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# Research on Accurate Perception of Crop Growth Environmental Factors in Facilities

**Gongao Hou, Xu Jian*, Guan Feng, Shang Haodong**

*Modern Agricultural Industrial Technology System, Beijing Innovation Team, Grain Economy Crop Team, School of Computer and Information Technology Engineering, Beijing University of Agriculture, Beijing 102206, China*
**Correspondence: 83327788@qq.com*

***ABSTRACT.*** *In view of the extensiveness of the current greenhouse facility sensing system and the lack of standardization of sensor equipment layout, an algorithm for accurately sensing the environmental factors of crop growth in the facility and a set of sensor layout solutions are proposed. The perception algorithm is based on the application of adaptive data fusion in industry. The algorithm is improved and simplified to a certain extent to fully adapt to the environment of agricultural facilities, and a set of sensor equipment layout schemes in practical applications are proposed for the environment of agricultural facilities. . This paper simulates the effect of the algorithm and the robustness of the greenhouse work. The results show that compared to using the average as the control method, the improved algorithm can more accurately obtain the value of the crop growth environment factor, and can cause abnormalities in the sensor equipment. Maintain the stable operation of the facility for a certain period of time.*

***KEYWORDS:*** *Greenhouse facilities; Accurate perception; Layout plan; Adaptive; Robustness*

## 1. Introduction

The road to the modernization of agriculture is inseparable from the support of information technology. Information technology has different application methods and applications in different fields of agricultural development. Intelligent facility agriculture is a way to overcome open-air agriculture's "feeding on the sky". By monitoring the environment in the facility and feeding back the monitoring data to the control system via the control logic formed by the data model, an artificial suitable environment is finally realized to meet The growth needs of crops. At this stage, research on facility agriculture is mainly focused on plant growth models, comprehensive control of multiple environmental factors, etc. By digitizing environmental and physiological states, relatively refined control is achieved, and planting efficiency and crop quality are improved. These contents are all based on idealized data acquisition and control, but in the actual working environment, it is very difficult to quantitatively control one or several parameters. One reason that

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cannot be ignored is: the accuracy of environmental data perception Performance, especially in the case of multiple sensing devices for one variable, the source on which the internal control of the greenhouse is based, that is, which sensing device value or several sensing device values are adopted by the control system, when multiple values are used How to deal with the unique values needed to form control. If the measurement of environmental data is inaccurate and the control method is extensive, the application of any comprehensive control algorithm is meaningless. Therefore, the effective solution of these two problems can effectively avoid the extensive control and at the same time reduce the operating cost of the facility.

## 2. Perceived accuracy of environmental data

Agriculture itself has the characteristics of extensiveness. This feature comes from the relatively broad tolerance of the crops to the environment. However, in facility agriculture, the industrialized production method needs to overcome the long-standing extensive production mode of agriculture, and quantify according to the industrialized method. Various factors in the production process, especially the data of the fertility environment. One of the main means of quantification is the perception of environmental data, and the accuracy of perception is related to the efficiency of various control algorithms, especially in a multi-sensor environment. The research on the multi-sensor data adaptive weighted fusion estimation algorithm proposed by Zhai Yili et al[1]estimates a non-random quantity from the measurement data of the observation noise, forming an adaptive multi-sensor error elimination Methods. Li Hongshenget al[2]proposed the use of adaptive data fusion in the process of strain detection as a way to eliminate uncertain factors in detection and improve the accuracy of detection results in practical applications of multi-sensing equipment.

## 3. Greenhouse perception weighting algorithm based on adaptive data fusion

The application algorithm of adaptive weighted data fusion in strain detection has two characteristics. One is that it can improve the unique data for control in a multi-sensing device environment, which is more accurate than directly obtaining an average; Ignore the values of abnormal sensing devices in a short time. The improved algorithm is applied to the multi-sensor device environment of agricultural facilities, and the accuracy of the perception of agricultural facilities, the overall stability of the facility, and the robustness of the control system are all improved.

The first is the first feature. The algorithm itself is self-adaptive and can freely arrange the position of the sensing device within a certain redundancy range. Agricultural facilities are different from industrial facilities. It is difficult to implement the precise arrangement of each sensing device in agricultural facilities in an industrialized manner. This will make it difficult to implement a fixed layout plan in the actual production process, and wrong layout may cause problems. Manipulation causes unpredictable effects. Second is the second feature, which can

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ignore abnormal equipment within a certain period of time and provide a certain buffer time for facility maintenance. Facility production in agriculture is a production method that eliminates labor. There is a certain period of time for maintenance personnel to respond. If there is a problem, crops cannot stop growing like industrial production, and any adjustments made by the control system that exceed the crop's capacity are irreversible. Therefore, the robustness of the control system is necessary.

