Silhouette Image-based Technique for Flexible Printed Circuit (FPC) Models for Automated Visual Inspection.

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Abstract

In manufacturing process, Quality Control (QC) inspection has been a crucial department among others. When quality involved, all concerns are subjected onto the products in all means of methods, managements, and even machine conditions. Recently, most of the electronic-based inspection process is relying on human expertise which is known to be a time consuming process that may lead to tiredness and inconsistency. Here, focus of the inspection process is on the Flexible Printed Circuit (FPC). Now, automated inspection process is brought upfront in which known to be a fast, effective and accurate process in inspecting of FPC though it consists of tiny and complex structure. This paper is aimed in automating the visual inspection by creating a database system based on standard part specification. In initial research stage, Computer-Aided Design (CAD) representing the FPC model as the subject and low level programming is developed as the platform in order to render CAD image before features recognition. Later, image enhancement is conducted by selecting the most appropriate technique between similarity method (image correlation) and subspace analysis. These two methods are sharing same focus in getting the correlation or matching for two constituents CAD images.

Keywords: *Rendering CAD model, image processing, feature recognition database, similarity method, subspace*

1. Introduction

The automation of manual inspection has become an instant step towards advanced quality control. FPC manufacturing desires a precise yet accurate measurement and also needs proper inspection to achieve a well-finished product. Automated is expected to gain those specific limitation in manufacturing FPC as the database in more accurate than the manual visual inspection. Human is prone to tiredness, and manual inspection is also time-consuming. The inspection result may vary from one operator to another as experience and inspection may takes place. Thus, by automating the inspection process can overcome such cons. Database is robust and can be adapted to various FPC model that having ability to match or detect the real-life inspection environment.

There are several factors that contribute the necessity for automated inspection. Firstly, the advance technology in design, fabrication, FPC is produced in more complex functionality. Moreover, the dimensional measurement are kept changing with product variations urges manufacturing process to be more adaptive. Secondly, FPC can be said as an important part in electronic appliances nowadays. Thus, high-speed FPC manufacturing is vital to meet the requirements. High productivity and production capacity is a must in manufacturing FPC. So, automated inspection is one of the ways to boost the lead time of the FPC manufacturing. Thirdly, the increased cost of labors becomes an

important force in automating inspection process. Effective system such this automated inspection can help in lowering labor cost because human inconsistency can lead to low accuracy of FPC manufacturing and give produce low quality product.

Flexible Printed Circuit (FPC) is a pattern of conductor which functioned as a dielectric base material. Top of the board is covered with dielectric material. Later, electronic components will be mounted on the FPC and forming an assembled electronic circuit. In this research, an FPC is designed as CAD model, later then go through a rendering process via low processing programming software. FPC manufacturing and assembly machines are commonly neglecting a device that enables quality inspection onto the FPC. The process often relies on manual inspection which are time-consuming, inconsistent and low productivity and capacity. FPC is going through robust improvements or changes depend on the functions. The increase of complexity with expectation on high productivity, limits the conventional manual inspection being unreliable.

A Computer-Aided Design (CAD) model is made up virtually meaning that it is freely can be designed accordingly to one's specifications. Once a model is made up, rendering can be a part of the modeling in a manner where the model is generated in a scene file. Lighting, shading, viewpoint, and texture are added onto the model to make it looks clearer and firmer. CAD modeling software provide useful features in rendering CAD model, e.g., fillet, holes, revolved, extrude.

In this project, FPC is designed through CAD drawing and later the part will be programmed to do the analysis and simulation of the part. Database is created onto the part that expected to be adapted into the automatic inspection. Here, two methods are applied in creating database for the automated visual inspection. Image correlation is applicated as the matching the subsequent images. Then, Euclidean distance from images is defined from Fast Fourier Transform in which having the same mean with the image correlation where image matching is involved. Later on, both methods (i.e. image correlation and Euclidean distance) are analyzed in finding the more accurate method.

