire agricultural industry (Zhou *et al.*, 2012). By the specific method, smart service design falls into two categories: creative service design and user-centered service design. The former is forward-looking, creative and unpredictable, but may be risky. app le is a strong advocate of creative service design, producing unique products that lead the market trend. Considering the high requirements and potential risks of creative service design, most of manufacturers prefer to adopt user-centered service design: the experience and quality of the existing products are improved constantly according to the potential needs of the users, so that the final products can fully satisfy customer demand and earn a huge sum of profits.

The general process of service design is illustrated in Figure 1 above. It can be seen that the service provider should analyze user demand through market analysis and user research, and put forward the service design and management model in light of the demand. Then, the service provider needs to communicate with the recipient via the service contact point on the service interface. The recipient will provide feedbacks on the service conditions. The subsequent services should be adjusted as per the feedbacks. In this way, a smart service system will be created, featuring high efficiency and perfection.

With the aid of smart mobile devices (e.g. smart phone, pad and laptop), the smart service system can provide users with accurate and fast services, and collect and evaluate feedback information as soon as possible. The system fits in well with the purposes of service: the service provider obtains profits or product information, while the recipient enjoys the knowledge and skills of the provider. Through the smart service design, it is possible to fully rationalize the resource allocate and create the maximal values for service participants (Vargo *et al.*, 2008).

Communication barriers are ubiquitous in the provision of sugarcane harvester services. The communication among manufacturer, maintenance station, operator and user is severely lacking, especially on service provision and management. For example, the manufacturer does not know if the maintenance personnel actually provide the service quality needed by farmers. Neither does it receive the farmers' true feelings or evaluation of the service. This information asymmetry cannot be solved by traditional after-service modes like telephone support or door-to-door service. The telephone support only solves simple problems and the door-to-door service is impossible in the busy harvest season.

Against this backdrop, it is very meaningful to resort to the information planning and guidance of smart service system. With such a system, common service problems can be solved under text, image or video guidance after the basic troubleshooting. If a problem is too complex to be solved by distance assistance, several maintenance points will be recommended to the user, which will dispatch personnel quickly to identify the abnormalities. The whole service process will be recorded for archive.

Many scholars have attempted to integrate the service design into the after-service of agricultural equipment. For instance, Ren created an agricultural information service system called the Agricore through service design, improved its availability through user research, existing system analysis and interface design, verified its applicability to target users and constructed an agricultural information database. Wan (2012) set up a problem-solving agricultural knowledge service system, which consists of knowledge warehouse, service platform and diagnosis and push entity, offering a new solution to the integration and communication of agricultural information.

Sun (2015) adopted a preventive maintenance strategy according to the features and failure modes of agricultural equipment, classified the spare parts through analytical hierarchy process (AHP) and activity-based classification, and developed an inventory management system for spare parts, shedding new light on maintenance demand prediction and spare parts inventory optimization. Liu (2004) put forward a product after-service system based on web and mobile devices, which provides rapid and efficient solutions to failure tolerance/diagnosis, pre-sale service, on-site service, dispatching, maintenance, retailing, etc.

Liu (2017) proposed a cheap and efficient after-service model of agricultural equipment based on smart phones; the following functions were integrated into the model: online customer service, failure reporting, after-service network search, accessories search, equipment maintenance, one button SOS, new product information and contact information. Lee *et al.* (2007; 2014) developed a bellwether system named Watchdog Agent capable of smart product and system monitoring, acquiring product degeneration information, forecasting service quality, managing product lifecycle, optimizing performance and even achieving self-maintenance.

To facilitate inventory management and system diagnosis, Pao *et al.* (2011) designed a smart mobile terminal for product lifecycle conservation and network management. Relying on smart phones, the terminal offers a novel interface that displays the location parameters of agricultural equipment and improves the user experience of the return material authorization (RMA) system. Joshi *et al.* (2010) described the next generation of Internet technology (IT) services as: the service delivery will be discovered, adopted, and combined with a technical environment through service management, monitoring, inspection, and the whole application process of smart services will be user-centered.

