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Design of greenhouse four seasons pear pollination UAV based on AHP _ QFD _ TRIZ integrated theory

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Abstract

In order to solve the problem of insufficient pollination caused by the closed internal environment of greenhouse and the lack of natural pollination media, improve the traditional pollination work,expand its use function, and meet the diversified needs of contemporary people, a greenhouse four-season pear polli-nation UAV was designed. The research interview method was used to summa-rize the user demand categories, and the AHP analytic hierarchy process was used to calculate the weight of each user demand. Using QFD quality function deployment to transform user needs into technical needs, and then get conflicts; through the separation principle and contradiction matrix of TRIZ innovation theory, the best method to solve the technical and physical contradictions is found out in 40 invention principles, and the ideal scheme is finally obtained. By integrating AHP, QFD, TRIZ and other theoretical models, it is put into the de-sign and development process of pollination UAV, and a greenhouse four-season pear pollination UAV is designed, which further verifies the scientificity and ra-tionality of the design process. The design process can provide reference for product design and development.

Keywords

AHP; QFD; TRIZ; Greenhouse Four Seasons Pear Pollination UAV; Product design

1. Introduction

In recent years, with the rapid development of technology, four season cultivation of pears in greenhouses has become a new cultivation technique in the production process of pear trees in China. Compared with outdoor cultivation, greenhouse cultivation can significantly advance the maturity period, control the climate, reduce the impact of pests and diseases, and improve single plant yield. At the same time, the application and development of agricultural drone technology have been rapid, providing tremendous assistance for crop pollination in agricultural production. Agricultural drones have the advantages of simple structure, low cost, and convenient operation. They are mainly used for crop protection and ground remote sensing in agricultural production, and can complete crop pollination operations, which has been widely applied in agricultural production. Agricultural drones can carry high-definition camera equipment to perform aerial photography tasks in the agricultural production process. Agricultural producers can use drones for low altitude aerial photography to timely obtain crop growth conditions, adjust agricultural production measures in a timely manner, ensure high and stable crop yields, improve fruit quality, reduce labor costs, and solve the pain points of manual and traditional bee pollination. In order to change the working and usage of traditional pollination drones and meet people's diverse needs, it is necessary to use models such as Analytic Hierarchy Process (AHP), Quality of Functional Deployment (QFD), and Theory of Invention Problem Solving (TRIZ) to construct the design process of pollination drones, accurately grasp human needs for design and development, and achieve innovation in the shape, structure, and function of year-round pear pollination drones in greenhouses. AHP can improve the accuracy and objectivity of user demand identification; QFD can provide theoretical basis for the product design process by connecting the technical requirements and user needs of the product; TRIZ has comprehensive problem-solving methods that can provide tools for solving problems encountered in engineering.

1.1. Research Background and Significance

The development of modern agricultural production technology is rapid, and greenhouse cultivation is widely used. Greenhouse cultivation plays an increasingly important role in today's agricultural production and cultivation. China's greenhouse cultivation area now ranks first in the world with 4.2 million square meters. Greenhouse cultivation of pears has become a new cultivation method for pear production in China. Compared with ordinary planting cultivation methods, this new cultivation method can greatly advance the maturity time of pear trees to meet market demand at different times and increase the economic benefits of producers. However, due to the isolation function of greenhouse from the external climate, there is a lack of natural pollination media in the greenhouse. Therefore, how to ensure pollination rate, improve yield and quality has become a major challenge faced by facility agriculture.

This article focuses on the study of unmanned aerial vehicles for pollination of Four Seasons pear in greenhouses. There are three main methods for pollination of Four Seasons pear flowers in greenhouses: artificial assisted pollination, liquid pollination, and bee pollination , as shown in Figure 1.

a. Artificial pollination b. Shake pollinator c. Bumblebee pollination

Figure 1. Pollination methods for greenhouse pear blossoms

Artificial assisted pollination refers to two methods: manual pollination and instrument spraying. This method adopts artificial assisted pollination when pear trees encounter serious natural disasters, which can remedy the impact of adverse environmental conditions on normal pollination of fruit trees, thereby ensuring fruit tree yield and quality. However, the labor cost of manual pollination is relatively high, and due to limitations in manpower, it is easy to cause damage to the flower buds during the pollination process, and the pollination effect cannot be guaranteed.