2. Literature Review.

Rendering Computer-Aided-Design (CAD) model is having mass development in today's industries, education fields and other field that related to this database of rendered objects or parts. Lots of studies, researches and applications have been done in which low processing programming is used as the tool in rendering CAD models. Making a database is a space consuming. Thus managing the database of solid model is relevant and some researches study on how to manage yet classify those large databases of solid models in a proper way (McWherter et al., 2001).

In many industries, e.g., the aerospace and automobile industries, manufacturers are increasingly relying on visualization technology to interactively view and inspect the product design in order to catch design problems at an earlier stage. The ability to view whole product structures and conveniently inspect each of its subsystems is considered essential for any engineering visualization system. Therefore, it becomes desirable to be able to render a selected subset of parts as transparent to reveal the design details that are otherwise occluded. Moreover, some parts may be made of transparent material such as glass and to render them transparently can substantially increase the realism of the scene. Therefore, providing realistic object transparency at interactive frame rates is important for effective visualization (Huang and Carter, 2005).

The traditional way to use a CAD model in a VR (virtual reality) system is to tessellate the original model into a mesh format and dispatch it to a graphics system for rendering. Because of a huge amount of triangles was produced, this approach is not efficient for VR system due to the tessellation for local visualization produces meshes with a large number of triangles that impose heavy transmission load. In certain situations, VR systems would be resulting in slow rendering and poor 3D manipulation. Therefore, it is necessary to develop a simple and general approach of CAD model's simplification and conversation (Tang and Gu, 2010).

In particular, edge and corner detection and structure preserving noise reduction. Non-linear filtering is used to define which parts of the image are closely related to each individual pixel; each pixel has associated with it a local image region which is of similar brightness to that pixel. The new feature detectors are based on the minimization of

this local image region, and the noise reduction method uses this region as the smoothing neighborhood. The resulting methods are accurate, noise resistant and fast (Tandianus et al., 2011).

Image recognition is often being related to the issue of determining the distance between images. The Euclidean distance is one of the methods to find the distance (Wang et al., 2005). Here, edge image is being the role of presenting the distance in a way to be the image database for the automated system. This Euclidean distance is supported with Fourier Descriptor (FD) algorithms initially. The convenient FD is carried out to define the contour of the images. Generally, FD describes the edge or the border of the images (i.e. closed curve) and FD will coordinate the points of the curves (El-ghazal et al., 2008).

3. Methodology

In this project, the FPC was design in CAD model. The model then undergone further processes which called image pre-processing that resulted image rotation, edge detection and image rendering of the FPC model. These results are combined as a database in which later can be referred in automatic inspection. The database is expected to fulfill the real-life situation in FPC inspection as the environment affect the FPC by its position, lighting and others.

Methodology of this project is illustrated in figure below:

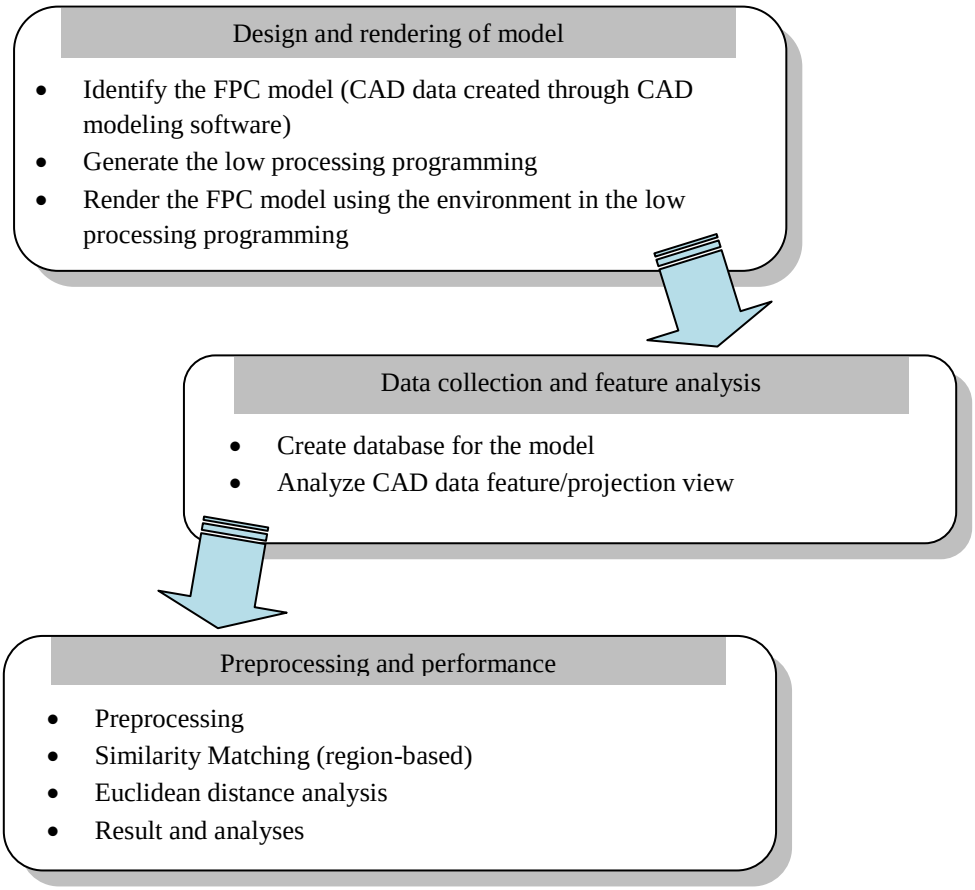


Fig. 1 The flow of methodology

3.1 Generate CAD Model in low processing programming

After the CAD Model had been saved into STL or SLP format file, the file is used for rendering in low processing programming. Environment setting is done through the low processing programming coding by adding or removes some of the image characteristics. For this research, the lighting from the image had been added or removed and the

image is set up to be rotated from isometric view to top view position by changing the angle of azimuth (horizontal rotation) and elevation (vertical rotation). In this process, the color of the image of its edges and faces color is also been set. After the CAD model is generated in the low processing programming, it is saved in JPG format and will be called for the next process.

3.2 Image Preprocessing

Image preprocessing is the term for operations on images at the lowest level of abstraction whose aim is an improvement of the image data that suppress undesired distortions or enhances some image features important for further processing. It does not increase image information content. Its methods use the considerable redundancy in images. [11]

There are three image preprocessing analysis phases:

1. Original

The real image of CAD model is used in the process where the generation of CAD Projection image in low processing programming platform.

2. Lighting as noise

Lighting is added to the image. During projection, the parameter of lighting angle for illumination is set so that, lighting will produce shadows to the image and it affects the quality of the image and the edge detection. The result of this image will be compared with the original image.

3. Image rotation

The FPC image is rotated about 360° with limitation of 1° in each rotation. Such preprocessing is done to adapt the FPC model in real inspection environment. In manufacturing line, specifically in inspection process, the FPC may come in various image position or angle. The input FPC angle may differ from the database. So, this method is expected to be an adaptable database for the automated inspection.

3.1 Edge Detection

Edge detection is a fundamental tool used in most image processing applications to obtain information from the frames as a precursor step to feature extraction and object segmentation. This process detects outlines of an object and boundaries between objects and the background in the image.

There are many methods that can used to detect edge in low processing programming. But in this research, Canny Edge Detection method had been chosen and implement. The Canny algorithm uses an optimal edge detector based on a set of criteria which include finding the most edges by minimizing the error rate, marking edges as closely as possible to the actual edges to maximize localization, and marking edges only once when a single edge exists for minimal response.

3.2 Feature Vector

In pattern recognition and machine learning, a feature vector is an *n*-dimensional vector of numerical features that represent some object. Many algorithms in machine learning require a numerical representation of objects, since such representations facilitate processing and statistical analysis. When representing images, the feature values might correspond to the pixels of an image, when representing texts perhaps to term occurrence frequencies.