### *3.1 Calculation of the weight of adaptive sensing equipment*

The control system needs an environmental parameter as the basis for starting and stopping the work, but the indoor does not use a sensing device, so it is necessary to combine the values of multiple sensors to set the weight to obtain an unbiased estimate of the room temperature, and the weight here is A weighted value obtained by calculation. Through the combination of the weighted value and each sensing device, a comprehensive value of the environmental factor for the control system can be obtained.

There are n sensing devices, assuming that there is a true value T of carbon dioxide concentration, the measurement values of each sensor are $T_1, T_2, \ldots\ldots, T_n$, and each measurement value is obtained independently, and the true value error variance of each sensor is set as $\sigma_1^2, \sigma_2^2, \ldots\ldots, \sigma_n^2$,the weight of each sensor is $P_1, P_2, \ldots\ldots, P_n$,satisfying the following two formulas:

$$T = \sum_x^n P_x T_x \quad (1)$$

$$\sum_x^n P_x = 1 \quad (2)$$

The total error variance is:

$$\sigma^2 = E[(T - \bar{T})^2]$$

$$= E[\sum_x^n P_x^2 (T - T_x)^2] = \sum_x^n P_x^2 \sigma_x^2 \quad (3)$$

From equation (3), it can be concluded that the total error variance $\sigma^2$is the multivariate quadratic function of each weight, so $\sigma^2$must have a minimum value, and the minimum value is a multivariate function whose weight P satisfies the condition of equation (2). The extreme value is obtained.

It can be introduced:

$$P_x = \frac{1}{\left(\sigma_x^2 \sum_i^n \frac{1}{\sigma_i^2}\right)} \quad (4)$$

Through the above method, the comprehensive value of carbon dioxide obtained by each sensing device according to the corresponding weight can be obtained, and the comprehensive value is used as the reference value for the control system to regulate and control, and more precise control can be realized.

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### *3.2 Acquisition of initial value*

In practical applications, the obtaining of $\sigma^2$ of each sensing device is a relatively complicated process, and the obtained data is still estimated based on statistical data. In view of the particularity of the greenhouse environment different from the high-precision measurement environment, Can accommodate a certain environmental factor difference within a certain period of time.

Therefore, only one of the most direct data in the growth environment of the crop is used as the initial value of the iteration, and the self-adaptability is used to converge to the final value, giving full play to the redundant characteristics of the greenhouse environment to reduce the complexity of algorithm implementation.

Through the simulation data, without considering the changes in the sensing device perception data, taking the true value of 500PPM carbon dioxide as an example, the initial values of the 5 groups of sensing devices are shown in Figure 1. It is found that it is almost stable around 492 after 13 iterations, The comprehensive numerical curve is shown in Figure 2.

| Initial value |
|---|
| 492 |
| 484 |
| 503 |
| 488 |
| 497 |

*Figure 1*

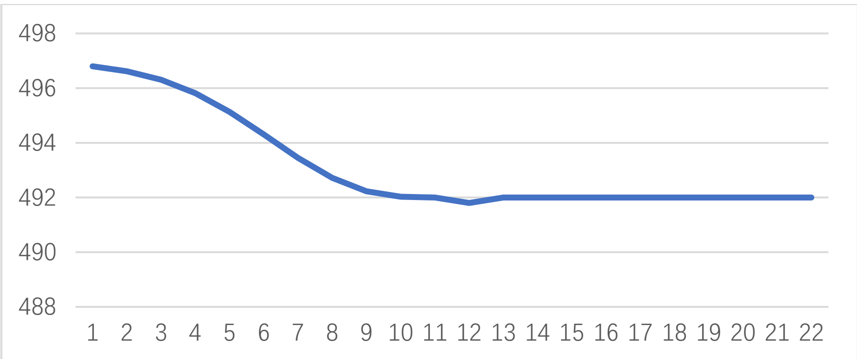


*Figure 2*

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## 4. Arrangement of sensing equipment in the greenhouse