The oscillation pollination mainly relies on the vibration characteristics of the oscillation pollinator, which acts on the plant stem, causing the plant to shake, thus completing the pollination operation . Although this method can reduce the harm caused by pesticide residues, improper operation can easily cause damage to plants. At the same time, when using this method for pollination operations, manual operation is required, which increases labor intensity and reduces work efficiency.

As a type of natural pollination, bumblebee pollination visits an average of 13.3 flowers per minute . Although it greatly saves labor costs and creates additional income, and the efficiency of natural pollination is also higher than the above two pollination methods, bumblebees have poor moisture tolerance and strong phototaxis, making them less suitable for year-round pear pollination in greenhouses. During winter, bee colonies usually do not go out to collect honey, so they cannot use bumblebees for pollination.

In order to effectively solve the above problems, a method of using drones to complete pollination operations has been proposed, which has achieved good results in large-scale operations. Drone pollination mainly relies on its different spraying amounts to achieve the optimal spraying amount for flowers and complete pollination. Moreover, drones have the characteristics of small size, work not limited by seasons and regions, and high comprehensive efficiency, making it possible to apply drones to greenhouse pollination. Domestic and foreign scholars often use computational fluid dynamics to analyze aerodynamic parameters and design and optimize unmanned aerial vehicles in the structure of components such as wings and propellers, and have achieved certain research results .

1.2. Design Process of Four Seasons Pear Pollination Drone in Greenhouse

By conducting questionnaire surveys and in-depth interviews with workers and relevant experts involved in the pollination of Four Seasons pears in greenhouses, we collected the needs of users and experts for Four Seasons pear pollination drones, and selected, decomposed, and combined them to establish a hierarchical classification of target users' needs. We used the Analytic Hierarchy Process (AHP) to determine the weights of users' needs for pollination drones in various aspects; Import user demand weights into the QFD quality house model, determine the correlation between user demand weights and technical demand characteristics, calculate the importance of pollination drone technology demand, and mark the positive and negative correlations of various technical demand indicators on the roof of the quality house; Based on the importance ranking of technical features and conflicting technical indicators, using the separation principle and contradiction matrix of TRIZ innovation theory, the best principle is extracted from 40 invention principles to solve the problem, and the ideal solution is finally obtained. This design and development process has strong scientificity and logicality, allowing design and production activities to no longer be limited to external, surface, intuitive, and emotional levels, but to guide the development and design of contemporary products in a strongly correlated and logical way.

2. Research on User Demand for Four Seasons Pear Pollination Drones in Greenhouses

2.1. Expand user level requirements

Through user research and expert interviews, the Analytic Hierarchy Process (AHP) was used to summarize, organize, classify, and expand the user needs of unmanned aerial vehicles (UAVs) for pollinating pears in greenhouses throughout the four seasons. The research was divided into three levels: target level, indicator level, and plan level. The first layer (target layer) is the total demand A of users for pollination drones. The second layer (indicator layer) divides the user demand for pollination drones into indicators such as functionality B1, human-computer interaction B2, and safety B3. The third layer (solution layer) further subdivides the indicator layer into more specific requirements, as shown in Figure 2. Clarify the hierarchy of user needs for pollination drones and begin the next matrix analysis.

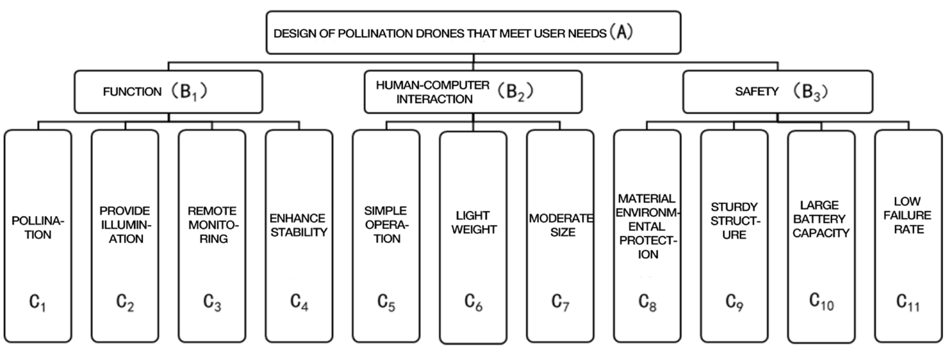

Figure 2. Expand the hierarchy of user needs

2.2. User demand weight

After constructing the hierarchy of user requirements, using the Analytic Hierarchy Process (AHP) to construct a user requirement judgment matrix can perform hierarchical processing and analysis on complex problems in multi-objective situations, and then verify the consistency of decision evaluation to further determine the weight of user requirements and reduce decision bias. The calculation steps are as follows.

