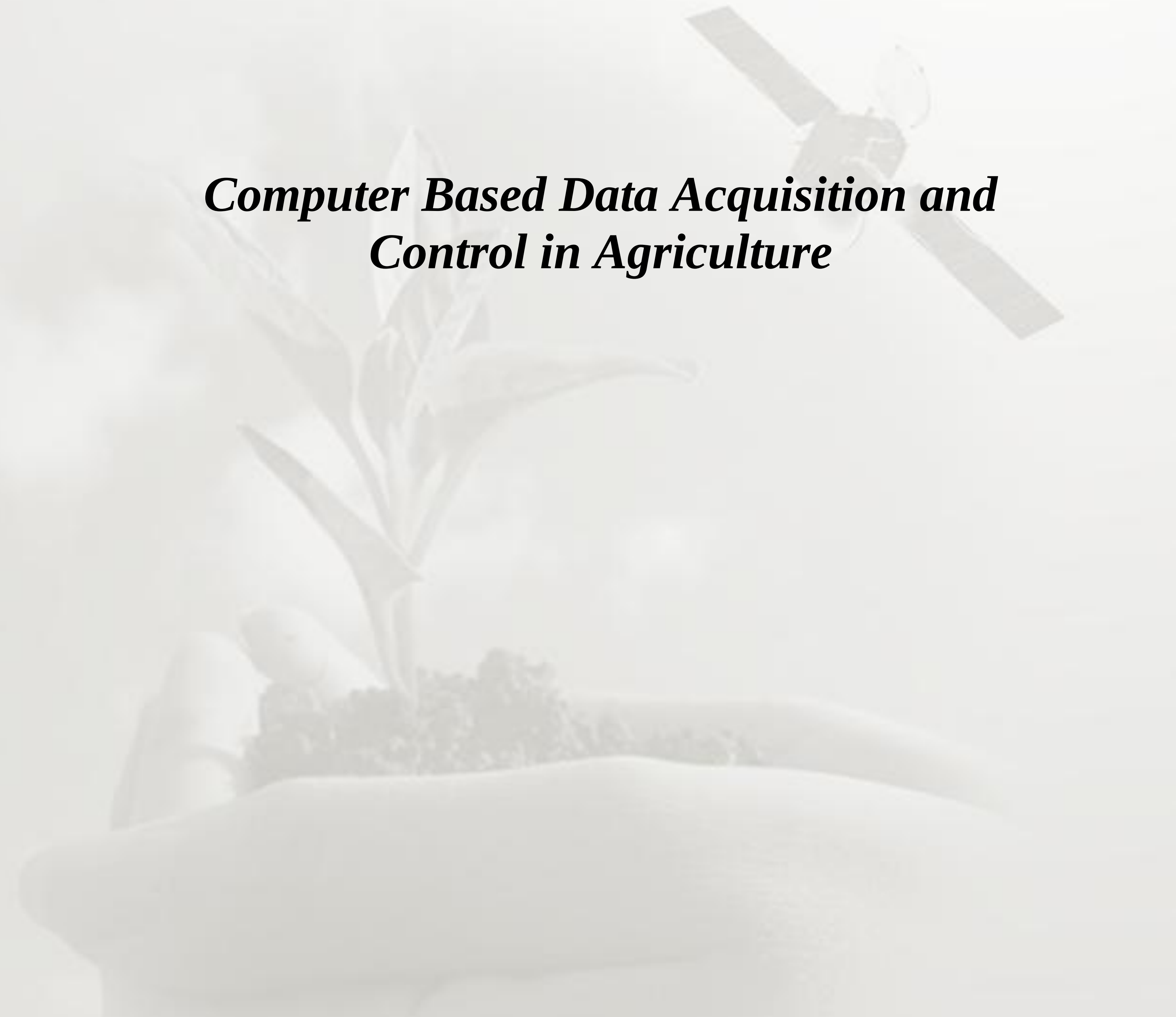
Computer Based Data Acquisition and Control in Agriculture



The Development of Automatic Coffee Sorting System Based on Image Processing and Artificial Neural Network

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Abstract — The objective of this research was to develop an automatic sorting system which consist of a computer program of image processing and artificial neural network to identify quality of green coffee. Image of the green coffee will be analyzed to get six quality parameters which match the green coffee quality criteria namely length, area, perimeter, defect area, index of red color, and index of green color. Those six quality parameters will be used as training data inputs (75 percent) of the developed artificial neural network (ANN). The weights of the ANN architecture will be used to identify the quality class of testing data (25 percent), then integrating with image processing program so the program can identify green coffee quality class automatically. The outputs of the program will be used as inputs for PPI 8255 as the I/O expansions port for the PC. The output of PPI 8255 will be connected with sorting simulator as the replacement of sorting mechanism.