To sum up, the smart service system for agricultural equipment should be user-centered, with the agricultural equipment as the information carrier. The modern IT should be integrated into the research and development (R&D), utilization and after-service of agricultural equipment, while the Internet Plus technology should be adopted to implement networked R&D, intelligence manufacturing and real-time service. The resulting smart service system will promote the development of a green industrial chain of smart agricultural equipment, and provide various agricultural services, ranging from disease diagnosis to online maintenance. However, the existing studied mainly emphasize on facilitating the provision of agricultural equipment service to users with Internet technologies, failing to consider the information needed by the manufacturer for product improvement. To make up for the gap, this paper designs a smart after-service system for sugarcane harvesters, aiming to provide users with timely and efficient services and help the manufacturer to collect the information for product improvement.

2.2. Product lifecycle-based solution to smart service system

In this paper, the product lifecycle refers to the whole process of the agricultural equipment, from demand analysis, R&D, production, transport, after-service and recycling. All these processes should be considered in the design based on product lifecycle, while ensuring the product function, greenness and economic efficiency. Our sugarcane harvester after-service process was optimized under the principles of product lifecycle theory: systematization, parallelization and integration. As shown in Figure 2, the sugarcane harvester is produced and maintained considering the entire lifecycle from the recovery of old products to the improvement of new products. For example, a spare parts warehouse is set up at the maintenance point, such that the required parts can be delivered in time, which reduces the service time and improves the efficiency. The location and storage of each maintenance point are determined according to the collected service information. The excellent parts provision mechanism ensures the service efficiency and accuracy, attracting more and more farmers to sugarcane harvester services.

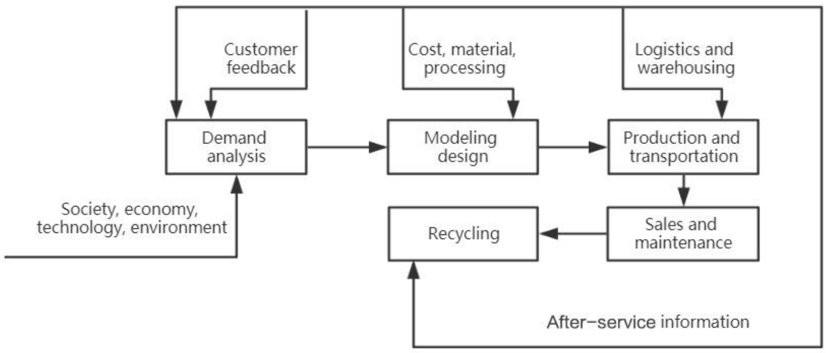

Figure 2. Function of after service in product lifecycle

As a product service system (PSS), the smart after-service system allows the manufacturer to provide services while selling products through continuous optimization of products and services according to the user demand. Our system serves as an integrated platform for the manufacturer to sell sugarcane harvesters and provide fast after-services. The platform integrates the discrete service resources and information into the product lifecycle, enabling systematical innovation in service mode, user consumption mode and working mode. As a result, the resources and services can be utilized more efficiently through the product lifecycle, living up to the spirit of sustainable development (Liu, 2015).

The thorough understanding of produce lifecycle and the product-service relationship helps to clarify the demand in each stage and highlight the room for improvement. Hence, the obstacles and problems in the service system may be identified in advanced and solved in time. The product lifecycle analysis lays the foundation of service system design. On the one hand, the elements extracted from product lifecycle make it easier to check the key links of the service system and implement the system reliably and satisfactorily. On the other hand, the product lifecycle analysis clarifies the service process and framework, so that the manufacturer can achieve life cycle management and optimize the after-service using the existing technical solutions (Takata *et al.*, 2004).