Step 1: Build a judgment matrix. Firstly, invite 5 experts to rate the total demand A for unmanned aerial vehicles for year-round pear pollination in greenhouses, as well as the specific requirements of indicator layers $B_1 — B_4$, in pairs, and construct a judgment matrix.

Step 2: Use geometric and arithmetic mean methods to calculate the user demand weight W and the maximum eigenvalue λ_{MAX} of the judgment matrix, and perform a one-time test. Use CI to represent the consistency index and CR to represent the consistency ratio. The calculation method is as follows:

$$CI = \frac{\lambda_{MAX} - \mathrm{n}}{\mathrm{n} - 1} \qquad CR = \frac{CI}{RI} \tag{2-1}$$

Generally speaking, when the value CR <0.1, it meets the consistency test; If the consistency test is not passed, the judgment matrix needs to be reconstructed.

According to the above steps, the weight of the demand for the target layer in the indicator layer of the demand hierarchy of the greenhouse four season pear pollination drone users can be calculated and verified in one go, as shown in Table 1.

Table 1. Judgment matrix and weights for each indicator requirement (B_1 - B_3) at the target layer

A	B_1	B_2	B_3	W
B_1	1	5	2	0.5949
B_2	1/5	1	1/2	0.1285
B_3	1/2	2	1	0.2766

According to the matrix calculation, $CI = 0.0029$, $CR = 0.0056$ <0.1, Meet the consistency check.

Table 2. The judgment matrix and weight of each requirement element (C_1 - C_4) under function B_1

B_1	C_1	C_2	C_3	C_4	W_1
C_1	1	5	3	3	0.5317
C_2	1/5	1	1/2	1/2	0.1223
C_3	1/3	2	1	1	0.1856
C_4	1/3	3	1	1	0.1856

According to the matrix calculation, $CI = 0.0029$, $CR = 0.0033$ <0.1, Meet the consistency check.

Table 3. The judgment matrix and weight of each requirement element (C_5 - C_7) under the

shape B_2

B_2	C_5	C_6	C_7	W_2
C_5	1	1/3	1/5	0.1096
C_6	3	1	1/2	0.3091
C_7	5	2	1	0.5812

According to the matrix calculation, $CI = 0.0019$, $CR = 0.0047$ <0.1， Meet the consistency check.

Table 4. The judgment matrix and weight of each requirement element (C_8 - C_{11}) under security B_3

B_3	C_8	C_9	C_{10}	C_{11}	W_3
C_8	1	1/3	1/5	1/7	0.0572
C_9	3	1	1/4	1/6	0.1101
C_{10}	5	4	1	1/2	0.3079
C_{11}	7	6	2	1	0.5248

According to the matrix calculation, $CI = 0.0407$, $CI = 0.0457$ <0.1， Meet the consistency check.

After passing the consistency test of each element, the weight values of each requirement in the user demand scheme layer of the greenhouse pear pollination drone can be multiplied by the weight values of their corresponding indicator layers to calculate the comprehensive weight values of each specific requirement in the entire target demand system, as shown in Table 5.

Table 5. Comprehensive weight of specific requirements

Target layer	Indicator layerW	Solution layerW1-W2		Comprehensive weight
A	B_1 (Function) W_1 =0.5949	C1	0.5317	0.3163
		C2	0.1223	0.0728
		C3	0.1856	0.1104
		C4	0.1856	0.1104
	B_2 (Human-computer interaction) W_2 =0.1285	C5	0.1096	0.0141
		C6	0.3091	0.0397
		C7	0.5812	0.0747
	B_3 (Safety) W_3 =0.2766	C8	0.0572	0.0158
		C9	0.1101	0.0305
		C10	0.3079	0.0852
		C11	0.5248	0.1452

