MEASUREMENT MODEL OF BRASS PLATED TYRE STEEL CORD BASED ON WAVE FEATURE EXTRACTION

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DEDICATION

This dissertation is dedicated to my beloved family, who taught me that the best kind of knowledge to have been that which is learned for its own sake. It is also dedicated to my mother, who taught me that even the most significant task could be accomplished if it is done one step at a time

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ABSTRACT

In the production of Truck and Bus Radial (TBR) vehicle tyres, one of the essential components is the wire that supports the tyre. There are several types of tyre wire, one of which is Brass Plated Tyre Steel Cord (BPTSC), produced by Bekaert Indonesia Company. BPTSC object has a micro-size with a diameter of 0.230 mm and has a wave shape. In checking the quality of steel straps, brass-coated tyres are usually measured manually by experienced experts by measuring instruments to measure the diameter using a micrometre, wave amount, and wavelength using a profile projector. The manual measurement process results in inaccuracy due to fatigue in employees' eyes and low lighting and must be repeated, thus, consuming more time. Technological developments that use computer vision are increasingly widespread. Moreover, from the results of studies in various literature, it is proposed to combine the models obtained to find new models to solve this problem. The objectives of this study were to implement and evaluate an automatic segmentation method for obtaining regions of interest, to propose a BPTSC diameter, wave amount, and wavelength measurement model based on its edge, and to evaluate the proposed model by comparing the results with standard and industrial measurement results. The technique to prepare the brass plated tyre steel cord was done in two ways: image acquisition techniques with enhanced image quality, noise removal, and edge detection. Secondly, ground truth techniques were utilised to find the truth about the stages of the image acquisition process. Finally, sensitivity testing was conducted to find the similarity between the acquired images and the ground truth data using Jaccard, Dice, and Cosine similarity method. From 148 wire samples, the average similarity value was 93% by Jaccard, 96% by Dice, and 91% by the Cosine method. Thus, it can be concluded that the acquisition stage of the brass-coated steel tyre cable with image processing techniques can be carried out. For the subsequent process, the pixel distance and the sliding windows model applied can correctly detect the diameter of the BPTSC properly. The wave amount and wavelength of BPTSC objects in the form of waves were measured using several local minima and maxima approaches. This included maxima of local minima maxima distance, the average of local minima maxima distance, and perpendicular shape to centre distance for measuring wave amounts. While for wavelength measurements, the midpoint of local maxima minima distance and the intersection of local maxima minima with a central line were used. Measurement results were evaluated to determine the accuracy and efficiency of the measurement process compared to standard production values using the accuracy, precision, recall, and Root Mean Square Error (RMSE) test. From the evaluation results of the two methods, the accuracy rate of diameter measurement is 97%, wave rate measurement is 95%, and wavelength measurement is 90%. A new model was formed from the evaluation results that could solve these problems and provide scientific and beneficial contributions to society in general and the companies related to this industry.