The lifecycle elements, including but not limited to production condition, processing mode and user experience, can be extracted from four aspects: the manufacturer, the product, the user and the environment. These elements can be categorized into three groups to promote service design, namely, demand, decision and evaluation. After replacing the traditional after-service with the smart service system, the manufacturer can improve the level of differentiated service through smart analysis of demand and intelligent provision of services, and eventually enhance the service system and product quality based on the timely feedbacks. In fact, the efficiency and speed of feedback reception is a prominent advantage of the smart service system, which alleviates the technical and capital pressures and overcomes function constraints and resource waste.

The design of smart after-service system reflects the philosophy of the design for service (DFS), a typical case of design for excellence (DFX), a.k.a. the design for all stages of product lifecycle. A smart after-service system usually supports smart failure diagnosis, smart technical training, smart technical consulting, smart spare parts selection, smart service reservation and smart information inquiry. For example, Reference (Hu *et al.*, 2010) establishes a product maintenance framework that can intelligently classify the parts and management the evolution product structure in the maintenance process.

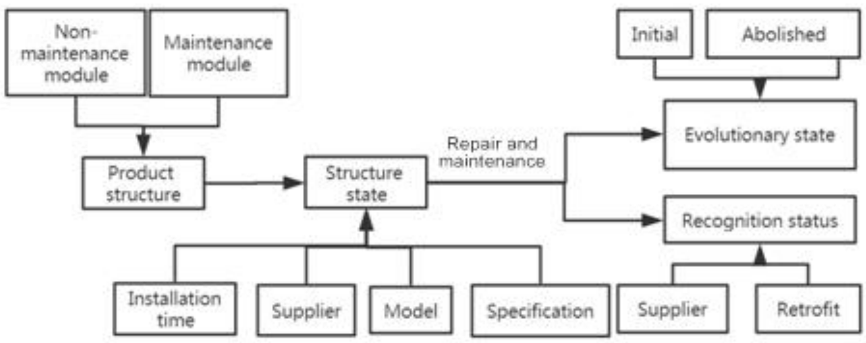

Figure 3. Evolution of product structure during the maintenance process

As shown in Figure 3, the repair and maintenance states of a product are recorded to form a whole picture on the evolution of the product structure, that is, a main record on the parts to be maintained. The product should be maintained in the evolution state and the identification state. Thus, the structure of the maintained product can be known in real time and traced back in subsequent maintenance or production.

The product lifecycle analysis and the smart after-service system supplement each other. The analysis results can guide the design of the system, while the feedbacks collected by the system can promote the product improvement. The system can be gradually optimized along with the product, forming a virtuous cycle. Obviously, the product lifecycle-based design of the smart after-service system can maximize the economy and competitiveness of the sugarcane harvester, minimize the negative environmental impacts, and promote the harmony between man, machine and nature.

3. System design

Our human-oriented smart after-service system was designed through the demand analysis of farmers, operators and other participants in sugarcane harvesting, and built on the Internet technology and mobile application, with the goal to promote user participation. Specifically, the entire operation process of the sugarcane harvester was investigated before establishing the information structure and function flow of the system. After that, the author completed the related design tasks, such as prototype design, user interface design and visual design, and tested the system online. The system was then applied to the after-service of sugarcane harvester. After a period of time, some data were collected and some feedbacks were returned from the users, who can leave comments and give advices on the harvester, the system and the related services through the feedback module. These data were used to improve the design of the harvester and its parts, aiming to improve user experience. When a failure is detected on the harvester, the system will look up the background information immediately, and recommend the tutorials, purchases, door-to-door maintenance or other services. In addition, there is also a daily conservation module for the operator to check and learn basic conservation knowledge. A reminder function was also provided to facilitate the regular conservation and eliminate the potential failure.

3.1. Operation and maintenance process of sugarcane harvester

Our system targets the 4GZQ-260 sugarcane harvester designed by Guangxi Agricultural Equipment Institute. The harvester consists of eight basic components: lifting guard, tip cutter, cutter, conveyor roller, cutting roller, first-stage impurity separator, elevator and second-stage impurity separator. These components can be classified into six function modules: lifting module, tip cutting module, sugarcane cutting module, unit cutting module, impurity separation module and unloading module.

