Photoelectric Design Competition Test Questions Analysis and Students Comprehensive Ability Cultivation

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Abstract. In 2021, China held the 9th National University Optoelectronic Design Competition. One of the questions in the competition was nondestructive testing of apple sugar content based on smart phone. We coached a group of students to take part in the competition of the test question and analyzed it. The measuring method of apple sugar degree and the possible role of smart phone in measuring sugar degree are analyzed. The realization scheme of nondestructive testing was determined, the experimental equipment was built, and the students were led to complete the competition topic. Finally, the paper analyzes how the questions of the competition cultivate students' comprehensive ability.

Keywords: Photoelectric Design Competition · Non-destructive testing of apple sugar content · Comprehensive ability formatting · cultivate

1 Introduction

College students are the main builders of the future society and their comprehensive ability is very important for the progress and development of the society. For a long time, because of exam-oriented education in our country, students pay more attention to the study of theoretical knowledge, with weaker hands-on ability. After entering the university, quite a few college students have the problem of strong theoretical knowledge and weak practical ability. Over the years, the phenomenon of valuing cognition over practice has not been completely changed. College students also need to strengthen their comprehensive application of knowledge. In recent years, every year our country has held college students electronic design competition, college students optoelectronic design competition and other competitions. These competitions provide a good opportunity for college students to cultivate their practical ability and comprehensive application of knowledge. These competitions exercise the practical ability and comprehensive ability of college students. In 2021, China held the 9th National University Optoelectronic Design Competition. One of the topics of the competition was nondestructive testing of apple sugar content based on smart phones. We guided a group of students to participate

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in the competition, analyzed the competition questions, and analyzed the training of students' comprehensive ability.

2 Analysis and Completion of Contest Questions

The content of the Photoelectric Design Competition was: Non-destructive measurement of the sugar content of an apple sample by adding a minimum of accessories, using the existing imaging, data processing and display functions of a smartphone.

The requirements of the competition are clear: make use of the phone's own functions and use the least accessories. This topic requires the students to have a variety of knowledge, have a relatively strong comprehensive knowledge application ability. There are many ways to measure the sugar content of an apple [1, 2]. Chen et al. used hyperspectral method to detect the sugar content of apples [3]. Hu Shuhe et al. used optical imaging to detect sugar content in apples [4]. This competition requires non-destructive testing of sugar content with mobile phones, and is completed within a limited time. It poses a challenge to students' comprehensive ability. Students are required to carefully analyze the competition questions, master the key points in the competition questions, synthesize their own abilities, search relevant information, and find out the appropriate implementation method.

2.1 An Analysis of Smartphone Functions

According to the requirements of the test questions, smart phones are the main tools to complete the test questions. A smartphone is a comprehensive electronic device, a combination of sensors and information processors. Smartphones may have several functions in completing the tasks specified in the contest questions. (1) Use smart phones as sensors. Smart phones are equipped with sensors such as cameras, which can be used to obtain relevant information of the tested object. (2) Smart phones can be connected to other devices and sensors through USB or TPYE C interface to obtain information of the object under test. (3) Smart phone has very strong data processing ability, can be regarded as a microcomputer, can install all kinds of apps for data processing. Apps can be prepared by themselves to realize information processing through algorithms, and the processor of smart phones is enough to meet the needs of data analysis.

2.2 Analysis of Required Measurement Attachment

The main function of the measuring attachment in the test questions is to obtain the information related to the sugar content of the apple. The degree of sugar is a unit that expresses the concentration of solids in a sugar solution. In industry, the degree of sugar is usually expressed as the degree of berix (BX), which is the number of grams of solid substance in a 100 g sugar solution. There are many ways to measure sugar content, which can be basically divided into three categories: physical method, physical chemistry method and chemical method. Since the topic requires nondestructive testing, the methods available are mainly physical.

In recent years, with the development of spectral technology, people began to use near infrared spectroscopy to detect the quality of apple [5]. The technology can be used to detect and analyze the contents of some internal components in apple according to the different reflection ability of some components in apple to different wavelengths of light. This technology is fast and convenient, does not damage the detection object and has low cost. The sugar content in fruit is closely related to the spectrum. As long as the relationship between the sugar content and the spectral data can be established, the sugar content of apple can be obtained from the spectral data of fruit. In consideration of the requirements of the contest questions, the attachments of this contest question are designed to assist smart phones to obtain the spectral characteristics of Apple.