ABSTRAK

Dalam pengeluaran tayar kenderaan Jejari Lori dan Bas (TBR), salah satu komponen penting ialah wayar yang menyokong tayar. Terdapat beberapa jenis wayar tayar, salah satunya ialah Kord Keluli Tayar Bersalut Loyang (BPTSC), keluaran Syarikat Bekaert Indonesia. Objek BPTSC mempunyai ukuran mikro dengan diameter 0.230 mm dan mempunyai bentuk gelombang. Dalam memeriksa kualiti tali keluli, tayar bersalut tembaga biasanya diukur secara manual oleh pakar yang berpengalaman dengan alat pengukur, untuk mengukur diameter menggunakan mikrometer, kadar gelombang dan panjang gelombang menggunakan projektor profil. Proses pengukuran manual menghasilkan ketidaktepatan disebabkan oleh keletihan pada mata pekerja, dan pencahayaan yang rendah, pengukuran mesti diulang, dengan itu memerlukan lebih banyak masa. Perkembangan teknologi yang menggunakan penglihatan komputer semakin meluas. Selain itu, hasil kajian dari pelbagai literatur, dicadangkan untuk menggabungkan model yang diperoleh untuk mencari model baru untuk menyelesaikan masalah ini. Objektif kajian ini adalah untuk melaksanakan dan menilai kaedah segmentasi automatik untuk mendapatkan kawasan yang menarik, untuk mencadangkan reka bentuk diameter BPTSC, jumlah gelombang, dan model pengukuran panjang gelombang berdasarkan kelebihannya dan untuk menilai model yang dicadangkan dengan membandingkan keputusan dengan standard dan hasil pengukuran industri. Teknik untuk menyiapkan wayar keluli tayar bersalut tembaga dilakukan dengan dua cara; teknik pemerolehan gambar dengan peningkatan kualiti gambar, penghapusan bunyi, dan pengesanan tepi. Kedua, teknik kebenaran tanah digunakan untuk mencari kebenaran tentang tahap proses pemerolehan gambar. Akhir sekali, ujian kepekaan telah dilakukan untuk mencari persamaan antara pemerolehan gambar dan data kebenaran tanah menggunakan kaedah persamaan Jaccard, Dice, dan Cosine. Daripada 148 sampel wayar, nilai persamaan purata ialah 93% oleh Jaccard, 96% oleh Dice, dan 91% oleh kaedah Cosine. Oleh itu, dapat disimpulkan bahawa tahap pemerolehan wayar tayar keluli bersalut tembaga dengan teknik pemprosesan gambar boleh dijalankan. Untuk proses berikutnya, jarak piksel dan model tingkap gelangsar yang diterapkan dapat mengesan diameter BPTSC dengan betul. Jumlah gelombang dan panjang gelombang objek BPTSC dalam bentuk gelombang diukur menggunakan beberapa pendekatan kaedah minima dan maksima setempat. Ini termasuk maksima bagi jarak minima maksima setempat, purata jarak minima maksima setempat, dan bentuk serenjang hingga jarak pusat untuk mengukur jumlah gelombang. Manakala bagi pengukuran panjang gelombang, titik tengah jarak maksima minima setempat, dan persilangan bagi minima maksima setempat dengan garis pusat digunakan. Hasil pengukuran dinilai untuk menentukan ketepatan dan kecekapan proses pengukuran berbanding dengan nilai pengeluaran piawai menggunakan ujian ketepatan, kepersisan, ingatan kembali, dan Punca Min Ralat Kuasa Dua (RMSE). Daripada hasil penilaian kedua-dua kaedah, kadar ketepatan pengukuran diameter ialah 97%, pengukuran kadar gelombang ialah 95% dan pengukuran panjang gelombang ialah 90%. Model baru telah dibentuk daripada hasil penilaian yang boleh menyelesaikan masalah ini dan memberikan sumbangan secara saintifik dan bermanfaat kepada masyarakat amnya dan syarikat yang berkaitan dengan industri ini.

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LIST OF ABBREVIATIONS

BPTSC	-	Brass Plated Tyre Steel Cord
CCD	-	Charged Couple Device
CD	-	Compact Disc
CT	-	Computerized Tomography
FWHM	-	Full Width at Half Maximum
FSIM	-	Feature Similarity Indexing Method
GM	-	Growing and Merging
HD	-	Hausdorff distance
HPF	-	High-Speed Camera
HSC	-	High Pass Filter
HSI	-	Hue, Saturation, and Intensity
HVS	-	Human Visual System
IR	-	Image Restoration
JSC	-	Jaccard Similarity
LED	-	Light Emitting Diode
MRI	-	Magnetic Resonance Imaging
MSE	-	Mean Square Error
PSNR	-	Peak Signal-to-Noise Ratio
px	-	Pixels
RGB	-	Red Green Blue
RMSE	-	Root Mean Square Error
RQ	-	Research Questions
SAR	-	Synthetic Aperture Radar
SEM	-	Scanning Electron Microscopy
SM	-	Splitting and Merging
SSIM	-	Structured Similarity Indexing Method
SW	-	Sliding window
TBR	-	Truck Bus and Radial
TV	-	Television