The harvester operation generally covers the following processes. Firstly, the operator should check the working environment and place the key components to the right positions. Secondly, the operator should start the harvester and test its normal walking function. Thirdly, the operator should inspect the states of the entire harvester and its key components, restore them to the right condition, harvest sugarcanes with the harvester and shut down it after the harvesting operation. Fourthly, the operator should clean the harvester after completing the operation. Fifthly, the operator should check the quality of the harvest and inspect the vulnerable parts of the harvester after cleaning. Finally, the operator should maintain the harvester and make proper adjustments.

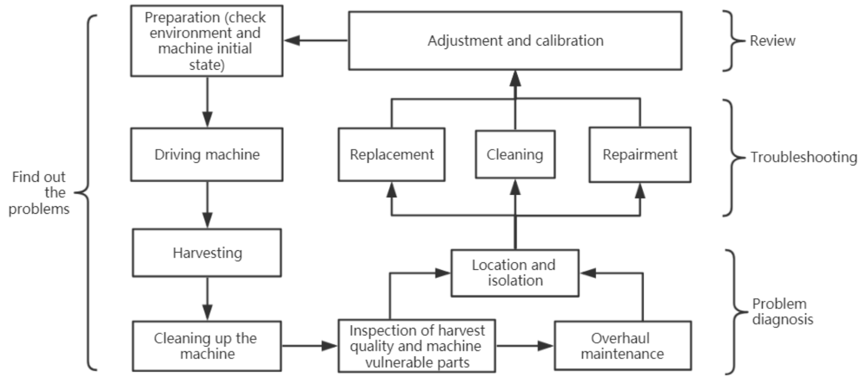

Figure 4. The typical maintenance process of sugarcane harvester

As shown in Figure 4, the typical maintenance process of sugarcane harvester was summarized as follows based on the said operation procedure.

(1) Information research: The failure information of sugarcane harvester consists of the background information and the user-related information. The former includes the failure time, purchase time, failure location and harvester state at the failure (routine maintenance, walking or operation), while the latter covers the age, driving age and maintenance knowledge.

(2) Problem diagnosis: The problems are often diagnosed preliminarily by the operator alone, with the aid of product handbook. However, many failures or abnormalities have multiple causes, which cannot be effectively identified by the operator. If the problems are not solved timely, the operator and the harvester will face potential danger.

(3) Troubleshooting: In good cases, the operator can handle the problems alone through maintenance and adjustment. If no spare part is available, the operator has to contact the after-service for help. However, the nearby maintenance point might not have some special or rare parts in its storage. In this case, the operator needs to

contact the manufacturer to deliver the necessary parts. The repair and replacement are extremely time-consuming, causing delay to the short harvest time. If everything goes smoothly, the operator can troubleshoot the problems alone, ask the after-service to solve the problems or bring the failed parts to the nearby maintenance point for repair.

(4) Verification: The function of the repaired and replaced parts will be tested to ensure that the harvester can work normally and enter into service as soon as possible.

The above analysis shows that there is no standard solution to the after-service of sugarcane harvester, and that the existing maintenance process cannot record or evaluate the failure states of the harvester and its vulnerable parts in a timely manner. In addition, the operator may be able to solve most failures under the guidance and assistance of the manufacturer, professional help is necessary throughout the troubleshooting process due to the lack of knowledge or spare parts.

Considering the above, the proposed smart after-service system includes the recommendation and guidance functions, enabling the operator to complete the general maintenance and access professional assistance if he/she cannot solve the problems alone. These functions also make it possible for the operator to receive online instructions from the manufacturer on parts replacement or on-site maintenance by special service personnel.