2.3 Apple Sugar Content and Apple Spectrum

As mentioned above, apple sugar content is closely related to spectrum, and the next step is to establish the relationship between apple sugar content and spectrum. Near infrared light is between visible and medium infrared light and has a wavelength range of 780nm-1100nm. The near infrared spectroscopy can be used to detect the sugar content of apple with high precision [6]. According to the theory of molecular spectroscopy, when the molecule of a substance is in the ground state, it is the most stable. After absorbing a certain amount of photon energy, it will jump to the excited state. Transitions include frequency doubling transitions (when vibrations occur between non-adjacent vibrational energy levels) and harmonic transitions (when molecules absorb energy to produce two or more fundamental frequency transitions). Therefore, chemical functional groups such as -CH, -OH, -SH and -NH will produce double and harmonic frequencies after absorbing spectral energy, thus forming absorption bands in the near infrared spectral region. According to the absorption spectrum band, the content of substances containing -CH, -OH, -SH, -NH and other chemical functional groups can be detected and analyzed. Different groups have different energy levels, and the degree of absorption will be different.

Sugar is an important factor in determining apple taste. Apple's sugar is mainly contained in the C-H and the O-H, which is different from the energy level of the two kinds of functional groups. They absorb different wavelengths of light and the energy of infrared light is different. Their absorption of light needs to be on a specific wavelength. When this wavelength is matched, the spectrum is absorbed. The absorption of the sugar spectrum of apple samples is selective, so apple can produce a characteristic absorption in near-infrared radiation.

When using light sources to illuminate the apple, the absorption of the apple sugar functional group will form a corresponding feature reflex. When the external interference source is blocked, the appropriate light source is exposed to the apple, and the reflecting spectra of apple will contain apple's sugar information. Apple's diffuse reflection spectra and apple's sugar have a corresponding relationship to light absorption. As long as we can identify this relationship in some way, we can get apple sugar content from apple's diffuse reflection spectrum.

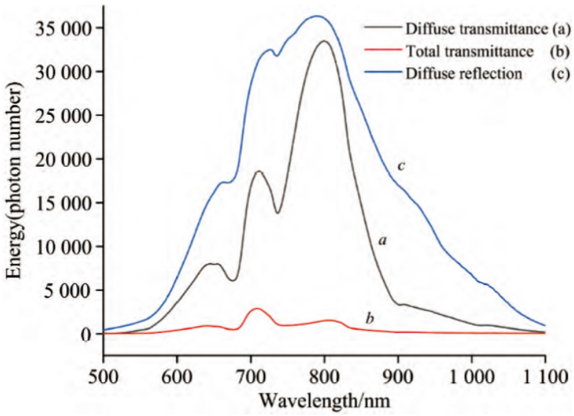

Fig. 1. The original spectra of Apple's diffuse transmittance (a), total transmittance(b) and diffuse reflection(c)

The spectrum of the apple is shown in Fig. 1 [7]. The figure shows the average original spectrum of the apple with diffuse transmission (a), full transmission (b) and diffuse reflection (c) ranging from 500 nm to 1100 nm. Diffuse reflection spectrum is the most energetic, followed by diffuse transmission spectrum, transmission spectrum is lower energy. It is a good choice to use diffuse reflectance spectrum to measure the sugar content of apple.

2.4 Apple Sugar and Spectral Relationship Acquisition Method

Use the following steps to establish relationship between apple's near-infrared spectrum and apple sugar.

1) **The Acquisition of Standard Apple Sugar**

To prepare the apple sample, the sample can cover all the pending indicators.

When the diffuse reflection of the sample of apple samples is collected, the method of collecting spectral data collection and the unknown sample collection spectra is the same. Use the commercial saccharifier to detect apple's sugar levels. The measuring range of the instrument is 0–32%, and the measuring precision is 0.2 percent, with temperature automatic compensation function.

2) **Use a Specific Wavelength Diode to Illuminate the Apple and get the Spectral Reflectivity of Apple on Multiple Wavelengths**

In order to improve portability, a laser diode with a specific wavelength is used as a light source. It is helpful to reduce the power of light source and improve the efficiency

of energy use. According to the common led light source in the market, the wavelength of the led light source is 780 nm, 850 nm, 905 nm, 940 nm and 980 nm.

3) **Use a Smart Phone to Shoot a Gray Image of Apples in a Light Source**

Using the diode source to illuminate the apple, the light of the apple reflect is collected. Get apple's reflective gray image on these wavelengths. The image is associated with the sugar index of the apple sample, and the prediction model is established.