LIST OF SYMBOLS

δ	-	Minimal error
D, d	-	Diameter
F	-	Force
v	-	Velocity
p	-	Pressure
I	-	Moment of Inertia
r	-	Radius
©	-	Copyright
®	-	Registered Trademark

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CHAPTER 1

INTRODUCTION

1.1 Overview

In the increasingly free market of the current globalization era, companies have continued to grow and develop. Concerted efforts are focused on increasing profits, marketing products, and achieving overall market share. The demand for companies to create quality products at the minimum production cost possible has never been more critical; product quality is direct to customer satisfaction (Chenavaz and Feichtinger, 2020). Moreover, product quality also determines the marketability of a product (Piveteau and Smagghue, 2019). Thus, it is often used as a benchmark to distinguish similar products (Sarkaniputra, 2018).

This study considered the manufacturing industry, specifically Bekaert Indonesia, a Belgian company processing brass-plated tyre steel cord (BPTSC) raw material in Indonesia. One of the tyre's most essential components is the wire it is made of (Dash, 2019). Tyre cords are usually checked manually by experts such as experienced staff to ascertain their quality (Balderstone and Livadeas, 2019). However, the wires used in tyres have experienced innovation over the past years and have had varied forms. In recent years, research interest is now moving toward wave-shaped tyre wire. The waveform is deliberately made to form a pattern to serve as the basis for the following process for wire fitting. However, the wavy form of the wire makes it difficult for inspection officers to detect the quality of the BPTSC in terms of diameter, wave amount, and wavelength of BPTSC. While this variation in shape is essential, it is also challenging to inspect the quality of BPTSC.

The basic principle of tyre wire defect detection is to guarantee the quality of the tyre wire (Li *et al.*, 2018). The common approach to this relies on direct contact detection techniques, in which a micrometre calliper is used to measure and obtain the wire diameters and profile projectors for getting the wave amount and wavelength (Tyurnina and Bandurin, 2019). In practice, the inspector usually chooses samples of BPTSC by cutting the end to a length that is estimated to be sufficient for direct measurement with a sliding gauge and profile projectors in the laboratory.

For more details, the current manual measurement method is carried out by the Lab Specialist PT Bekaert Indonesia which takes BPTSC samples from each running production machine. The measurement of BPTSC quality consists of diameter using a micrometre calliper while measuring the number of waves and wavelengths using a projector profile. The measurement process is carried out three times, the measurement results of the three BPTSC samples are averaged by adding and dividing by three according to the results of each measurement. The final result of manual BPTSC measurement is the average value of the diameter, number of waves and wavelength which will be compared with standard values having a minimum and maximum range. In determining the criteria for good quality BPTSC, Bekaert has standard specifications they refer to Table 1.1

Table 1.1 Standard measurement value BPTSC (Bekaert Indonesia Company)

No	**Item Test**	**Specification (mm)**		
		Min	**Aim**	**Max**
1	Wire Diameter	0.230	0.240	0.250
2	Wave Amount	0.330	0.400	0.470
3	Wavelength	3.420	3.600	3.780

Table 1.1 shows the wire specifications for standard BPTSC in terms of the minimum, aim, and maximum values. The aim shows the target values while the min and max show the minimum and maximum values, respectively. If the results of measurements fall outside the specifications, the BPTSC is declared defective or Not Good (NG).

In the development of defect detection, several approaches have proposed the use of non-contact detection. The method favoured by most large-scale companies is photoelectric and electromagnetic (Brekhna *et al*., 2019; Barros *et al*., 2020). These techniques and the needed experts to operate them are inherently expensive. Moreover, the use of image processing technologies to obtain parameter information from the sample surface without physical contact has also been proposed (Karothiya *et al.*, 2019).

The application of digital image processing techniques via a series of evaluative and identification approaches has been investigated by various researchers (Liu, 2018). These techniques have been used in multiple fields to facilitate assessing, inferring, and obtaining information from digital images (Zhou and Wang, 2019). Although the research directly related to measurement of wire objections still remains non-existent so far, there are similar studies in pertinent literature that attempted to determine the yarn diameter carried out by image processing (Sigworth, 2016). Images are taken using a digital microscopic camera at a magnification of 800x with a threaded object stretched in a straight position (Mantiuk and Richter, 2019). Furthermore, digital image processing techniques are used to measure the diameter of the yarn using the principle of pixel length, which is converted into metric units, resulting in performance similar to the theoretical count, which has an accuracy of 93% (Wijayono and Vidia, 2017). Similarly, the image of fibre slope angle on yarn can be measured using a fibre tracing method.