3.2. Smart after-service model

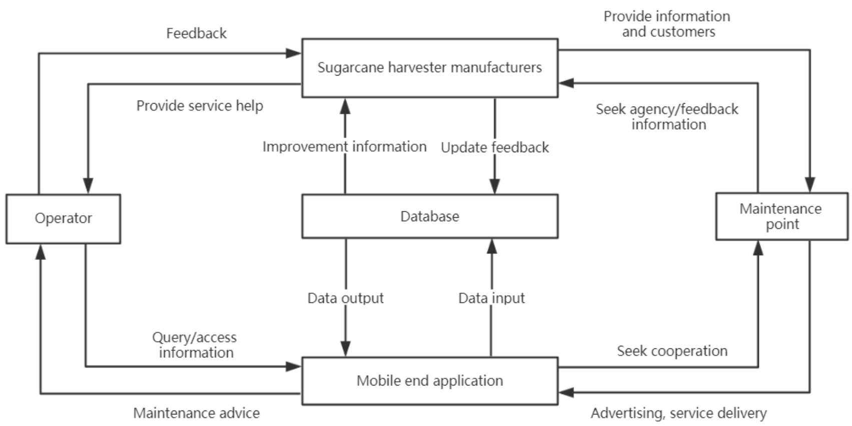

Figure 5. Smart after-service model

The after-service efficiency is now restricted by two factors. The internal factor lies in the defects of sugarcane harvesters, such as potential mechanical problems and imperfect parts quality, while the external factor is about the operating environment, land condition, operator skill, and many other issues. Considering these constraints, the author put forward a smart after-service model for sugarcane harvesters (Figure 5).

As shown in Figure 5, the proposed smart after-service model involves the following participants: sugarcane harvester operator (the target user), maintenance point (the main service provider) and sugarcane harvester manufacturer (the terminal of service). The model works in the following manner: the operator diagnoses and identifies the mechanical failures with the model; the operator obtains consultation and technical supports from the service providers recommended by the manufacturer through the model; the operator queries for and reserves door-to-door support through the system to solve the problems; all troubleshooting records are collected by the system into a database; the database information is returned to the manufacturer to create reports and feedbacks, laying the basis for product improvement.

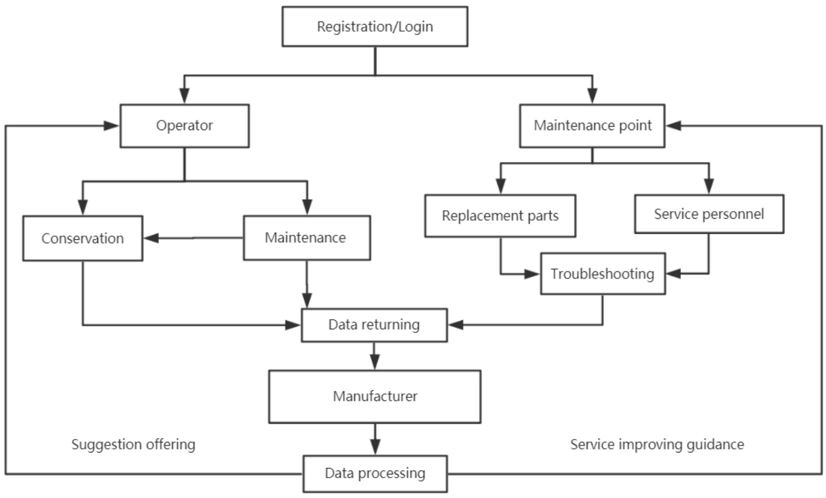

Figure 6. Service modules for different participants

The system contains different service modules designed for the operator, the maintenance point and the manufacturer. It can be seen from Figure 6 that the operator is provided with guidance services of maintenance and conservation, the maintenance point with the supply service of spare parts and real-time response and the guidance services of staff training, and the manufacturer with sufficient spare parts inventory, technical support, data collection and analysis, and product improvement.

Figure 7 presents two main functions of the smart after-service system: maintenance and conservation. The work flow of each function is described briefly below.

(1) Maintenance

Step 1: The background information of the user is collected and subjected to big data analysis, providing reference for subsequent steps.

Step 2: The failures are diagnosed preliminarily by the user using the system's failure screening function.

Step 3: The historical and common maintenance information is provided by the system for reference.

Step 4: The user is provided with image, video and other forms of instructions on troubleshooting, and, if necessary, given suggestions on spare parts support or assistance from nearby maintenance points.