4) **Training the Model**

The machine learning algorithm was used to establish a prediction model to correlate the image gray level with the apple sugar level. PLS (partial least squares regression) algorithm [8] and GA (genetic) algorithm were used to process the data. The model is used to predict a group of apple samples with known actual sugar content values, that is, the correction set, and the predicted results are compared with the actual measured values to judge whether the prediction model is reasonable.

5) **PLS (partial least squares regression) Algorithm**

The general base model of PLS is

$$\begin{aligned} \mathrm{X} &= TP^T + E \\ Y &= UQ^T + F \end{aligned} \tag{1}$$

where X is the prediction matrix of n × m, and Y is the response matrix of n × p; T and U are the projection of X (X fraction, component or factor matrix) and Y (Y fraction), respectively; P and Q are orthogonal load matrices of m × l and p × l, respectively. The matrices E and F are error terms, assuming they are independent and uniformly distributed random normal variables. We decompose X and Y in order to maximize the covariance between T and U.

6) **GA (genetic) Algorithm**

Genetic algorithm is an optimization method based on Darwin's biological evolution theory of survival of the fittest and survival of the fittest, which simulates the genetic and evolutionary process in the biological world. Through mathematical method, the algorithm uses computer simulation operation to convert the solving process of the problem into a process similar to the crossover and mutation of chromosome genes in biological evolution. When solving complex combinatorial optimization problems, compared with some conventional optimization algorithms, it is usually able to obtain better optimization results faster. Genetic algorithm uses the operation of operators such as selection, exchange and mutation, accompanied by continuous genetic iteration. After several iterations, the "offspring" with good modeling effect replaces the original individual. The algorithm structure is shown in the Fig. 2.

7) **Model Evaluation**

Select 80% of the samples from the sample set as the modeling set, and the remaining 20% as the prediction set. According to the modeling set, the PLS quantitative prediction

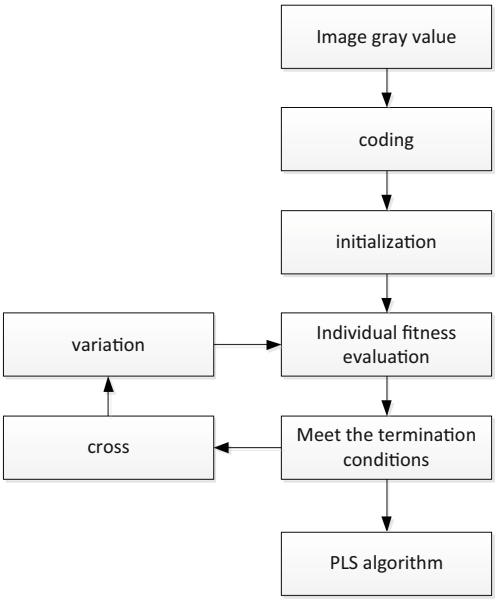

Fig. 2. GA algorithm

model of apple sugar content was established using the all-band data, and the prediction set was used to evaluate the model.

The main evaluation index of partial least square regression model is the correlation coefficient and root mean square error of modeling set and prediction set. The closer the correlation coefficient is to 1, the smaller the root mean square error is, and the better the accuracy of the model is. Model correlation coefficient R^2, root error of modeling set RMSEC and root error of prediction set RMSEP were used to evaluate the model establishment and validation effect, respectively. The calculation formula of each evaluation index is:

$$R^2 = \frac{\sum_{i=1}^{n} (y_i^{'} - \overline{y})^2}{\sum_{i=1}^{n} (y_i - \overline{y})^2} \tag{2}$$

$$RMSEP(RMSEC) = \sqrt{\frac{\sum_{i=1}^{n} (y_i - y_i^{'})^2}{n}} \tag{3}$$

where, y_i is the measured sugar content of sample i of the modeling set (prediction set); $y_i^{'}$ is the inversion value of sugar content in the ith sample of the modeling set (prediction set). $\overline{y}$ for modeling set measured average sugar content; n is the number of samples.

