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Deep learning algorithm based tablet drug screening system

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Abstract: *At present, the world's major pharmaceutical companies often identify defective tablets by visual inspection, but because of the fatigue of staff and the human eye's recognition limit of tiny parts, so there are often missed inspection, inefficient inspection phenomenon.[1] How to effectively monitor and ensure more qualified inspection rate in the inspection activities, which is the current problems encountered by pharmaceutical companies. How to efficiently detect and maintain a high detection rate in the testing process, which is currently the difficulties faced by pharmaceutical companies. In order to improve the service quality of the company, the adoption of machine inspection and sorting technology to replace manual inspection and sorting has become a trend. [2]Therefore, after systematic research, we obtained a method for monitoring surface defects of tablet products based on convolutional neural network. Using this method, we developed a tablet screening technique for surface defects, which significantly improved the accuracy and efficiency of surface defect detection.*

Keywords: *tablet drugs; deep learning; sorting system*

1. Introduction

At present, in the pharmaceutical market, oral pharmaceuticals can be broadly divided into tablets, capsules, granules, pills and syrups, among which tablets occupy a large market among the five major categories of oral pharmaceuticals. The production process of tablets in pharmaceutical companies is mainly the pressing method, of which pressing and coating are the more critical processes in the pressing method. Preliminary tablets can be obtained after the tablet pressing process, but the preliminary tablets are often accompanied by tablet cracking, burriness, roughness or depression on the tablet surface.[3] In addition, in the coating process, there are often problems such as tablet adhesion and coating film not completely covering the core of the tablet. For defective tablets, major pharmaceutical companies often use manual visual observation to identify defective tablets, but due to the visual fatigue of staff and the limits of the human eye to identify the subtle parts, there are problems such as missed inspection and inefficiency. In order to ensure the production efficiency of enterprises, it is urgent to replace manual inspection and sorting with mechanical inspection and sorting.

By analyzing the research status of tablet surface defect detection at home and abroad, it can be found that most of the foreign tablet surface defect detection uses machine learning and neural network, genetic algorithm, pattern recognition and edge detection to identify and locate defective tablets. Among them, Možina et al. (2013) used pattern recognition-based detection technology to identify the tablets to be tested, firstly, by establishing a standard model to set the passing criteria, and then predicted whether the tablets to be tested passed or not by comparison analysis. The algorithm is able to obtain a high accuracy rate, so this kind of method is exactly what is needed in this paper.

Most of the domestic tablet surface defect detection algorithms use pattern recognition-based detection algorithms. [4]This algorithm requires a large amount of a priori knowledge to design a reasonable and efficient feature extractor, and has the disadvantage of being computationally intensive and having very limited application areas. The emergence of neural networks provides a new way of thinking to solve this problem. For a specific pill surface defect detection task, the convolutional neural network can autonomously select the required feature extractor according to the learning algorithm, and extract the necessary features to detect the pill surface defects, which greatly reduces the complexity of the algorithm. In addition, the number of parameters of the convolutional neural network is greatly reduced due to the weight sharing strategy, which improves the speed of training. [5]Therefore, a convolutional neural network-based surface defect detection algorithm is proposed. With the help of this algorithm, a new defective tablet screening system is designed and developed, which effectively improves the accuracy and speed of defective tablet detection.

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2. Overall design of tablet drug screening system

2.1 Performance parameters

2.1.1 Processing capacity

The processing capacity is the number of materials that can be processed per hour. The factors that affect the size of the processing capacity per unit time are mainly the movement speed of the servo system, the maximum speed of the conveyor belt and the purity of the raw material. If you want to quickly send the actuator to the position corresponding to the impurities, you only need the servo system movement speed, you can also improve the speed of the conveyor belt to increase the processing capacity, and vice versa, that is, to reduce the speed of the conveyor belt. The amount of processing per unit time is proportional to the movement speed of the conveyor, and the faster the conveyor speed, the greater the output. If there are few impurities, the greater the interval between the two impurities, the longer the reaction time left for the servo system, and the speed of the conveyor can be increased. At the same time, the unit time processing capacity and the required selection accuracy is closely related.