3. User demand conversion of unmanned aerial vehicles for pollination of pear in greenhouse seasons

After clarifying the weight of various user requirements for the greenhouse four season pear pollination drone through the Analytic Hierarchy Process, it is necessary to use the QFD quality function to transform the user requirements of the greenhouse four season pear pollination drone into the technical and production requirements for the design of the greenhouse four season pear pollination drone. The core of quality function deployment is to take user needs as the starting point, comprehensively evaluate the technical requirements, production requirements, design requirements and other factors related to each user's needs, so that the designed and developed products meet and satisfy user expectations. In the entire QFD quality function deployment, the construction of the House of Quality (HOQ) model is the focus. Through the expansion chart of the HOQ, the positive and negative correlations between user expectations and various technical requirements indicators are more intuitively and clearly expressed, enabling designers to more effectively calculate the importance weight values of various technical requirements indicators, as well as the positive and negative correlations between various technical indicators, and quickly identify negative correlation conflicts, as shown in Figure 3.

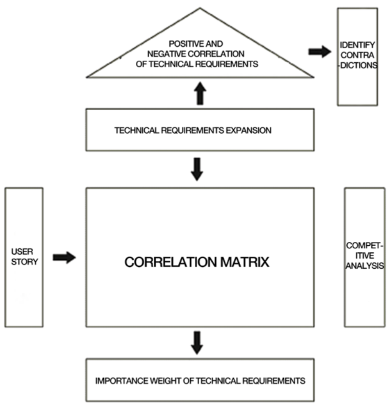

Figure 3. Expand the hierarchy of user needs

Based on the technical requirements required by various user needs, the various technical indicators of the greenhouse four season pear pollination drone were analyzed and developed, as shown in Table 6.

Table 6. Correspondence between User Requirements and Technical Characteristics

User level requirements	User's secondary requirements	Corresponding to the required skill indicators
Function(B1)	Pollination(C1)	Micron nozzle
		Wing size
		Automated settings
		Space size
	Provide Illumination(C2)	LED plant fill light
		Automated settings
		Space size
	Remote Monitoring(C3)	Panoramic high-definition camera
	Enhance Stability(C4)	Bottom bracket
Human-computer Interaction(B2)	Lightweight(C5)	Lightweight
	Simple Operation(C6)	Meet the operating conditions
		Automated settings
	Moderate Size(C7)	Meet the operating conditions
		Functional effectiveness ratio
Security(B3)	Eco-friendly Materials(C8)	Environmentally friendly

		Lightweight
	Sturdy Structure(C9)	Sturdy material
		Structurally stable
		High safety factor
	High Battery Capacity(C10)	High safety factor
	Low Failure Rate(C11)	High safety factor
		Structurally stable

Extract and summarize the correspondence between user needs and technical characteristics in Table 6, and divide the greenhouse four season pear pollination unmanned aerial vehicle into three design focuses: micro nozzle, wing, and overall. The micro nozzle, panoramic camera, and LED plant fill light are the design focuses of the body part; Structural stability, wing size, and automation devices are the design priorities of the wing section; The overall design focus of pollination drones is on simple design, small spatial dimensions, reasonable colors, environmental friendliness, compliance with operating conditions, high safety factor, and lightweight materials. The design and development of unmanned aerial vehicles for year-round pear pollination in greenhouses should revolve around the above design elements, as shown in Figure 4. Import the comprehensive user demand weights from Table 6 into the left wall of the House of Quality (HOQ); The technical requirements and indicators of the four season pear pollination drone in the greenhouse shown in Figure 4 were imported into the ceiling of the House of Quality (HOQ), and a HOQ model was constructed.

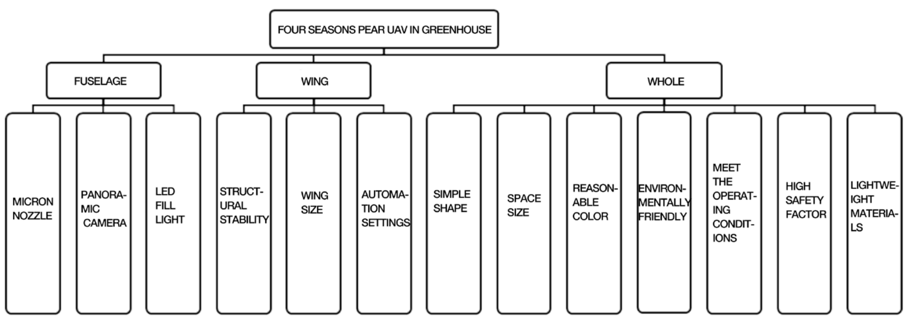

Figure 4. technical requirements deployment of greenhouse Siji pear pollination UAV