Keywords: sorting, green coffee, image processing, artificial neural network

I. INTRODUCTION

Coffee is a widely-consumed stimulant beverage prepared from roasted seeds, commonly called coffee bean, of the coffee plant. Coffee is the second commodities the most trade in the world after oil. Indonesia is the world's fourth largest coffee producer and exporter after Brazil, Vietnam, and Colombia.

Mechanical coffee grading technique in Indonesia is still limited based on size and density. Some of machine vision based on size and color has been developed in Indonesia for orange, mango, and manggosteen. Machine vision for grain is not well developed in Indonesia.

Currently, commercial grain quality inspection relies primarily on visual inspection. Apart from poor efficiency, the objectivity and consistency of manual grading pose major problems, so the development of effective automated inspection equipment and methods is needed and important. Using computers coupled with machine vision devices, automated visual inspection machines can provide faster and more objective grain quality inspection for characteristics such as grain contour, size, color variance and distribution, damage, etc.

There have been many studies on image processing for grain quality inspection. For example, Blasco [1] developed a computer vision-based machine used color feature to inspect arils and classify it in four categories. The machine is capable of detecting and removing unwanted material and sorting the arils by color. Pearson [2] developed a low-cost line scan imaging system was developed to inspect and sort grains and other products at high speeds (40 kernels/s). The device captures bi-chromatic images from opposite sides of each kernel and processes the images in real time using high speed microcontrollers. Wan [3] developed an automatic kernel (rice, wheat, Job's–tear, and sorghum) handling system unit, consisting of an automatic inspection machine and an image–processing for machine vision inspection of grain quality. Steenhoek [4] used color features and shape feature such as area to evaluate corn damaged, Shatadal [5] used color features in the RGB (red, green, blue) images of grain to classify sample soybean seeds damaged.

Artificial neural networks are gaining widespread acceptance in cereal grain classification and identification tasks. Artificial neural network (ANN) classifiers, which are regarded as an extension of many classification techniques developed over several decades, are emerging as the best suited classifiers for pattern recognition. These networks are inspired by the concept of biological nervous system, have proved to be robust in dealing with the ambiguous data and the kind of problems that require the interpolation of large amounts of data. Instead of sequentially performing a program of instructions, ANNs explore many hypotheses simultaneously using massive parallelism. Neural networks have the potential for solving problems in which some inputs and corresponding output values are known, but the relationship between the inputs and outputs is not well understood or is difficult to translate into a mathematical function. Thus, these classifiers have a great potential in tasks involving grading, sorting and identifying agricultural products [6]. Published literature indicates that in most of the efforts to classify agricultural products using ANN classifiers, multi-layer feed forward networks were used [7], [4], and [5].

The green coffee bean classification standard provided by the SCAA is an excellent method to compare coffee bean. It is superior over some systems in that it better accounts for the relationship between the defective coffee bean and the cup quality [8]. In this research, back propagation NN (BPNN) used to separate specialty grade green coffee bean with defective green coffee bean.

II. Objectives

The objectives of this study were to:

1 Develop a green coffee bean sorting system that can continuously present multiple matrix–positioned green coffee bean for photographing, and provide individual green coffee bean images with image processing.
2 Develop a photographing station using two cameras to get above and beneath surface of green coffee bean.
3 Develop a BPNN algorithm that can classify specialty green coffee bean and defective green coffee bean accurately.
4 Study the performance of the system

III. Materials and Methods

A. Data Source

The Indonesian Coffee and Cocoa Research Institute, Jember, East Java, provided the green coffee samples used in this study. Mix grade of Coffea arabica were the coffee samples used in this study.

B. The Automatic Sorting System

The system was composed of two main parts: a sorting machine and an image–processing unit, as shown in fig. 1. The sorting machine had a trapezoidal profile and was constructed with a conveyer belt on top of a stainless steel frame. The trapezoidal frame had a glossy surface and smooth upper corners to provide an even path for the grain kernels moving on it. The dimensions of the machine were 147.5 L × 38 W × 70 H cm.

The surface color of the conveyer belt was white. The shape of the carrying holes of the conveyer belt was round, about 9 mm in diameter.