The perception accuracy of the sensors, the number and arrangement of the sensors greatly affect the perception of environmental data. Taking carbon dioxide as an example, there are two main ways to adjust and supplement carbon dioxide. One is to exchange air with fans to exchange indoor and outdoor gas. This method has almost no cost, and the control method and logic are simple. The other is to directly add high concentration inward. The effect of this method is obvious, and it can reach the gas concentration that cannot be achieved by ventilation, which is beneficial to the growth of high-concentration crops, but its cost is relatively high, and the control method and logic are more complicated than simple ventilation. But no matter which method is used, it is always necessary to use mechanical equipment to assist the transportation of gas. Different from natural ventilation, the flow field formed by mechanical ventilation in the air inside the facility is not uniform. Even under the condition of stable air supply, it is difficult to achieve uniform mixing of the air inside the facility, which causes the internal air mixing process to exist The phenomenon of short circuit, that is, the internal air has replaced the internal environment before being fully utilized. Therefore, under the premise of the weighting algorithm, the sensor layout can also improve the accuracy of environmental data perception for control to a certain extent.

The principle of sensor device layout is that the environment it perceives is the direct growth environment of the crop, and it should be placed as close to the crop as possible to reduce the error caused by the distance. At the same time, the layout is as dispersed as possible to obtain a more representative comprehensive value of environmental factors.

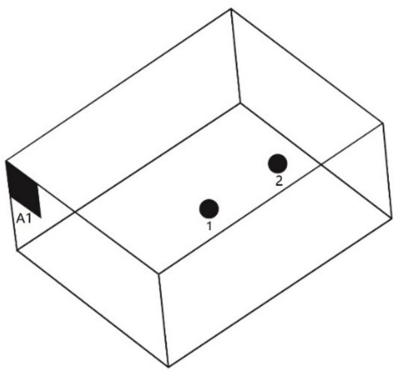


*Figure 3*

The sensor equipment is arranged indoors with three axes, x, y, and z, to fix its position. x and y represent the length and width directions of the space, and the z axis represents the horizontal and vertical directions. According to experience, the z-axis should be placed at the level of the most sensitive part of the crop to

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environmental factors, and different control thresholds should be set according to different heights. The x and y axis are arranged in accordance with the expression of National Indoor Gas Measurement Standard([3]) Close the doors and windows, pass in the appropriate amount of tracer gas indoors, move the air source to the outdoors, and stir the air with a swing fan 3 -5min to make the tracer gas evenly distributed, and collect air samples at diagonal or quincunx dots." The sensing device is arranged in the middle of the crop and the farthest point of the carbon dioxide supplement diagonal. The arrangement is shown in Figure 3. As shown, A1 is the gas exchange and supplement equipment, and 1 and 2 are gas sensors.

When the volume of the facility is large, the No. 1 position not only refers to one sensor, but multiple devices can be arranged according to the size and budget of the equipment. The arrangement of multiple sensors is based on the connection of the No. 1 device and the No. 2 device, and is divided into two. The distance between the points, as shown in Figure 4

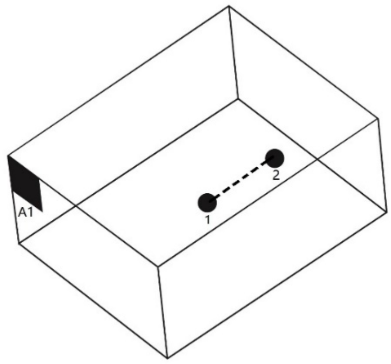


*Figure 4*

In order to improve the detection accuracy, the sensing equipment can be arranged in a plum-shaped distribution according to the standard, as shown in Figure 5.

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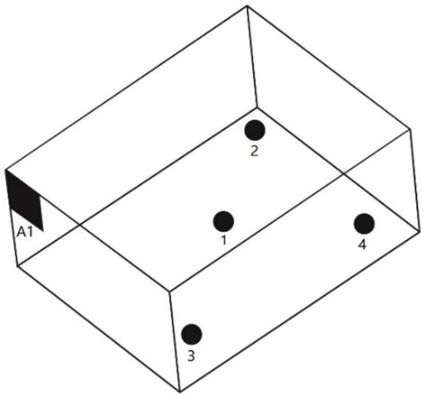


*Figure 5*

**5. The influence of weighting algorithm on the stability of control system**

Another feature of the greenhouse perception weighting algorithm based on adaptive data fusion is that it can eliminate the influence of equipment abnormality or drift on control in a short time. We take the arrangement of Figure 5 as an example to carry out the robustness of the algorithm. Design four sets of simulation data for comparison.