2.1.2 Light selection accuracy

Light selection accuracy refers to the number of impurities selected from the raw material as a percentage of the total number of impurities. Light selection accuracy is mainly related to the movement speed of the conveyor belt and the purity of raw materials, that is, the slower the conveyor belt movement speed, the longer the time between adjacent impurities, the servo system to have enough time to remove impurities, improve the accuracy of light selection. Similarly, the higher the initial purity of the raw material, the less impurities, the higher the accuracy of light selection. At the same time, the light selection accuracy is also limited by the design of the servo system itself, when there are more than two impurities in the same frame image, only one impurity can be rejected, the light selection accuracy decreases, the use of multiple selection structure is better than the single selection structure.

2.1.3 Band-out ratio

Take-out ratio is the ratio of the number of impurities to the number of normal materials in the waste material selected by the optical selection machine. Take out the ratio of high and low is adjustable, mainly relying on the control of the actuator power on time to complete the adjustment of the take out ratio. If the belt-out ratio is set too high, it will affect the selected rate and processing capacity of these two indicators; if set too low, the selected waste contains too much normal material, will cause waste, if further processing needs to be considered to invest a certain amount of manpower and material resources, will cause a lot of trouble and economic losses.

2.1.4 Selected rate

Selection rate refers to the process of screening, the number of impurities selected in a screening process as a percentage of the total flow. The clearer the imaging of tablets, the easier it is for the algorithm model to analyze and identify the defects contained in the tablets. At the same time, the selection rate is also affected by the separation system, which works properly to ensure that the command signal is executed correctly.

In the actual production process, the four indicators of processing capacity, optical selection accuracy and band-out ratio, and the elected rate are one and the same, i.e. they are all key indicators and must be examined simultaneously.

2.2 Workflow

The overall screening system is mainly composed of feeding system, optical detection system, signal processing system and separation system.

As shown in Figure 1 tablets from the feed hopper 1 into the fabric machine 2 forward transport, the material drop into the optical sieving machine tablet chute 3, the material in the process of falling through the optical selection scanning area 4, the scanned picture is transmitted to the control cabinet 5 for image processing and discrimination, high-pressure air valve group 6 according to the instructions of the control cabinet 5, the precise blowing out of waste to the waste hopper, after the optical selection of qualified products then into the next process. The whole system can be connected to network 8 for remote support.

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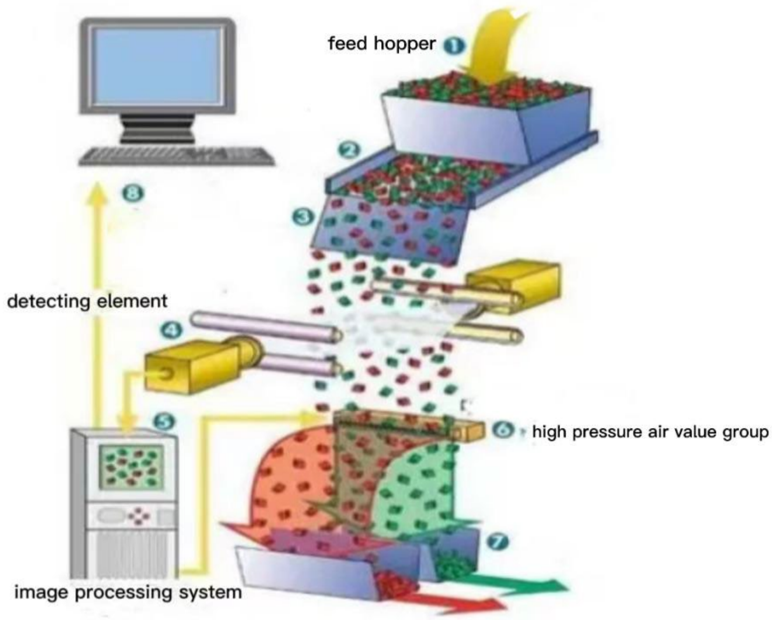