Counterclockwise, the machine consisted of a manual feeding section, a photographing station, and a simulation of discharging section. The conveyor belt was wound around the three sections and driven by a stepper motor connected to the bearing on the lower left corner. The stepper motor was Sanyo Denki 103H581-70B1 0.72 degrees/step (at full step) 0.75 amperes 24 – 36 VDC, completed with DC type Power Supply Driver PMM-BD-5702.

In brief, the green coffee bean handling procedure involved the following steps. First, green coffee bean were dropped in feeding section and scattered manually over a predetermined matrix positioned on a conveyer belt in the manual feeding section. Second, the conveyer belt moved the positioned kernels to be photographed by the two CMOS cameras on top and bottom connected to the computer of the image–processing unit via USB connections.

The computer segregated the green coffee bean images from the background, calculating quality parameter, provided a recognition process with BPNN, and transferred the final sorting results to the PPI 8255 via parallel port.

Third, in the discharging section, the program signaled each LED to identify the green coffee bean corresponds to the each quality. An interface protocol was developed between the sorting machine and the image–processing unit to coordinate their concurrent activity.

Photographing station composed of two The Imaging Source DFK 21BUC03 color CMOS digital camera was used on top and bottom of photographic section to examine green coffee bean illuminated from above and below. Under the conveyer belt, a piece of stainless steel frame in the photographing station was replaced by transparent glass. In the second photographing section, the transparent glass permitted illumination from below for detecting characteristics of green coffee bean or inspecting the underside of the grain kernels by adding another photographic device below. Both light sources were 220V, 10 W Philips fluorescent desk lamps. The CMOS cameras had a resolution 640 (H) × 480 (V) effective pixels. They sent RGB signal via USB connections to the PC. The camera lens was a Computar T4Z 2813 CS Vari-Vocal 4×, 2.8~12 mm, F1.3.

The fields of view of the cameras were designed to cover 4 × 4 matrix of carrying holes (a 10 × 10 cm square area), with a total of 16 carrying holes in an image frame. The conveyor belt was temporarily stopped for the cameras to photograph green coffee bean. The level of illumination varied according to direction of lighting sources, voltage fluctuation, lamp decay, and camera diaphragm setting.

A Pentium IV 3.0 GHz Laptop was used for image processing, quality recognition, and machine operation. The laptop had USB connections to for two CMOS camera, also had parallel port connected to the programmable parallel interface PPI 8255 expansion card. PPI 8255 used to expand the port became 3 × 8 bit data lines. 4 data lines used as output for stepper motor control, and 16 data line used as output for signaled 16 LED parallel discharge simulator.

C. Development of Green Coffee Quality Evaluation with Image Processing

In this study the evaluation applied to divide green coffee bean become 4 criteria namely A, B, C, Reject (RJ). Target quality expected was specialty grade green coffee based from SCAA (Specialty Coffee Association of America). Therefor A, B, C was specialty grade. The difference between A, B, C were size, whereas A class was green coffee bean blocked by 7.5 mm diameter sieve; B class was green coffee bean blocked by 6.5 mm diameter sieve, and C class was green coffee bean blocked by 5.5 mm diameter sieve. RJ class consisted of small green coffee (slip off 5.5. mm sieve) and defected green coffee.

According to Ciptadi [9] and Siswoputranto [10] the main aspects to determine the green coffee bean quality were: (1) size; (2) shape; (3) color; (4) defect; and (5) other materials. Those five aspects ware quality criteria and could be described to quality parameters that represented image processing feature. Those features were (1) area, (2) length, (3) perimeter, (4) defect area, (5) red index, and (6) green index. Each green coffee bean image extracted individually to get those six quality parameters, stored in text files, and will be used as inputs of the developed BPNN.

An Intel Pentium IV 3.0 GHz laptop with 2 GB main memory was used for image processing. The two CMOS digital cameras were connected with USB connector in the laptop. The color image used RGB 32–bit format 640 × 480 resolution and was stored in the BMP (bit–mapped protocol) format. The inspection software for machine control and image processing was developed in the Windows XP environment using a C # language from SharpDevelop 3.2. In the software, a photographed image was scanned from left to right and top to bottom to find a starting edge point for each green coffee bean.

D. Neural Network Architectures

Back-propagation networks are the most commonly used networks because of their ability to generalize. A back propagation neural network (BPNN) consists of an input layer, one or more hidden layers, and an output layer.