In the body matrix of the house of quality, ● (strong correlation), ◎ (medium correlation) and △ (weak correlation) are respectively used to map the user requirements and technical requirements of the greenhouse Siji pear pollination UAV, where ●=5, ◎=3, △=1, and the blank space between two represents 0 correlation. According to the correlation degree between the user demand weight and the technical demand index, fill in the symbol to score the correlation degree, and construct the correlation degree matrix, that is, the housing body of HOQ. According to formula (3-1), calculate the absolute weight and relative weight of the importance of technology demand, and W_j is the absolute weight of technology demand; W_i is the weight of user demand; P_{ij} is the correlation coefficient; W_k is the relative weight of technical requirements.

$$
W_{\mathrm{j}} = \sum_{i=1}^{q} W_i P_{ij}
$$

$$
W_k = \frac{W_j}{\sum_{i=1}^{q} W_j} \tag{3-1}
$$

The user demand weight of the greenhouse Siji pear pollination UAV is converted into the technical demand weight to form the basement of the house of quality (HoQ). Finally, the positive and negative correlation between each index of UAV pollination technology demand is analyzed and marked on the roof of the house of quality (HoQ). The positive correlation is represented by "+" and the negative correlation is represented by "—". Therefore, contradictions and conflicts between technical requirements can be obtained. See Figure 5 for the house of quality of the greenhouse Siji pear pollination UAV.

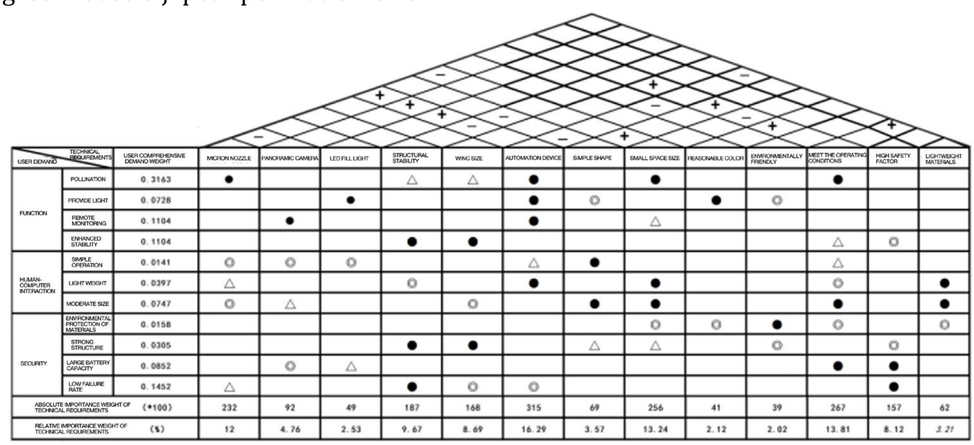

Figure 5. house of quality of UAV for pear pollination in Greenhouse

From the basement part of the house of quality model of the greenhouse Siji pear pollination UAV, it can be seen that in the design and development of the greenhouse Siji pear pollination UAV, the automation device (16.29), meeting the operating conditions (13.81), small space size (13.24) and micro nozzle (12.00) are the most important, which are the top priorities in the design and development; Structural stability (9.67), wing size (8.69) and high safety factor (8.12) are important, which are still the key points in the design and development; Panoramic camera (4.76), simple shape (3.57) and lightweight materials (3.21) are generally important; Led plant fill light (2.53), reasonable color (2.12) and environment-friendly (2.02) are the most important.

4. Contradiction analysis of four season pear pollination UAV in Greenhouse

4.1. Contradiction analysis

As an important method to solve engineering problems, TRIZ innovation theory can be perfectly combined with QFD quality function deployment. By observing the roof part of the house of quality, we can intuitively understand the positive and negative correlation between the technical requirements of the greenhouse Siji pear pollination UAV, as shown in Figure 6. "+" indicates a positive correlation. The improvement of one technology will lead to the optimization effect of another technology; "—" indicates negative correlation. The improvement of one technology leads to the deterioration of another technology; The blank part indicates that there is no correlation between technologies. Through the positive and negative correlation of the technical indicators of the house of quality roof, the contradiction and conflict are obtained.