Step 5: The sugarcane harvester problem is solved.

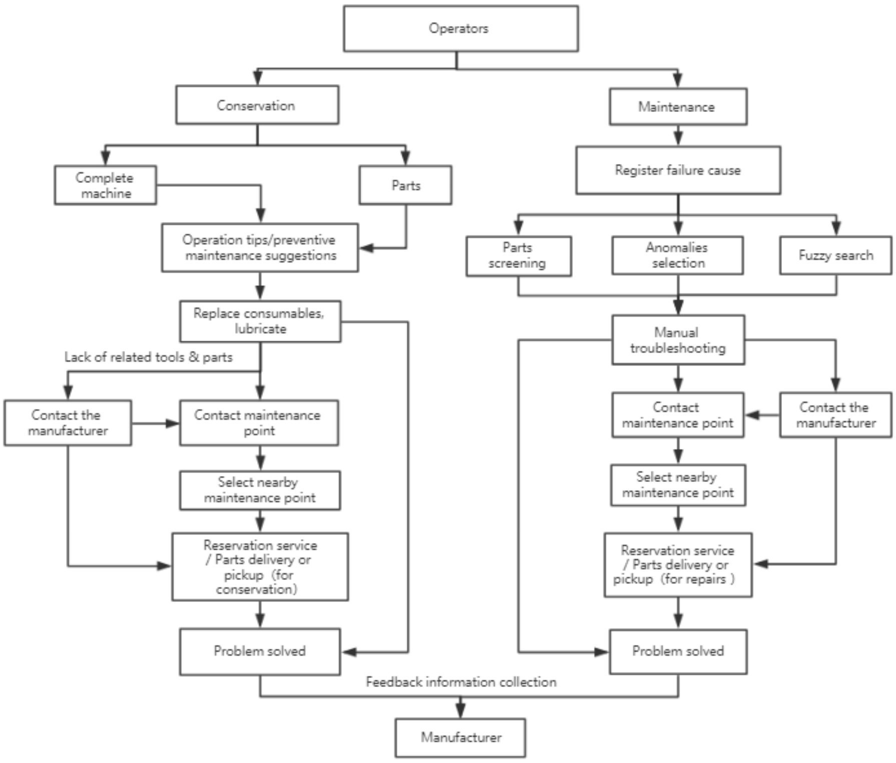

Figure 7. The maintenance and the conservation processes of the system

The above steps are recorded by the system backstage, together with the data on maintenance. During the process, the user can make a fuzzy search on the problem at any time or directly contact the after-service personnel.

(2) Conservation

Step 1: A personalized plan containing various conservation tips is generated in light of the historical maintenance records, as well as the user's operation habits.

Step 2: The conservation tips for vulnerable parts are given to the user, making them the focal points of each maintenance.

Step 3: The failure prevention measures for such parts are generated through big data technology and pushed to the user in the related area, aiming to reduce failure and accelerate repair.

3.3. Mobile terminal APP

Through modelling and questionnaire survey, the author created an app of the smart after-service system for mobile terminals. The functional framework of the app is illustrated as Figure 8 below.