For each class, six quality parameters (as input layer neurons) from the color images of 2500 kernels (625 each from 4 classes) were extracted. While training the network, 2000 green coffee (500 each from 4 classes) were randomly chosen for training and 500 green coffee bean (125 each from 4 classes) were used for testing the performance of the trained network. Bipolar number will be used to represent two output neurons. The algorithm of BPNN described in table 1, and the BPNN architecture described in fig. 2. Matlab program will be used to analyze the BPNN.

The weights of the ANN architecture will be used to identify the quality class of testing data (25 percent), then integrating with image processing program so the program can identify green coffee quality class automatically. The outputs of the program will be used as inputs for PPI 8255 as the I/O expansions port for the PC. The output of PPI 8255 will be connected with sorting simulator as the replacement of sorting mechanism.

TABLE 1. BPNN STRUCTURE

Characteristic	Specification
Architecture	
– Input layer neurons	6
– Hidden layer neurons	Trial and error
– Output layer neurons	2 target definition
Initial weight	Nguyen-Widrow
Activation function	Sigmoid bipolar (input – hidden)
	Sigmoid bipolar (hidden–output)
Mean Square Error	Trial and error
Learning rate	0.1 – 0.3
Momentum	0.9 – 0.7

TABLE 2. TARGET DEFINITION FOR OUTPUT LAYER NEURONS

Class	Target	
A (blocked by 7.5 mm sieve, not defective)	1	1
B (blocked by 6.5 mm sieve, not defective)	1	-1
C (blocked by 5.5 mm sieve, not defective)	-1	1
RJ (slip off 5.5 mm sieve, defective)	-1	-1

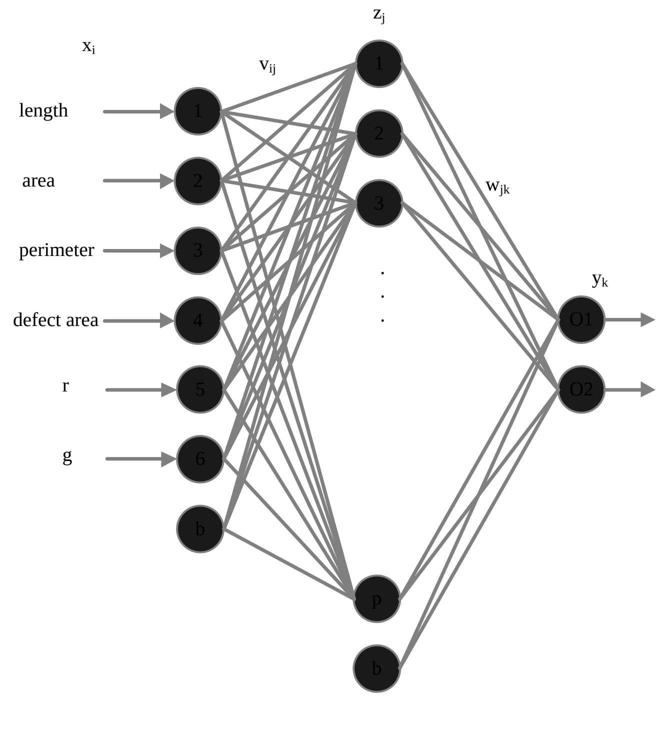

Figure 2. BPNN Architecture.

IV. PROGRESS OF THIS STUDY

Fabrication of sorting machine almost finished. Previous research has been conducted to study the performance of image processing to analyze the green coffee bean image. In this previous research, six quality parameters could extract successfully from green coffee bean image. Statistical method used to analyze the six quality parameters. The report said that using those six quality parameters, image processing could classify the sample into 4 criteria. From 512 samples the overall accuracy was 78.32%. Details of the accuracy were: A class 64.84%; B class 64.06%; C class 87.50%; RJ class 96.88%.