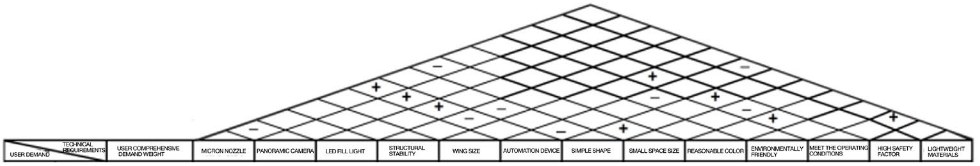

Figure 6. positive and negative correlations of house of quality

① Contradiction between micro nozzle and panoramic camera. When the micron nozzle is used for pollination and spraying, the shooting effect of the panoramic camera should not be affected. This is a pair of technical contradictions under different conditions, which requires the principle of separation of conditions.

② The contradiction between micro sprinkler and small space size. When the micro sprinkler works, it can increase the pollination surface as much as possible and increase the fruit setting rate. This is a pair of technical contradictions under different conditions, which requires the principle of separation of conditions.

③ The contradiction between automation and simplicity. It is necessary to ensure the all-round automatic operation of UAV and the simplicity of its shape. This is a pair of physical contradictions, which requires the principle of conditional separation.

④ The contradiction between structural stability and automation devices. It is necessary to ensure that there are automatic devices and the shape of the pollination UAV is simple, and the structure cannot be exposed. This is a pair of technical contradictions in the same space, which requires the principle of conditional separation.

⑤ The contradiction between stable structure and simple shape should ensure that all structures of UAV can work normally and stably, ensure the best efficiency of work, and keep the shape simple and uncomplicated.

⑥ Contradiction between automation devices and lightweight materials. The automation device will increase the weight of the pollination UAV. It is necessary to ensure the automation degree of the pollination UAV and the maximum lightweight of the pollination UAV.

⑦ The contradiction between automation devices and environmental friendliness. Automation devices will bring waste of energy and consumption of materials, so it is necessary to save energy and materials as much as possible on the basis of ensuring automation.

⑧ Contradiction between small space size and operating conditions. A large number of automation devices will bring structural instability. It is necessary to ensure both high automation and structural stability to ensure the operating conditions.

The eight pairs of contradictions of the greenhouse Siji pear pollination UAV are classified into corresponding technical contradictions and physical contradictions through TRIZ related principles. The invention principle of technical contradictions can be obtained by querying the contradiction matrix table, while the invention principle of physical contradictions is obtained by using the separation principle, as shown in table 7.

Table 7. contradictions and corresponding invention principles

Contradictions and conflicts	Types of contradictions	A3	A4	W
①Micron sprinkler - Panoramic camera ②Micron sprinkler - Space size ④Structural stability - Automation device ⑤Stable structure - Simple shape ⑦Automation - Environmentally friendly	Technical contradiction Technical contradiction Technical contradiction Technical contradiction Technical contradiction	Working object area Harmful factors produced by objects Degree of automation Degree of automation Degree of automation	Area of working object Moving object area Weight of a stationary object Harmful factors produced by objects Complexity of the system	1，7，4，14 17，2，40 2，7，35 2 2，24，10
③Automation device - Simple shape	Physical contradiction	Separation principle - Conditional separation		1，5，6，7，8，13，14，22，24，25，27
⑥Automation devices - Lightweight materials	Physical contradiction	Separation principle - Conditional separation		1，2，6，7，8，13，14，22，24，25，27
⑧Small space size - Meet operating conditions	Physical contradiction	Separation principle - Conditional separation		1，2，3，4，7，13，17，24，26，30

4.2. Conflict resolution

According to the specific situation and requirements of the design of the four seasons pear pollination UAV in the greenhouse, find out the appropriate invention principle and practice.