The first group, based on a carbon dioxide concentration of 500 ppm, uses 4 sensors, and the sensors work normally. The data simulation is shown in Table 1.

*Table 1*

| Truth value | Numbering | Measurements | Weights | Weighted calibration value | Weighted average | Error |
|---|---|---|---|---|---|---|
| 500 | 1 | 492 | 0.20689 | 101.79310 | 496.68965 | 0.00662 |
| | 2 | 484 | 0.10344 | 50.0689655 | Average value | |
| | 3 | 503 | 0.55172 | 277.51724 | 491.75 | 0.0165 |
| | 4 | 488 | 0.13793 | 67.310344 | | |

Combined with the data in Table 1, when the sensor works normally, the error of the weighted average is slightly lower than the average.

The second group, based on the carbon dioxide concentration of 500 ppm, uses 4 sensors, of which the value of sensor 3 has drifted.

*Table 2*

| Truth value | Numbering | Measurements | Weights | Weighted calibration value | Weighted average | Error |
|---|---|---|---|---|---|---|
| 500 | 1 | 492 | 0.45625 | 224.47866 | 492.69988 | 0.0146 |
| | 2 | 484 | 0.22812 | 110.41430 | Average value | |
| | 3 | 819 | 0.01144 | 9.3711561 | 570.75 | 0.1415 |
| | 4 | 488 | 0.30417 | 148.43575 | | |

Combining the data in Table 2, it can be clearly found that the error of the average has exceeded 10%, but the error of the weighted average can still be maintained at a relatively low level.

The third group, based on a carbon dioxide concentration of 500 ppm, uses 4 sensors, of which the No. 3 sensor is completely broken.

*Table 3*

| Truth value | Numbering | Measurements | Weights | Weighted calibration value | Weighted average | Error |
|---|---|---|---|---|---|---|
| 500 | 1 | 492 | 0.461512 | 227.06403 | 492.615804 | 0.014768 |
| | 2 | 484 | 0.230756 | 111.685967 | Average value | |
| | 3 | 65535 | $5.68 \times 10^{-5}$ | 3.7204835 | 16749.75 | 32.4995 |
| | 4 | 488 | 0.307675 | 150.14532 | | |

Combining the data in Table 3, it can be clearly found that the error of the average value has reached the situation that it cannot be used normally, but the weighted average almost ignores the abnormal value, and its error can still be maintained at a low level.

The fourth group, based on a carbon dioxide concentration of 500 ppm, uses 8 sensors, and the layout is according to Figure 3. Two sensing devices are placed at each point, two of which are completely broken and one device drifts.

*Table 4*

| Truth value | Numbering | Measurements | Weights | Weighted calibration value | Weighted average | Error |
|---|---|---|---|---|---|---|
| 500 | 1 | 492 | 0.316039 | 155.49113 | 494.943378 | 0.010113 |
| | 2 | 484 | 0.158019 | 76.481410 | Average value | |
| | 3 | 65535 | $3.89 \times 10^{-5}$ | 2.5477491 | 33011.25 | 65.0225 |
| | 4 | 65534 | $3.89 \times 10^{-5}$ | 2.5477494 | | |
| | 5 | 800 | 0.008428 | 6.7421629 | | |

| | | | | | | |
|---|---|---|---|---|---|---|
| | 6 | 484 | 0.158019 | 76.481410 | | |
| | 7 | 483 | 0.148724 | 71.833779 | | |
| | 8 | 488 | 0.210693 | 102.81798 | | |

Combining the data in Table 4, it can be clearly found that the weighted average can still keep the error at a lower level and maintain the stability of the working state.

Therefore, it can be considered that this algorithm can effectively avoid the influence of abnormal sensing equipment on the control system while improving the control accuracy, and greatly improve the stability of the system.

## 6. Conclusion

Accurate control requires an accurate sensing system as an aid, and an accurate sensing system requires a reasonable sensor device layout and compensation algorithm to provide environmental parameters for accurate control. This paper improves the adaptive data fusion algorithm applied to industry and applies it to the perception of environmental factors and the stability control of facilities in facility agriculture. At the same time, a set of sensor equipment layout schemes applied to facilities are proposed to further strengthen the effectiveness and accuracy of perception.

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