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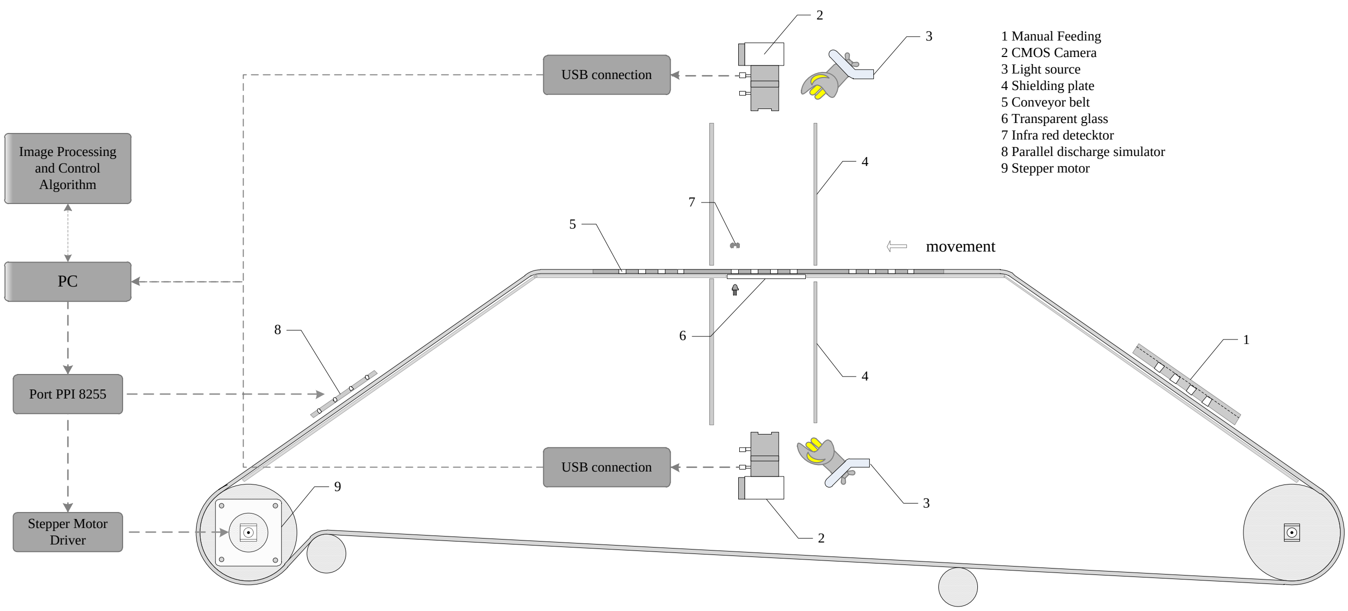

Figure 1. Design of the Automatic Coffee Sorting System

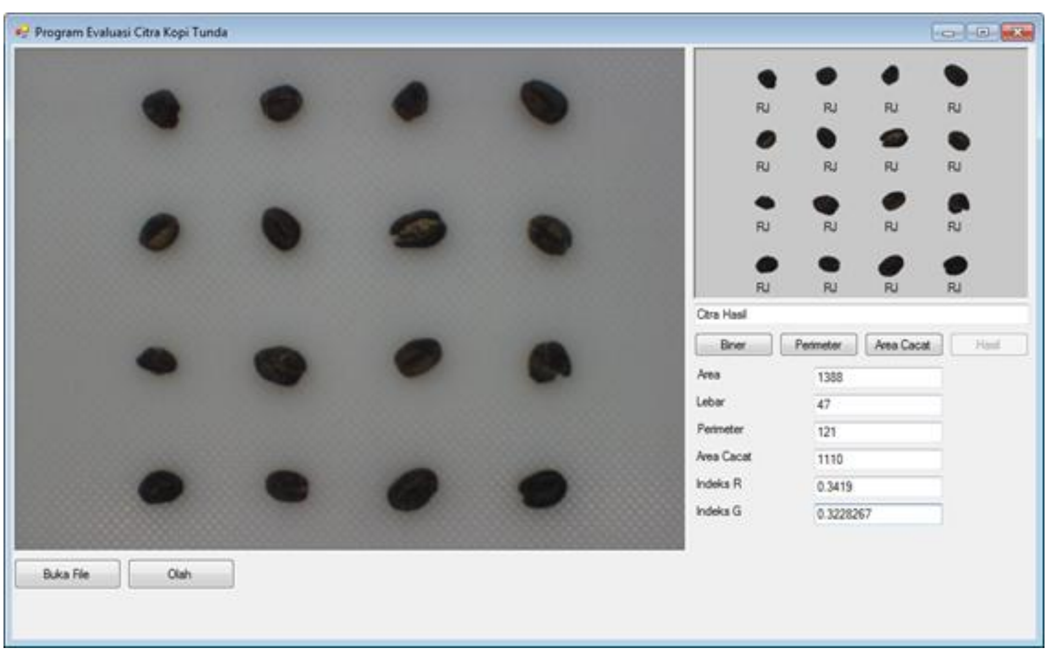

Figure 3. Image Processing Program from Previous Research