Figure 1: Principle of drug residue color sieving machine

2.3 Mechanical system design

2.3.1 Feeding system design

The feeding system is an important part of the overall screening system. After the feeding system, the drug enters the optical detection system and the separation system in an orderly manner. The feeding hopper (drug bin), fabricator and chute are the important components of the system. The finished coated tablets enter the feeding hopper. In order to reasonably control the movement speed of the tablets and facilitate the fabricating machine to fabricate the tablets, the feeding hopper adopts a trapezoidal interface design, with a large port at the top to facilitate the entry of the tablets and improve the screening efficiency, and a small port at the bottom to reasonably control the falling speed of the tablets and reduce the defects of the tablets caused by movement and falling.

As the final device of the feeding system, the tablet is separated from the chute and enters the optical selection system, whose main role is to provide a uniform and stable tablet flow for the subsequent system, so the design of the chute has an important impact on whether the subsequent systems can work in a normal and orderly manner. As shown in Figure 2, this system adopts U-shaped chute design, each chute is equally spaced, and 11 chutes form an overall U-shaped chute, the width of the chute is slightly larger than the width of the tablet, and at the same time, when installing the chute, the tilt angle of the chute is reasonably adjusted so that the tablet slides down smoothly along the chute. As the tablet does slide down and move in the chute, the surface of the chute channel is an important factor that affects the state and speed of tablet flow, so the surface of the chute should be as smooth as possible. Generally, the surface of the chute can be plated, which can effectively increase the smoothness of the chute surface and thus improve the accuracy of the screening system.

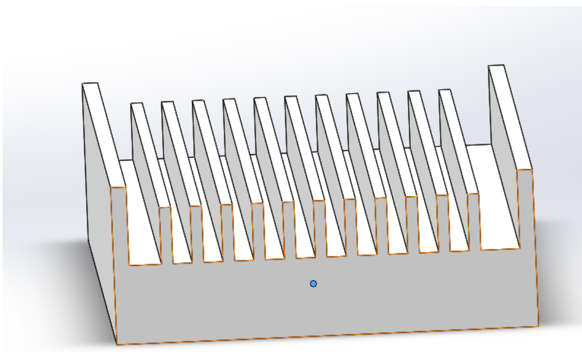

Figure 2: Slide groove

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2.3.2 Optical detection system (optical selection room design)

The optical detection system (optical selection chamber) is the most important device of this system, which mainly consists of, LED light source, camera, and information transmission device (sensor). When the tablet drug enters the optical selection system through the chute, the optical selection system relies on the four light sources photometric stereo imaging method and deep learning algorithm for the initial identification of the tablet, and after the defect identification is completed, the information command is transmitted to the separation system, and the separation system rejects the defective tablets, of which the four light sources photometric stereo imaging method is the most important component of the optical selection detection system (optical selection chamber), as shown in Figure 3.

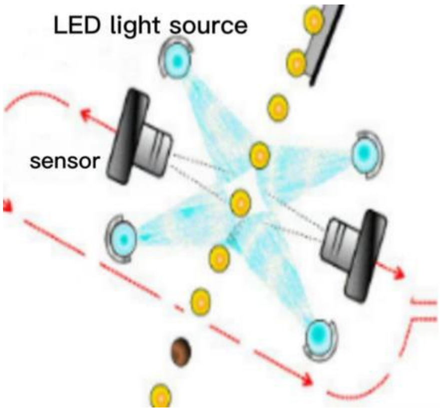

Figure 3: Optical detection system

The method is composed of four light sources in different positions with the same light intensity and two cameras in opposite positions. The camera captures a real-time image of the drug tablet to be tested under a dense light source and then analyzes the image dynamically in real time with the help of a deep learning algorithm to identify surface defects and other information of the tablet to be tested. To ensure that the four-degree light source stereo imaging method device imaging clear, the primary solution is the four groups of light source position arrangement problem, namely, the angle between the LED light source and the camera, if the angle is too large, easy to cause the camera shooting area dim, if the angle is small, making the shooting area overexposed, resulting in image distortion, for the subsequent deep learning algorithm to identify the tablet surface defects, after testing, the results show that when the light source and the camera optical axis into about 45 ° evenly divided, the best stereo imaging effect, after the best imaging effect, this screening system for the biased drug light selection accuracy and accuracy has also been correspondingly improved.

