本软件使用 Java 编写，应用于安卓平台。使用者可自选多门外语同时学习，并且在单词的学习和复习时，多种外语的单词形式、释义、音标等信息同时显示在同一屏幕内便于使用者类比记忆。在词汇表的选用上，既可以自行导入也可以使用系统预置的词汇数据库中的词汇进行学习，复习计划将由系统根据前文所介绍的"单词敏感度"机制配合艾宾浩斯遗忘曲线安排。使用者也可以自定义每日学习和复习的强度。相信在未来，更多科学高效的外语学习方法将相继出现，多语言学习将变得更加友好，外语学习者们也能切实体会到科技带来的便利。

УДК 004.42

A NOVEL LITHIUM BATTERY ANODE-CATHODE DISTANCE DETECTION METHOD BASED ON X-RAY IMAGES

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Summary. *Lithium battery is a promising energy source that can used in power the electric motors of a battery electric vehicle or hybrid electric vehicle. However, in recent years, many serious safety accidents in electric vehicle that caused by the defect of the anode and cathode harm the industry. Therefore, we proposed a novel distance detection method, which can detect the defect of the anode and cathode automatically with high accuracy and speed.*

Battery testing and failure analysis is important in helping improve design and confirm the correct working of battery internal features. Digital radiography and computed tomography X-ray inspection may examine the internal electrode arrangement after assembly and then find out the defects. One of the potential defects of the battery is caused by the improper distance between anode and cathode, either too large or too small distance may obviously reduce the lifetime of the battery and then leads to the incident [1]. Traditional detection method of battery defect is conducted by using human labor, whose efficiency is low and examining accuracy is not satisfactory, therefore, we proposed a novel lithium battery anode-cathode distance detection method that based on X-ray images.

The proposed method uses the X-ray images of the battery as input and outputs the distance values between all pairs of the anode and cathode, on which it is easily to judge the current battery is qualified or not. The proposed method mainly consists of three basic stages: key points detection stage, key points matching stage, relative distance measurement and quality examine stage.

In the first place, during key point detection stage, all cathode and anode points are detected by using a modified Yolo method. Yolo [2] method has become one of the most popular neural-network based object detection methods due to its speed and accuracy after it has firstly introduced in 2015. Yolo method can provide us both the positioning and classification information. In order to adapting our task, we modified the original Yolo architecture and algorithm for achieving the transfer learning.

Secondly, during key point matching stage, we adopted Hungarian algorithm to pair the anode and cathode. Hungarian method [3] is a combinatorial optimization algorithm that solves the assignment task in polynomial time. For our task, supposed that there are N_1 anodes and N_2 cathode ($N_1 < N_2$), we first construct a $N_1 \times N_2$ matrix M, and for *i-th* anode and *j-th* cathode, their Euclidean distance (assignment cost) are filled in the position of $M(i, j)$ and then this assignment can be solved by using Hungarian method.

The last stage is relative distance measurement and quality examine. During this stage, the distance between each pair of anode and cathode are simply calculated since the coordinate of these two points are known. And then we compare each of them with given distance ranges, if all the computed distances are within the given range, then this battery is qualified, otherwise this battery is not qualified.

All three main stages of the proposed method are summarized in fig.1.

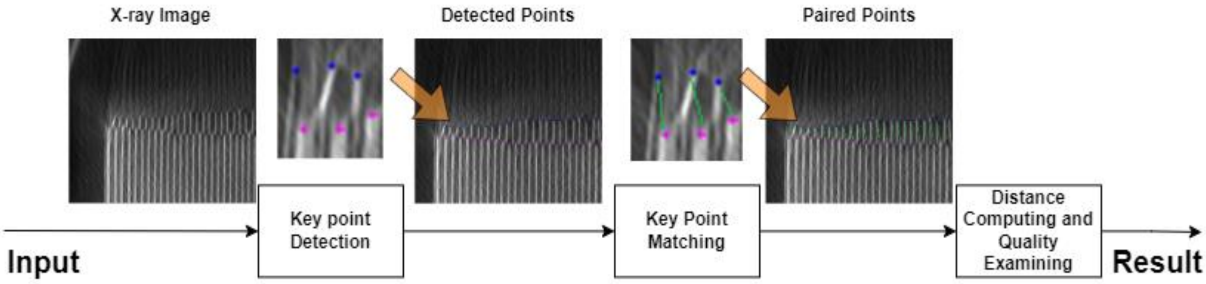

Figure 1 – Three main stages of the proposed method

Eventually, the modified algorithm can generate a precise predicts on key points, which has maximum Euclidean distance offset for anode is 2.23 pixel and minimum offset is 0.71 pixel (see tab. 1). This high precise location provides a probability to achieve the high accuracy on battery quality judgement, it makes our algorithm metrics significantly exceed the industry wide level (positioning deviation 3–5 pixels).

Table 1 – Statistic Result on Detection of Key Points

	Euclidean Distance (pixel)		Manhattan Distance (pixel)	
	Anode	Cathode	Anode	Cathode
Average	1.17	1.12	1.64	1.61
Variance	0.83	1.15	1.00	1.37
Minimum	0.71	0.92	0.53	0.63
Maximum	2.23	2.03	2.88	2.77

At present, our algorithm and toolkit have been applied to the quality inspection of 35-layer batteries on workflow in actual production, and have achieved good performance. Based on the same application environment, we tested the 101-layer battery, results are as good as before: the size of the input X-ray image is 1100×450, the average time consumption of key point detection stage was 0.024 s, key point matching stage consumed about 0.036 s, and distance compute and quality examine stage required 0.013 s. As a result, total time consumed by the proposed method for 101-layer battery detection task is less than 0.08 s.

Our method performs well in terms of both accuracy and executing efficiency. The high accuracy of the proposed method is derived from the high precise electrode location by adopting the modified Yolo neural networks. On the other hand, since both of the Yolo and Hungarian algorithm are not time-consuming algorithm, the processing of the two former stages are very fast. Therefore, our proposed method has high potential in many fields of industrial inspection, whether it is castings, welding parts, automobile parts or food and drug packaging.

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