In ① contradiction, the contradiction between the micro nozzle and the panoramic camera. The 14th principle of the conditional separation principle, the principle of curve and surface, is adopted to transform from straight line and plane to curve and surface square or function, so as to make full use of and improve efficiency. The micron nozzle is transformed from square to round, which can be rotated and sprayed and combined with panoramic camera monitoring to improve efficiency.

In ② contradiction, the contradiction between micro nozzle and small space size. The principle 17-Multidimensional operation principle is adopted to transform the micron nozzle from a single-layer nozzle to a multi-layer nozzle for scalable spraying and pollination. At the same time, the available shrinkage can be reduced when not needed, and the practical space can be maximized.

In ③ contradiction, the contradiction between automation device and simple shape needs to ensure the effective operation of automation device and simple shape at the same time. The interior of the UAV fuselage is divided into five functional areas by using the No. 1 Principle in the space separation principle - the division principle, and each necessary function is operated separately.

In ④ contradiction, the contradiction between structural stability and automation device. Principle 7- nesting principle is adopted. The mechanical devices operating up and down and all motor devices are embedded in a metal body, which not only ensures the normal operation of the motor structure, but also ensures that the structure is not exposed, so as to achieve the purpose of simplicity.

In ⑤ contradiction, the contradiction between structural stability and simple shape. It is necessary to seamlessly connect the micron nozzle of the four seasons pear pollination UAV in the greenhouse with the panoramic camera to better observe the pollination effect, and to ensure that the two parts are concise in shape. The principle 2- extraction principle is adopted to extract the redundant parts between the operating device of the panoramic camera and the micron nozzle for turning and folding.

In ⑥ contradiction, the contradiction between automation devices and lightweight materials. The automation device will increase the weight of the pollination UAV. It is necessary to ensure the automation degree of the pollination UAV and the maximum lightweight of the pollination UAV. Using principle 2- extraction principle, three of the four motor devices that were originally required were extracted to drive the UAV greenhouse Siji pear pollination, leaving only one motor to drive the greenhouse Siji pear pollination UAV. This not only ensures the automation function of the pollination UAV, but also reduces the weight of the pollination UAV to a certain extent.

In ⑦ contradiction, automation device is environment-friendly. The No. 2 Principle - extraction principle is also adopted. Three motors are extracted and only one motor is left to drive the UAV. This not only ensures the normal function of UAV, but also relatively saves energy and materials.

In ⑧ contradiction, small space size - operating conditions. Principle 7- nesting principle is adopted. Due to the small size of the operation space, the requirements for the size of UAV are also relatively reduced, and the control systems of various operation functions are nested inside the fuselage and wing. This ensures normal operation in an environment with relatively small space size.

5. Design of four season pear pollination UAV in Greenhouse

5.1. Design of pollination UAV fuselage

By comparing the droplet size, droplet coverage, droplet density and droplet deposition of different spraying amounts, it was found that under the operating conditions of wind speed less than 2.0m/s, UAV flight height 1m from the top of the tree, nozzle atomization particle size 120 μm, and flight route above the top of the tree, the spraying amount of 2.0L per 667 ㎡ was the best pollination effect. Comparing the pollination effects of different pollination methods in the field, the inflorescence fruit setting rate and flower fruit setting rate of Siji pear pollinated by UAV were 64.47% and 22.40%, respectively, which had no significant difference from that of artificial pollination. Therefore, the use of micro sprinkler has a higher and more accurate control of the spraying amount, which can further save costs and improve the pollination effect. As shown in the figure, the nano sprinkler is combined with the high-definition camera to comprehensively observe the real-time pollination and ensure the fruit setting rate of pear in four seasons in the greenhouse.

According to the study of LED plant fill light on plant growth and pollination process, the formation of red light carbohydrates near 660nm has an impact, such as flowering and pollination of flowering plants. Therefore, with ordinary LED lights, there is no big problem in the early stage of seedling raising, but in the later stage, it will grow slowly and need to supplement red light. Therefore, the wing of Siji pear pollination UAV in the greenhouse is equipped with LED plant fill light, which is a red light supplement light, which plays a certain role in promoting the growth of Siji pear flower pollination and after pollination. The design of UAV wing led fill light.