2.3.3 Separation system design

The main function of the separation system of this device is to accept the instruction given by the information processing system, and to reject the defective tablets by the method of air spraying, which consists of pneumatic nozzle, electric valve, compressor, signal receiver and receiving box.

This design ensures that the nozzle inlet cross-section is larger than the outlet cross-section, which increases the amount of high-pressure gas injection, fully ensuring that the change in the trajectory of the falling movement of defective drugs.

The quality of the compressor for air compression directly affects the sorting function of the separation system, so it is necessary to ensure the stability and uniformity of its air pressure. In addition, the compressed air pipeline of the compressor can be installed in the gas dryer, air filter and other gas treatment devices to ensure that the high-pressure gas emitted by the nozzle will not cause pollution to the tablets.

The receiving box includes the good receiving box and the defective receiving box, and the discharge port is set under the good receiving box, so that the tablets flowing out are qualified tablets and can proceed to the next process, while the tablets in the defective receiving box can be put into the medicine bin in the feeding system again for secondary screening to improve the screening accuracy.

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2.4 Design and application of deep learning algorithm

2.4.1 Deep learning algorithm - YOLOv5

Before there is no convolutional neural network (CNN), the main way to complete the target detection is still based on statistical or knowledge-based algorithms, with deformable component model algorithm (DPM) as the primary representative of its feature attributes rely mostly on manual design. However, the detection targets by this algorithm are relatively limited and there are obvious limitations. With the continuous development of CNN algorithm, a series of excellent improvement algorithms have emerged, among which the classical ones include OverFeat, R-CNN, Fast R-CNN, R-FCN, Mask R-CNN based on deep learning classification algorithm, SSD, YOLO series based on deep learning regression algorithm. The deep learning based regression algorithm is better than the classification algorithm in detection speed and model size, and the YOLO neural network can recognize 45 images per second, so this system uses YOLOv5 algorithm in the application process.

YOLOv5 is a single-stage detection algorithm, which can output the position and category confidence of the predicted frame at one time, with very fast detection speed and high detection accuracy. The first part is the input layer, which mainly implements data pre-processing before training, with the main functions of Mosaic data enhancement, adaptive anchor frame calculation and adaptive image scaling. The second part is the backbone, which mainly implements the extraction of target features. It consists of Focus structure and CSP structure. The third part is the Neck network, which mainly implements the collection of target features and consists of FPN+PAN structure. Where the FPN can be called the enhanced feature extraction network of YOLOV5, the three effective feature layers obtained in the backbone part will be feature fused in this part, and the purpose of feature fusion is to combine feature information from different scales. In the FPN part, the effective feature layers that have been obtained are used to continue extracting features. The Pnet structure is still used in YOLOV5, where we not only upsample the features to achieve feature fusion, but also downsample them again to achieve feature fusion. The fourth part is the Prediction layer, which is mainly used to predict the information loss. In summary, the whole YoloV5 network is about feature extraction, feature enhancement, and prediction of objects corresponding to feature points.

2.4.2 Application of YOLOv5 algorithm

The YOLOv5 algorithm needs to be simulated and trained in a certain environment during the formal application practice. In this paper, we use Python 3.9 as the training environment for the YOLOv5 algorithm, install PyCharm to optimize and develop the code, install OpenCV and other computer vision library functions, and install PyTorch and other deep learning libraries to improve the training efficiency. The i7-12700F 12-core processor and RTX3090 graphics card are used to guarantee the training of the algorithm. After the model algorithm is trained, the real-time images in the light selection room are transferred to the fully trained model, and the program can accurately identify whether there are defects in the tablet drugs and can smoothly transfer the information to the separation system to ensure that the whole process is smoothly carried out to complete the work.

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