3.3 Similarity

Shapes matching or shapes correlation is studied through this similarity method. The matching process is aided by angle orientation of two constitutive images. Reference image is set with its orientation angle then later being matched with query image in the range of 0° and 360° with the limitation of 1°. The matching result will later be analyzed by relating the target and query images through their Euclidean distance.

3.4 Euclidean distance

Edge detection from the Fourier descriptor is based on the edge image. Points of the closed border or edge image are further analyzed to get the distance between query and target image. Here the distance being the role of database which consist the relation or the closeness distance between the query and target images.

4. Results and discussions

4.1 Image rotation

Low processing programming algorithm is further studied and resulting the ability of programming in rotating image. FPC model is brought up front to undergone this preprocessing. FPC model is rotated about 360° with the limitation of 1°. Thus there are 361 images resulted from this process starting from the image of 0° until 360°. Image below shows image rotation of the FPC model:

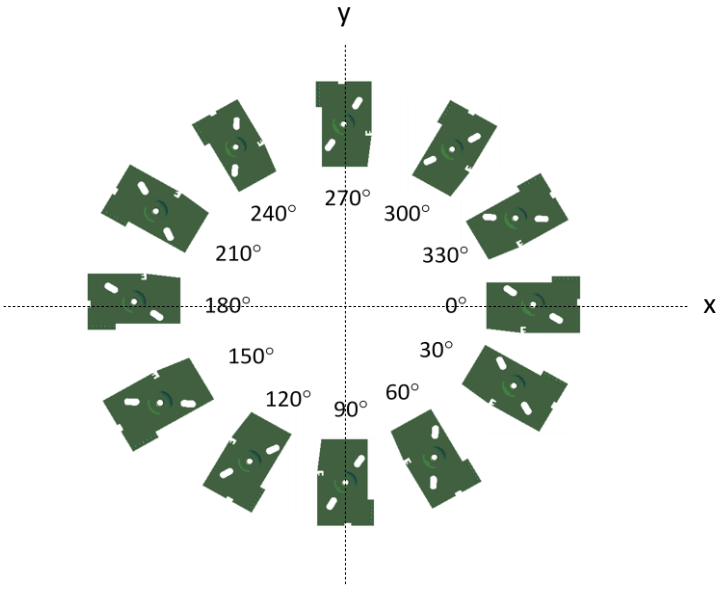
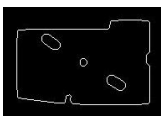
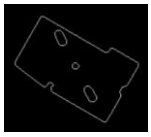
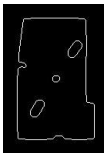
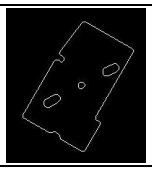
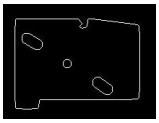
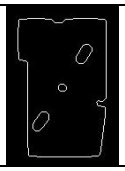


Fig.2 Image rotation

4.2 Edge detection

FPC model is gone through the preprocessing that detecting the edge of the image. The image of every rotation angle is having its own edge image. This process is vital is detecting defects on the FPC model. From table below, the features of consecutive image can be seen clearly (e.g., features like the holes, fillet and curvature). This will ease the system to detect the defect with the regards of the input orientation angle of the FPC model.