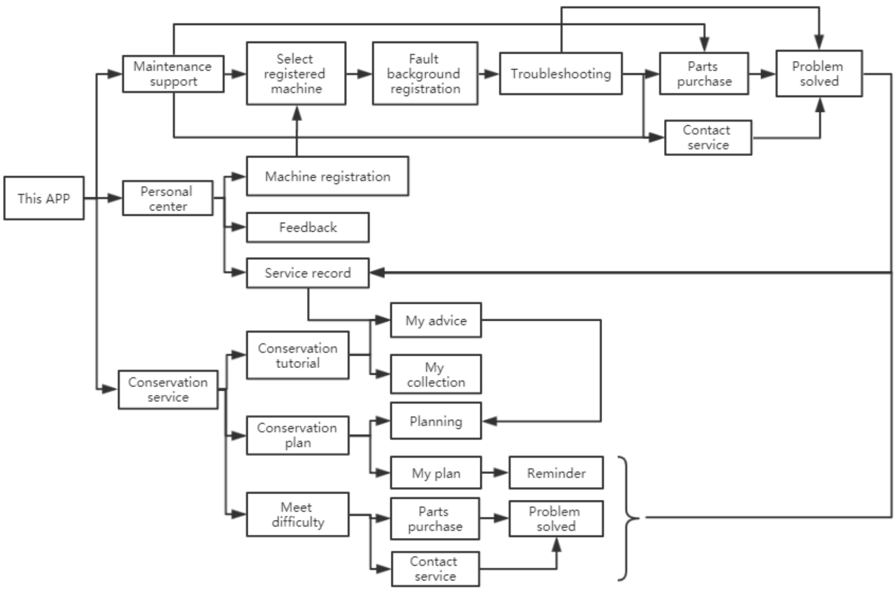

Figure 8. The functional framework of the smart after-service APP

Next, storyboard, customer journey map and service blueprint were introduced to improve the working mode and process of the app, according to the basic theories on service design, and the interaction and other user experience was refined in light of the functional requirements on the app for mobile terminal operation. The goal is enabling the manufacturer to collect failure data of different parts during service provision, and to improve the harvester through data analysis and processing. The final version of the app is presented as Figure 9 below.

Figure 9. The main interfaces of the smart after-service APP

As shown in Figure 9, the app lies the potential failure factors of the harvester, which are provided by the manufacturer. Once a potential factor is clicked, the system will display the corresponding self-checking and troubleshooting solutions. When the operator uses the app for the first time, he/she needs to input phone number and the basic data on the sugarcane harvester. If any trouble emerges in the harvester operation, the operator can confirm in the system that the equipment has failed and fill out the background conditions. Then, the failure can be screen preliminarily by personal experience, and mitigated using the solutions provided by the system. Should troubleshooting fail, the operator can contact the nearby maintenance point or the manufacturer for help, such as purchase maintenance services or reserve door-to-door repair. In this way, the harvester failures can be solved in time, eliminating problems caused by mis-operating or overusing. After the problem is solved, the record on the entire process will be sent to the manufacturer, and the operator will be given new suggestions on maintenance.

3.4. Data collection and feedbacks

To verify the effectiveness of our smart after-service system, the app was tested with the help from 28 harvest service teams and Guangxi Agricultural Equipment Institute. Before the test, all service teams downloaded and familiarized them with the interfaces and basic processes of the app. Then, these teams used the app in the sugarcane harvest season. The operators were asked to troubleshoot as many failures as possible through the app, and to fill in details on the failure information. According to the product lifecycle theory, the maintenance data on different parts and modules were recorded through the test and integrated by the efficient and convenient classification method. Next, the different parts and modules were evaluated comprehensively. On this basis, the services like inventory and supply were optimized and the improvement opinions were put forward for the design. A series of maintenance records were prepared by the system, forming an after-service database, which is a solid guarantee for subsequent data storage and analysis. With the elapse of time, the data will have a growing statistical significance.

Table 1. After-service database

Type	Item	Information			
Personal information	Name	Zhang Lilong			
	Phone number	1XXXXXXXXXX			
	Driving age	1.5 years			
Failure information	Agricultural equipment	Manufacturer	Model	Date of manufacture	Others
	Equipment 1	Guangxi Agricultural Equipment Institute	4GZQ-260	2017.9	/
	Background	Failure location	Failure time	Work status	Others
		Liu Dong New District, Liuzhou, Guangxi Autonomous Region	20171125 morning	After work	/
	Troubleshooting	Manual troubleshooting			

	method				
	Failed parts	Cutter blade			
		Number	Material	Technology	Others
		2	/	/	/
	Failure Phenomenon	Rupture of cane root			
	Cause	Knife damage			
	Solution	Replace the cutter			
	Service delivery	Agricultural equipment service station			
		Production cost	Test results	Recycling	Evaluation
		/	Overwork	Non-recovery value	Satisfactory
…	…	…	…		

The contents of Table 1 show that the data generated by the app fall into three categories: information, failure information and maintenance information.