A yarn measurement system using computer vision can determine diameter, diameter variation, and number of thick yarns in tangled fibres in one round. The accuracy of the developed instrument is much higher because it can sense changes in the measured parameter pixels. The developed system is also useful for coloured threads with the right background. The measured parameter pixels have higher performance than manual measurement. Coloured threads against a background can also be finished using this image processing system (Sengupta *et al*., 2015). Image processing techniques and computer vision are new technological solutions to obtain an automatic characterization of linear mass, diameter and hairiness parameters. Cotton and polyester yarns were used as image test data. The results of automatic parameter extraction research can improve product quality in the textile industry (Goncalves *et al*., 2015). A microscopic image of the thread has been used to measure the diameter. The thread diameter determines the fabric structure and the effective processing arrangement. A high-speed camera (HSC) has also been used to measure the yarn diameter and its variance. The measurement results of this system can detect short-term, long-term and periodic measurements of a yarn diameter (Eldessouki *et* *al*., 2015). Digital image woven fabric samples are measured in diameter automatically. Radeon transformation is used to identify the warp and weft frequencies. Data sets of woven fabrics totalling to 81 were used for testing. The proposed method can measure yarn count and yarn liner density (Tapias *et al*., 2011). Defective chenille yarn can be controlled via digital image. Morphological unfolding and border-to-binary operations are used in image pre-processing of chenille yarns. The proposed system is capable of chenille yarn defect control. Cheap Web cameras and USBs with image processing techniques can spot the hairiness of threads. The proposed image processing uses segmentation to obtain the yarn core from fiber extraction (Roy *et al*., 2014). Before the measurement process is carried out, the image will first be converted to black and white using the im2bw feature in MATLAB® (Widiyanto and Yuli, 2017).

In addition to diameter measurement, measurement of the wave amount and wavelength of wire is often carried out (Zhiliang *et al.*, 2021). In the literature, not many researchers have investigated measuring corrugated wire objects with image processing techniques (Robertson *et al.*, 2018). However, this can be hypothetically derived from previous research by first detecting a different feature pattern with edge detection techniques and then finding out the wire wave pattern using Skeletonize technique on the wireframe. To find out the wave amount, the first thing to do is to obtain the highest and lowest points from the feature of the corrugated image before using the minimization and global maximization technique. To find the wave amount value and wavelength combined with the wave frequency theory formula (Stiller *et al.*, 2018).

From the preceding, there exists ample room for research improvement that can be used to produce methods that combine various image processing techniques and wave frequency physics techniques (Stober and Sommer, 2018). In this research, the proposed method is expected to predict measurement accuracy in diameter, wave amount, and wavelength of BPTSC. It will classify BPTSC into wire specifications with the minimum and maximum standard assessment specifications so that wire specifications other than that are declared defective or Not Good (NG).

1.2 Problem Background

Given that unwanted raw materials are used in manufacturing facilities to make BPTSC, they sometimes produce high quality-looking goods that are defective below the desired standard value (Ling *et al.*, 2018). Traditional quality inspection processes are mostly carried out through physical inspections, resulting in long reviews. Moreover, measuring the same BPTSC often differs in value when carried out by different people. Several measurements ensure good quality in traditional inspection, where an average is taken to ensure the gauge is correct. The conventional measurement method causes visual fatigue, affecting accuracy and low efficiency despite being highly labour intensive (Ngan *et al.*, 2011).

Consequently, computer vision-based detection techniques have become an essential and efficient alternative tool to improve product quality and improve manufacturing efficiency (Fang *et al.*, 2019). Figure 1.1 depicts the problem in the quality detection study on a BPTSC.