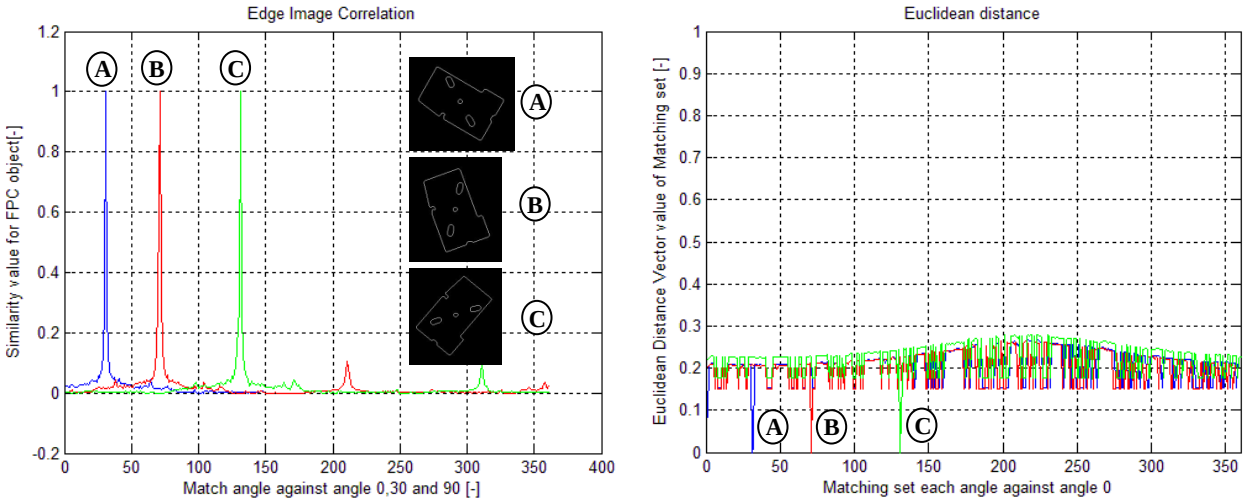
Table 1 Edge images

Edge image and its orientation angle					
0°	30°	90°	120°	180°	270°
					

4.3 Similarity

Similarity method here is a process to find image correlation. For example, database is set to 0° (reference image) and the input data (query image, which FPC image captured by the camera in manufacturing line) is 2°. This method will find the correlation between these two (2) images (the 0° and 2° image). The image correlation is defined within value of 0.00000 until 1.00000. The numbers indicate the similarity between the query images with the reference image. Value of 1.00000 shows that the two images (e.g., reference image and query image) are perfectly matched with identical orientation angles. Graph below show the variation of image correlation with the reference images of 30°, 70° and 130°:

From the graph in Fig. 3, it is clearly shown that on the angle of 30°, 70° and 130° having the highest peaks with the value of 1.00000. This shows how the two constitutive images that are being compared are sharing the same orientation angle. While the other images that not sharing the same image shows the value closer to zero with some randomly small peaks in between. This phenomenon also can be applied to the rest of 360 degree angle.



a) b)

Fig. 3 a) Graph of edge image correlation, b) Graph of Euclidean distance

4.4 Fourier Descriptor and Euclidean distance.

Fourier descriptor is developed to recognize the contour points of the edge image. The points later go through the matching stage where Euclidean distance is taken into the analysis. Hundreds of points indicating the curvature of the FPC edge images are being matched to the target images using the Euclidean distance.

Table 1 Correlation value and Euclidean distance of target image with query images.

	Reference angle					
	30°	70°	130°	30°	70°	130°
Query image angle	Correlation value			Euclidean distance		
0°	0.02144	0.00212	0.00165	0.08361	0.20246	0.22175
30°	1.00000	0.01336	0.00201	0.00000	0.20886	0.22775
50°	0.27133	0.01885	0.00255	0.20828	0.20668	0.22517
70°	0.13179	1.00000	-0.00178	0.20886	0.00000	0.2265
90°	0.07723	0.01726	0.01526	0.15313	0.15014	0.176
110°	0.05985	0.00468	0.02173	0.21918	0.21766	0.23582
130°	0.04639	-0.00178	1.00000	0.22775	0.2265	0.00000

5. Conclusions

In this research, the developed low processing programming algorithms is adaptive and significant in being database for the automated visual inspection for FPC product. The algorithms are made to match with the reality in inspection environment. Several image processing is done in developing a robust database. Feature vector and image correlation by using Similarity method can be used in matching input data which the database. It shows relevant result as the image is being analyzed based on its orientation angle. Meanwhile Fourier Descriptor detects the curvature of images and matching the target image using the Euclidean distance are also relevant for the for the database purpose. These two methods are still in analysing stage in finding the better result for database image processing.

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