5.2. Wing design of pollination UAV

The wing is an important component of UAV. PA nylon resin is used to achieve lightweight, solid material, environment-friendly and excellent performance. During the flight of UAV, the rotor blades rotate around the axis and move in a straight line at the same time, thus generating lift and tension. Its geometric parameters are often closely related to the aerodynamic characteristics and flight performance of UAV. Therefore, in the process of UAV design, when selecting the rotor, it is necessary to first determine the airfoil profile of the rotor blade profile related to the shape. Based on the culvert UAV, this paper designs the overall aerodynamic layout and important parts of the UAV, and gives the design requirements of the culvert four season pear pollination UAV considering the operating environment of the UAV in the greenhouse.

5.3. Overall modeling design of pollination UAV

Multi rotor UAV has high requirements for power supply. To ensure the overall safety factor, it needs to meet the conditions of light weight and large capacity. Lithium batteries are generally used. The standard voltage of a battery is 3.7V. With the increase of battery capacity, the stored energy and endurance time will also increase, but the weight will also increase. The UAV designed in this paper is small in size. In order to control the overall weight, it is not suitable to use batteries with large capacity. Combined with the above motor parameters (motor rated voltage is 3.7V, rated current is 0.15A), gb1-1100mah 1s LiPo battery is finally selected. The battery voltage is 3.8V, the total weight of the battery is about 25g, and the size is 60 × 25 × 10mm.

Based on the theories of QFD and TRIZ, the innovative design of the greenhouse four season pear pollination UAV was carried out. The above TRIZ conflict resolution principle was integrated to solve the 8 pairs of main contradictions and conflicts of the greenhouse four season pear pollination UAV, and the structure, shape, function, operation mode and other aspects of the pollination UAV were innovated, forming the greenhouse four season pear pollination UAV design, as shown in Figure 7.

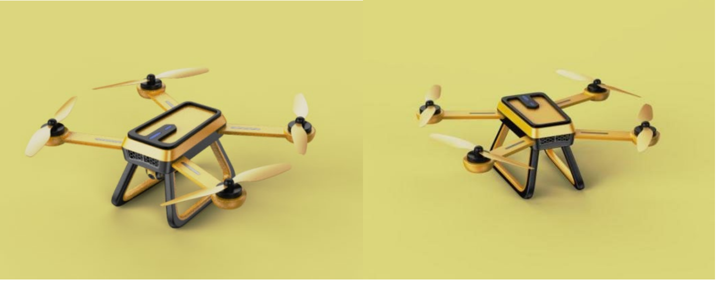

Figure 7. overall design of greenhouse Siji pear pollination UAV

The modeling design of the four seasons pear pollination UAV in the greenhouse is characterized by modern simplicity. Due to the need to meet the user's lightweight requirements, carbon fiber composite materials are used as the fuselage materials. The metal parts of the fuselage and support are made of light magnesium alloy. The support part is made of composite materials and metal, which not only ensures the hardness of the support, but also meets the lightweight requirements, visually highlighting the collision between different materials. According to the structural analysis of the pollination UAV, the operation mode of the pollination UAV is described as operating the switch at the Bluetooth link end of the mobile phone client to observe the pollination situation through the droplet size, droplet coverage, droplet density, UAV flight speed, panoramic camera, and control the plant growth state, so as to close the internal environment of the greenhouse, and fundamentally solve the problems of insufficient pollination, high cost of artificial pollination, and uneven pollination caused by the lack of natural pollination media.

6. Conclusions

The weight of user demand is calculated by AHP, and the correlation degree between user demand and technical demand is established by combining with QFD quality function deployment. The importance ranking of technical demand is calculated, and the contradictions and conflicts between technical elements are obtained. The contradictions and conflicts in the design of greenhouse Siji pear pollination UAV are solved by using TRIZ theory, and the innovative design process of user demand products is outlined. This design mode, which integrates the requirements of complex and multi-objective, not only makes up for the defects of the monolithic design theory, but also allows counterpart enterprises to understand user needs, which is convenient for enterprises to develop corresponding products based on customer needs and seize market opportunities. As mathematics and engineering principles, AHP, QFD and TRIZ have strong logicality and relevance, and can effectively guide the design to grasp the needs of users and solve practical engineering problems. This paper takes the greenhouse Siji pear pollination UAV as an example to further verify the scientificity and rationality of the integrated design mode of AHP, QFD and TRIZ, so that the design and production activities can be carried out under the guidance of scientific and rigorous theory.

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