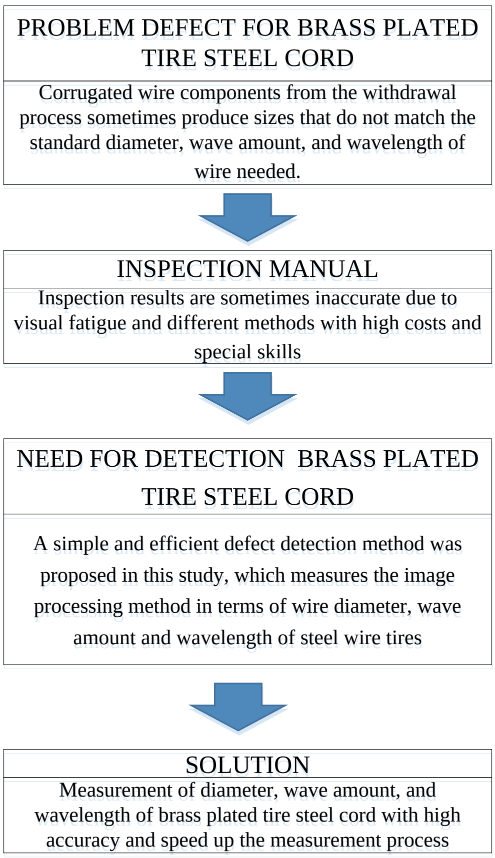

Figure 1.1 The scenario which leads to the research problem

Many methods based on different theories, such as texture analysis and spectral analysis, have been proposed to overcome the limitations of manual inspection (Chen and Mar, 2019). Defect detection compares the texture-based detection method's different texture patch image features. The main problem of this method is feature extraction (Lin *et al.*, 2019; Tong *et al.*, 2017).

The literature has also reported a dictionary-based tyre defects detection method that analyses the distribution of representation coefficients. However, this method of detecting tyre defects is only designed for images of tyre sidewalls. As a result, it fails to work for tyre tread images because of their complex structure. Although density projections based methods have been proposed to detect tyre tread images (Yang *et al.*, 2020), this method only provides defective orientation information and is mostly inaccurate.

The disadvantages of the methods mentioned above are that they do not adequately capture the distortion of the image texture. To overcome this challenge, a simple and efficient detection method is proposed in this study, which takes advantage of the similarity of the features of tyre wire drawing. In particular, for inspected images, the proposed method first estimates the texture distortion level of each pixel with the weighted average difference between this pixel and its neighbour within a local window. Local windows produce a bizarre map of the image of the tyre wire being examined. After that, the defect is located by grouping this anomaly map with a simple thresholding function.

Image processing techniques are necessary to distinguish standard quality BPTSC from defective ones (Zhang *et al.*, 2016). Metal objects such as tyre wire have a micro-size below 1mm, which causes severe shadow and scratch artefacts that are difficult to detect visually. Also, images of BPTSC have structures that can degrade pixel quality; thus, this requires a better method. One method is image processing to scan objects in the form of a brass plated steel tyre cord (Toet *et al.*, 2019). Another practicality problem is that image distortion occurs if the image is taken from a corroded brass cord plated steel tyre cord (Sarih *et al.*, 2020). This is because raw materials and the manufacturing process are imperfect. Hence, brass plated steel tyre cord tyres can contain various types of defects such as impurities, bubbles and overlaps (Zhao and Qin, 2018).

Hausdorff worked based on the principle of similarity between pixels of texture images so that there is an implicit dependency between one pixel and its neighbour (Goldenfein, 2019). Therefore, a pixel can be represented as a weighted linear combination of the surrounding pixels. Although suitable for observing straight objects, Hausdorff tended to rely on pixels that seem horizontal and vertical but not wave-shaped BPTSC, making it challenging to follow BPTSC element.

A review of pertinent literature has shown that no direct research has been found to measure wave-shaped wire objects with image processing techniques. But hypothetically, previous research can develop it by detecting a different feature pattern with edge detection techniques (Ibrahim *et al.*, 2020). The skeletonize technique has then been used to find out the wire wave pattern of the wireframe. To find the wave amount, the highest and lowest points of the feature of the corrugated image has to be obtained using the global minimization and maximization technique (Liu *et al.*, 2019). From that place, the wave amount value and wavelength combined with the wave frequency theory formula can be found (Ozturk, 2019).

