学　位　論　文　内　容　の　要　旨

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学　位　論　文　題　名

Multiple Paired Pixel Consistency Model for Robust Defect Detection in Printed Logotypes
（印刷されたロゴタイプのロバストな欠陥検出のための複数ペアピクセル一貫性モデル）

Quality control (QC) is an important procedure in modern manufacturing. Product defect detection always plays an important role in quality control. This ensures that the product will make a good impression on the customer. In this research, we are interested in assessing how currently available vision systems perform a variety of QC tasks on printed products. Mainly we consider the inspection of printed characters/text or logotypes for defects, such as holes, scratches, dents, and foreign objects. Presently, the printing defect detection is often assessed by human inspectors, which is a labor-intensive and time-consuming job. However, the results of an inspection might be unreliable because humans may give different results depending on the time, mood, skills, and experience of the inspectors. Therefore, human inspection is being replaced by automatic visual inspection (AVI) systems.

Traditional defect detection algorithms can be divided into two categories: conventional features-based ones and data-driver based ones. The conventional feature-based methods can be classified into four categories: statistical-based, structural based, filter-based, and model-based method. There are roughly two categories of data-driver based methods. They are traditional machine learning methods and deep learning techniques. Both algorithms have their advantages and disadvantages. The feature-based method usually has clear algorithmic implications; therefore, it is easy to control. For different application scenarios, suitable features can be designed for unique goals. Furthermore, feature-based methods are usually efficient and easy to implement because they do not rely on huge amounts of data. However, feature-based algorithms also have some problems, such as the lack of satisfactory detection of small size defects and texture irregularities samples. Data-driven methods are usually implemented by designing some learnable parameters in the model and then training the model with the data. The training data typically contains images and corresponding annotations that are manually annotated. Although data-driven methods exhibit high accuracy and generalization, they require large amounts of learned data and manual annotations. The training process also requires huge computational resources and time.

This dissertation focuses on the detection of printing defects on a surface embossed with randomly distributed 3D micro-textures. This type of surface is made using embossing processes for creating tiny mixed convex and concave patterns on the surfaces of metal, plastic, or other materials. The changes in illumination on such surfaces have a significant influence on the appearance, which causes difficulties in defect detection. To realize this goal, a method called Multiple Paired Pixel Consistency (MMPC) model was proposed. We firstly propose a consistency measure based on correlation for consistent pixel pairs to realize a robust defect-free model. And then introduce a novel evaluation strategy for precisely detecting defects. Furthermore, a modification method called Position-dependent Data inhibition (PDI) is proposed to further improve the robustness and performance of MPPC.

This overall dissertation is organized as follows.

Chapter 1 introduces the importance of defect detection, and the related works in defect detection. Some challenges in defect detection are involved and discussed. Furthermore, the motivations and contributions of this study are described.

Chapter 2 introduces the orientation codes (OC) which can reduce the influence of illumination fluctuations so that we use OC as the basis of the proposed method. First, introduce the original version of orientation codes and then next extend it by providing two kinds of operation: a precise spatial differentiation for calculating the codes with a higher resolution and signed difference between any two codes as preparation for making a more precise statistical model of their difference. By using these operations, we introduce a more precise scheme to describe the statistical relationship in the pair of any pixels on the logotypes.

Chapter 3 introduces the proposed Multiple Paired Pixel Model (MPPC) in detail, including the basic concept and essential mechanism of MPPC. Firstly, we observe the defect-free images of logotypes to find the relationship between any pair of pixels both on the logotype. And then, we introduce the kurtosis to find the potential distributions. After observing, we describe how to select a supporting pixel for each target pixel, and finally build the MPPC model for each pixel pairs.

Chapter 4 discusses discuss how to utilize the proposed MPPC model of the relationship between pixel pairs in the defect-free logotype for detecting many sorts of logotype defects in this chapter. The defect detection can be divided into two main steps. Firstly, judge the statement of each pixel pair. And then identify the normal or the abnormal states at the corresponding position defined by the elemental MPPC model.

Chapter 5 focuses on the Position-dependent data inhibition Modification (PDI), which is proposed based on MPPC to further improve the robustness of MPPC and stabilize the efficiency of MPPC. In this chapter, the basic knowledge and mechanism of PDI are discussed in detail. Finally, we verify the ability of PDI with adequate experiments.

Chapter 6 introduces the experimental setup in detail. In this chapter, the comparative experiments for MPPC and MPPC+PDI using several real defective images and synthesized or artificial defective images under different conditions such as illumination fluctuation, different noise intensity are designed, and through these experiments, we measure the robustness and efficiency of our methods.

The final chapter summarizes the main points of the study and discusses our algorithms. Finally, the plan and concept of future work are presented.