(1) Personal information

The personal information is inputted by the operator during the first use of the app. The user name and phone number are required to ensure the rapid contact of the operator. The driving age helps to evaluate the operator's driving proficiency and troubleshooting ability. The smart after-service system can improve the accuracy of its services to the operator, after analyzing the relationship between the long-term maintenance data and the driving age. In addition, the basic information of the agricultural equipment is needed so that the manufacturer can know about the usage information and batch failure rate.

(2) Failure information

The background information like the time, place and harvester working status of the failure is collected to disclose the effects of environmental conditions on the harvester. After long-term data accumulation, the users in different conditions can be provided with proper and timely services under the guidance of big data technology. As more and more data are collected, the app will accurately associate the failed parts with the corresponding solutions, and make accurate maintenance recommendations to the operator. The failure data acquisition is directly invoked by the manufacturer in the background and displayed clearly in the failure information table. The data will be considered to improve the existing parts or design new products. Furthermore, the failure phenomena and causes are also recorded and correlated with the service solutions. Based on the historical data, the app will recommend the service solution that matches the current failure phenomenon. The service provision information is also collected to analyze the failure cause and to improve harvester use and production.

(3) Maintenance information

Table 2. An example of failure screening and data collection process

Page theme	Screening of failure phenomena	Identification of failed part	Screening of failure causes	Maintenance tips	User operations	Evaluation feedbacks
Page content	1.High breaking rate of sugarcane roots; 2. Sugarcane roots being pulled up; 3. Torn sugarcane incision.	The cutter	1.The cutting blades are blunt, notched or bent.	Sharpen the blades.	A) Complete. B) View text or video tutorials. C)Buy new blades.	1. The problem is solved perfectly. 2. The problem is solved partly. 3. The problem is not solved.
			2.The sharp corners of the cutting blade are worn.	Replace the blades.		
			3.The length of cutting blades is not suitable.	Adjust the length of blades.		
			4.The cutting blades have shift phenomenon.	Reset blades		
			5.The bolts have come loose.	Fasten the bolts.	A) Complete. C) Purchase accessories.	
			6.The cutterheads are bent or worn.	Contact the service personnel.	A) Complete F) Contact service personnel.	
			7. The gear box blowholes are clogged.	Dredge the blowholes or contact service personnel.		
			8. The hydraulic line and/or components are damaged or leaked.	Contact the service personnel.		
Backstage record (brief)	01	CUT	02		C	1

The failed parts will be pushed to the operator several times after being repaired, reminding him/her that these are vulnerable parts. The system will also provide the operator with the conservation tips against the common failures reported by other operators.

The details on the failure data were not listed because any data on the criticality and possibility of failure causes are confidential to the manufacturer. Through the test by 28 harvest teams, it is confirmed that the smart after-service system can collect relevant data satisfactorily and support the maintenance services through the sugarcane harvest period. The smart maintenance and conservation measures can be further optimized in the following harvest seasons. After long-term accumulation, the collected data will allow the manufacture to provide better products and services.

4. Conclusions

After the review of relevant literature on product lifecycle and smart service design, this paper investigates the requirements of the three major participants, namely, operator, maintenance point and manufacturer, in the lifecycle of sugarcane harvesters through questionnaire survey. On this basis, the author designed a smart after-service system for sugarcane harvesters and developed an app of the system, with the aim to solve the problems satisfactorily in the sugarcane harvest period. The system collects and analyzes the data on the failed parts, common failures and related working and environmental conditions, and then provides the operator with maintenance and conservation tips in real time. Besides, the operator will be offered a daily maintenance plan, which is prepared by the system considering the historical failure data of the sugarcane harvester, as well as the internal and external factors. The effectiveness of the app was proved through a test on 28 harvest teams. The test results show that the proposed system provides a good reference for the design and improvement of sugarcane harvesters. The future research will explore the agricultural equipment after-service for ordinary farmers, and try to integrate whole-process services into the service system.

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