1.3 Problem Statement

Several problems exist in the wire measurement models, more often than not, leading to inefficiency of the measurement techniques. Issues such as the complexity of wire measurements with conventional methods, the physical condition of employees' eyes when measuring (Vahle Hinz *et al.*, 2014), the need to repeatedly carry out wire measurements, and low-quality room conditions may be considered to have a significant adverse effect on the accuracy of measurements. There are several challenges and difficulties in this model. The development of wire measurement models with digital imagery is challenging when depicting wire drawing objects.

Because the shape of the wire drawing object is small, the digital wire images cannot be directly processed for measurements. The feature extraction technique is needed to optimise wire measurement through image processing. The feature extraction method uses segmentation based on the shape of the wire that resembles a line (Liulei *et al.*, 2018). The segmentation algorithm is divided into manual and automatic segmentation. Manual segmentation method takes a long time and is not accurate and automatic segmentation has been used for maximising micro image pre-processing (Guan *et al.*, 2008). There are many automatic segmentation methods in digital image processing. Based on previous researches, the canny segmentation method is able to solve 2D line feature extraction problems (Kim and Lee, 2015). The results of cany extraction are stronger, especially line objects that have curvature, are more effective in representing all objects, and are easier to use without thresholds (Kim and Lee, 2015). In addition, the canny algorithm is able to reduce noise contained in the object background and detect broken lines, so that the edge detection results can be maximised with a performance level of F1.79 score (Dhillon and Chouhan, 2022). Therefore, the Canny method is highly recommended for line feature extraction before measuring similarity such as dice similarity, Jaccard similarity, and correlation coefficient metric (Huang and Bhalla, 2022).

From the problems of digital image problems, therefore, ensuring the setting with proper lighting setup and focus for an appropriate photo of the wire is a challenging task at the early stage of developing a measurement model for a small size wire object with a diameter of only 0.23 mm. Thus, taking pictures of such a wave-shaped wire requires various wire measurement models with image processing techniques.

The afore-highlighted problems make the wire drawing measurement model challenging for researchers and need further research. Thus, the research hypotheses are formulated of this study as follows; the accuracy of the computer vision-based wire detection and measurement model can be improved by using a combination of measurement models of diameter, wave amount and wavelength in BPTSC wave using computer vision. An improved accuracy and time efficiency are also hypothesised, such that the results of the proposed method will be better and consistent than conventional measurements schemes.

1.4 Research Questions

In line with the afore-highlighted research problem, the related research questions that this study seeks to proffer answers to are as follows:

1. How to implement and evaluate an automatic segmentation method in obtaining regions of interest in BPTSC images?
2. How to propose a model design for measuring the diameter, wave amount, and wavelength of the BPTSC based on its edge?
3. How to evaluate the proposed model by comparing the resulted values with standard values and industrial measurement results?

1.5 Research Aim

This study aimed to implement and evaluate an automatic segmentation method for obtaining regions of interest and propose a design a BPTSC diameter, wave amount, and wavelength measurement model based on its edge and evaluate the proposed model by comparing the results with standard and industrial measurement results.

1.6 Research Objectives

The objectives of the research are:

1. To implement and evaluate an automatic segmentation method for obtaining regions of interest in BPTSC images.
2. To propose a model design for measuring the diameter, wave amount, and wavelength of the BPTSC based on its edge.
3. To evaluate the proposed model by comparing experimental results with standard and industrial measurement results.

1.7 Contribution of the study

The main contribution of this research is to develop a model that extracts representative features from images to reflect the quality of a BPTSC by measuring diameter, wave amount, and wavelength. It can be used to detect abnormality in a BPTSC. The three significant contributions that this research study provides are as follows:

1. The automatic segmentation method with edge detection gives high similarity results based on the edge of the wave-shaped BPTSC.
2. Development and design of a new model in image processing for measuring the diameter, wave amount, and wavelength of the BPTSC based on its edge.
3. Implementation and automation of the detection of quality BPTSC using computer vision for the industry.