8) **Establishment of Apple Sugar Detection Model**

This article uses the wavelength of 780 nm, 850 nm, 905 nm, 940 nm, 980 nm laser diode irradiation apple surface respectively. Then use the mobile phone to shoot the diffuse image of apple, and obtain the gray value of the image. PLS algorithm and GA

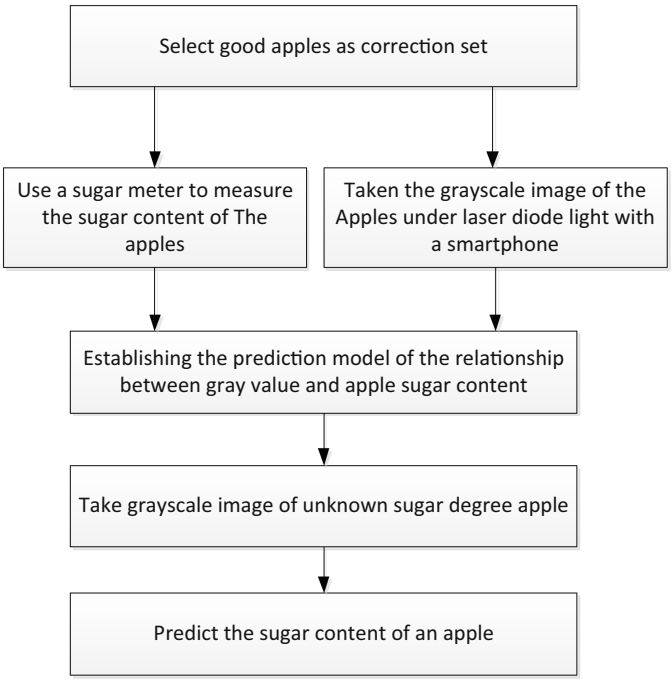

Fig. 3. Apple sugar detection process

algorithm were used to process the obtained data, and a prediction model was established to correlate the image gray level with the apple sugar level. The establishment route of the apple sugar content detection model is shown in Fig. 3.

The near infrared diffuse light signal of unknown apple samples is collected, and the signal is input into the established prediction model, and then the content of sugar in apple samples is obtained.

2.5 Smart Phones Are Used for Optical Signal Acquisition and Data Processing

Write a smartphone APP to do this work. The use of smart phone for optical signal acquisition processing is to shoot the image. Then the image is preprocessed to get the gray value of the image. The obtained data are substituted into the established prediction model for calculation. The sugar content of apple sample to be tested was obtained.

3 An Analysis of the Training Effect of Competition on Students' Comprehensive Ability

Participating in the photoelectric design competition is a good way to cultivate students' comprehensive ability. In this competition, several students form teams to compete and cooperate with each other to complete the test questions. This model not only cultivates the individual ability of students, but also cultivates the team organization ability of

students. It is conducive to the overall improvement of students' comprehensive quality. The cultivation of students' ability is mainly reflected in the following aspects.

1) Enhance personal ability. The test questions of the competition cultivate the students' basic knowledge and comprehensive application ability. Enhance the students' ability to solve practical problems, improve the students' reasoning ability. Training a student's professional skills and work ethic.
2) Enhance the students' self-learning ability. Although the system of knowledge in textbooks is complete, in the context of the current knowledge explosion, one's grasp of knowledge is always limited. Therefore, it requires students to have very strong self-learning ability. In this competition, the sugar of apples involved chemistry and biology knowledge, light detection and the use of diodes involved physics knowledge, building and using models involved mathematics knowledge, and sugar prediction involved students' programming ability. It can be said that this question not only requires students to have a certain depth of knowledge, but also requires a certain breadth of knowledge. Students should have strong learning ability, be able to search relevant knowledge, and extract the required knowledge from the ocean of knowledge, the cultivation of students' learning ability is comprehensive and specific.
3) Students' learning has changed from passive to active. During the competition, some unknown knowledge is involved in the process of solving problems, so students need to take the initiative to look up information, learn and think, and integrate knowledge to solve practical problems. This is an active learning process, in which learning and practice complement each other, which is very helpful for students to master relevant knowledge.
4) Cultivate students' ability of team organization. The questions involved multiple disciplines and required a variety of abilities, which required a team of students to complete the competition. The team should make appropriate division of labor according to each student's own good knowledge, so as to cultivate the spirit of cooperation among students. It helps students integrate into the group.

4 Conclusion

The nondestructive testing of apple sugar content based on smart phone is one of the questions in the 9th National College Students Photoelectric Design Competition. The possible functions of smart phones used to complete the test and the possible measurement accessories are analyzed. The relationship between apple sugar content and apple spectrum was analyzed. The corresponding technical process was established to establish the relationship between apple sugar content and apple spectrum. Non-destructive measurement of apple sugar mainly has the following steps: using sugar meter to measure apple sugar, using characteristic wavelength diode irradiation apple, using smart phones to shoot apple reflection gray image, using PLS + SA algorithm to establish a training model for model training, Making apple sugar forecast and evaluating the forecast results. Finally, the training effect of the contest on the comprehensive ability of college students were analyzed.

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