1.8 Research Overview

This study focuses on detecting and measuring diameters, wave amounts, and wavelengths using the BPTSC dataset. Images of BPTSC have a relatively broad domain with various camera angles, dimensions, scale and sizes, aspect ratios, compression ratios, extensions, qualities, and quantization levels. Figure 1.2 presents an overview of the research conducted.

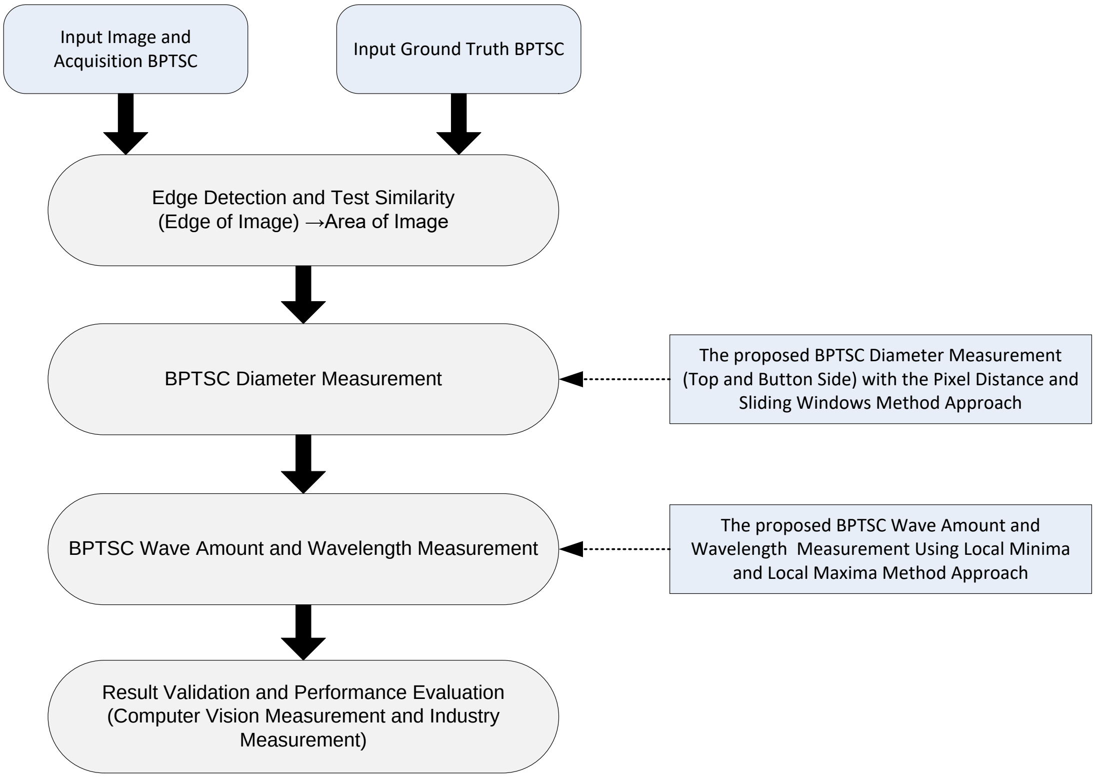

Figure 1.2 The overview of proposed research flow.

Image acquisition and ground truth are two methods in pre-processing that must be carried out before measuring the diameter, wave amount and wavelength of BPTSC. Details of this stage are further elaborated in Chapter 3. This is followed by edge detection, which was carried to perform segmentation of the input image, conversion of coloured images to black and white or binary format. The measurement of BPTSC diameter uses top and bottom and pixel distance methods for the sliding windows. In contrast, the wave and wavelength measurement stages use local minima and maxima approach models to complete the measurement process. Result validation was done by calculating statistical data to find the difference between computer vision and industry measurements.

1.9 Research Scope and Limitation

This study focused on detecting and measuring the diameter, wave amount, and wavelength using sample images of BPTSC. Images of BPTSC have a relatively broad domain with various camera points of view, dimensions, scale and sizes, aspect ratios, compression ratios, extensions, qualities, and quantization levels. In terms of intrinsic features, this study is limited to the following:

1. Using the exact image size, to ensure constant calibration measurements in this study.

2. The extension of BPTSC images where in typical image extensions like BMP, JPG, TIF, and PNG covered this research's scope.

3. Quality of detection of BPTSC functions like a BPTSC gauge. In the detection and measurement process, features vectors determine the diameter, wave amount, and wavelength. The difficulty in this stage lies in the variability of feature values. Therefore, various techniques were used to determine the detector that gives the most satisfactory results.

4. The file size of 100KB, a resolution of 1280 x 960 px, horizontal, a vertical resolution of 96 dpi and a bit depth of 24.

1.10 Thesis Structure and Organization

This thesis is organized in line with the proposed measurement stages of the BPTSC quality detection with image processing method.

Chapter 1 presents the objectives of this study and a brief review of the research background. The scope, limitations, research contributions, and research overview are also highlighted.

Chapter 2 presents a comprehensive review of pertinent literature in BPTSC, digital image processing, and image similarity. A critical discussion of BPTSC measurements and the disadvantages of the famous manual measurements are also presented.

Chapter 3 explains the research methodology, which consists of data preparation, research framework, operational research procedures, principal and theoretical background of the proposed algorithm, applied in BPTSC detection and measurement studies.

Chapter 4 explains the proposed intensity of image standardization as an essential process of image acquisition, segmentation, and methods of testing similarity. The performance and evaluation methods proposed are discussed in this chapter. Furthermore, the conclusion from evaluating the similarity of ground truth and image acquisition data using Jaccard, Dice, and Cosine similarity methods is also presented. The performance of each technique in measuring the diameter, wave amount and wavelength discussed in Chapter 5 and are evaluated discussed in Chapter 6. The conclusions in terms of research findings, limitations, advantages of the proposed method, and recommendations for future work are presented in Chapter 7.

1.11 Definition of Terms

The terms that are often used throughout this thesis are defined as follows:

1. The figure of BPTSC:

   Images displaying items or containing explicit descriptions intended to be tested. Brass plated tyre steel cord: Steel tyre cord has been used to reinforce tyre products with excellent elasticity and strength.

2. Detection model for edge detection:

   The operation carried out to detect edges that limit two homogeneous image regions with different brightness levels.

3. Variation of image background:

   Image background variations or background reduction is an easy and effective method for detecting foreground objects in a stationary background. However, in real-world, especially in outdoor settings, restrictions such as stable backgrounds often become impractical because the background scene is unstable.

4. The Intensity of image brightness:

   The intensity is a measure of wave energy, which is directly proportional to the square of the wave amount. Brightness depends on wave amount and wavelength. So, the difference between bright blue light and dim blue light is due to the difference in wave amount because they have the same wavelength. However, for blue and yellow light, the brightness depends on the wave amount and the wavelength. The human eye is more sensitive to yellow light, so this study considered it the brightest.

5. Image Processing:

   Image processing is a method of carrying out several operations on an image to get an enhanced picture or extract some helpful information or features. Image processing is signal processing where the input is an image, and the output is a form of images or characteristics or attributes associated with the image. Nowadays, image processing is one of the fastest-growing technologies. This forms the core research field in the discipline of computer vision.

6. Feature descriptors:

   The feature descriptor represents and measures image patches centred on points detected by the feature detector.

7. Feature extraction:

   Feature extraction refers to identifying meaningful information and features of an image using feature detectors and representing them numerically by feature descriptors. The feature extraction technique finds image anomalies and discontinuities or recognises image semantics. Indeed, this anomaly can provide clues to predict image semantics.

1.12 Summary

This chapter provides an introduction to this research, starting from the background of the study, followed by identifying problems and the relevant research questions (RQ). The research objectives have also been incorporated into the theoretical framework and the scope of the study. Further elaboration has also been given on the original contribution and significance. This chapter ends with a brief outline of the structure of the thesis, its organization, and the definition of some common terms.

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