Application of Image Processing and Computer Vision on Rice Seed Germination Analysis

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Abstract
This paper presents a machine vision application designed for rice seed germination analysis by using image processing and computer vision technology. The application is called “Rice Seed Germination Analysis (RSGA)”. RSGA consists of five main processing modules which are image acquisition, image preprocessing, feature extraction, quality control analysis and quality results. The experiments is conducted on six variation Thai rice seed species of CP111, RD41, Chiang Phatthalung, Sang Yod Phattalung, Phitsanulok 2 and Chai Nat 1 in Bangkok and Chiangmai province of Thailand. RSGA extracts four main features which are color, size, shape, and texture. Then, RSGA applies Artificial Neural Network techniques in crop germination prediction. The precision rate is 93.06 percent, with the speed 8.31 seconds per image.

Introduction
Thailand is one of agricultural countries which produces a huge number of food products each year. Thailand is one of agricultural countries which produces a huge number of food products each year. Nowadays, the agricultural industry is probably more widespread in the world. One product that is highly widespread in the world especially in Thailand is rice. Oryza Sativa (Rice) is a vital worldwide agricultural product. Rice is a very popular exported product in the world. In Thailand, there are more than 114 well-known Thai rice species. It is essential to grade the quality of commodities in order to command the better price in the market competitions. The quality of the rice is mostly based on the quality of the seeds. Paddy rice is mostly offered based on the good quality of products. To measure the seed quality assessment, many factors is considered in the germination test, for instance, seed quality additives, species purity, physical purity, insect pests and diseases, seed germination and seed vigor. However, it is very difficult to identify which kind of seeds should be better used in seed germinations. Thus, this research is applied the image processing and computer vision technique instead of using only human vision. The traditional way to conduct the germination test is based on human abilities, it takes times and high labor to conduct the germination test in the seed quality control process. Nevertheless, it is very difficult to identify the quality of rice seeds by using only human vision because it is time-consuming and uses high labor to assess the quality control process in order to earn benefits from the rice productive. The germination test in this research was applied following the standard seed germination test in ISTA (1996) with the top of paper method for crop germination. Moreover, images have been collected to predict the germination of rice seed images by using image processing techniques which can identify the quality of products.

Therefore, the objective of this research is to propose the novel technique by applying the image processing and computer vision technology to assess the crop germination prediction in order to reduce times and costs. Thus, the computer software which can predict rice seed image for crop germination by using image processing techniques is developed. Due to the advance of video camera technology, people can take a digital picture or digital video stream easily in any places and any time by a camera or by a mobile phone device. It is not only very easy to use a digital camera, but also it is inexpensive. Moreover, it is easy to transform and process by using a computer system. Thus, this research employs a digital camera to capture the image. Many researches have been conducted the rice seed classification and rice seed recognition systems based on varieties, shape and size [7-8, 11, 13-16, 18, 20-22, 24]. The system of this research aimed to allow users to load an unknown whole rice seed image into RSGA which the system attempts to predict which kind of seeds were germinated or non-germinated for crop germination. Finally, the RSGA displays the germination results on the system’s graphic user interface (GUI). Many experiments were conducted to evaluate the seed germination by using machine vision technology.

Related Work
Many researchers tried to classify and identify each rice seed by applying several techniques which can be classified into two categories:
2.1) Computer techniques and
2.2) Biological techniques.

These below details show the information relating to the techniques used in this research.

For computer techniques, Pornpanomchai [17] classified pattern recognition approaches into three main categories:
1) Statistical pattern recognition (StatPR),
2) Structural or syntactic pattern recognition (SyntPR) and
3) Neural-based pattern recognition (NeurPR).

The details of each category are as follows:
Statistical pattern recognition (StatPR)
This approach has a statistical basis for classification of algorithms. The classifier design attempted to use statistical and a priori probabilities to build the recognition algorithms. The input features were extracted from a set of pattern characteristic measurements.

Patil and Yadahalli [16] applied minimum distance and k-nearest neighbor for classifying 21 classes of different food grains by using color and texture features without performing preprocessing and segmentation. The precision rate was 83.66%.

Pandey et al. [15] used content based image retrieval (CBIR) technique for identifying different seeds (wheat, rice and gram). The CBIR technique was used to identify and recognize the images based on color, shape, texture and size features. Finally, Euclidean Distance (ED) and artificial neural network techniques were applied in order to do seed identification. The training data set contained 150 images and the testing data set contained 50 images. The precision rates were 84.4% for ED and 95% for artificial neural network.

Kaur and Singh [10] applied Multi-Class SVM to grade the rice kernels (Premium, Grade A, Grade B and Grade C) for different varieties of rice grains based on interior and exterior quality. Maximum variance method was used to extract the rice kernels from background and extract chalk from rice. Ten geometric features were used to determine the percentage of head rice, broken rice and brewers of the rice samples. The precision rate was more than 86%.

Structural or syntactic pattern recognition (SyntPR)
This approach was a structural entity used for classification and descriptions. The classification was based on measurements of structural pattern similarity. The structural or syntactic information was used to generate knowledge related to patterns by extracting the similarity of patterns in order to build pattern syntax or structural rules. The information of pattern syntax rules were used to explain, classify and recognize unknown patterns. This approach was classified into two subcategories which were Rule Based Expert Systems and Fuzzy Expert Systems.

Punthimast et al. [34] applied a rule based system to identify rice seeds and stick rice seeds based on RGB color histogram. The precision rate was 96.34% for “Jasmine” rice seeds and 100% for stick rice seeds.

Maheshwari and Jain [26] proposed a method for counting the number of Oryza sativa L (rice seeds) with long seeds as well as small seeds by comparing the degree of quality and quantifying these degrees for the rice seeds based on combined measurements. They applied a rule based system to construct the rules based on histogram of area, major axis, minor axis and eccentricity of the seeds in order to classify the rice seeds into normal, long and small seeds. Finally, they compared the results with the ground truth table based on Human Sensory Panel of various sample.

Ajay et al. [1] proposed an algorithm of evaluating the automatic evaluation method for the determination of the quality of milled rice seed based on shape and geometric features. They applied rule based system of the length of the rice kernel to classify the broken rice and non-broken rice by using morphological features applied with the minimum bounding rectangle method. It was proved that this method was efficient. Moreover, this method was able to improve the traditional one.

Sansomboonsuk and Aftzulpurkar [20] developed a computer system for evaluating the quality of rice kernels. The system applied fuzzy logic to organize and classify the class of each kernel into broken rice and long grain rice by using the point and line touching features (area, perimeter, circularity and shape compactness). A rule based system was applied to generate the fuzzy set of rules in order to classify each rice kernel. The precision rate was 90% for evaluating the quality of rice compared with human inspection methods.

Neural-based pattern recognition (NeurPR)
This approach was a nonalgorithmic or black box strategy which was trainable. This approach also fed input features into neural network nodes to identify patterns. The NeurPR emulated knowledge of how biological neural system stored and manipulated information. The artificial neural system called “neural networks” could solve the problems of automatic reasoning including the pattern recognition problem. This approach classified patterns by predicting the properties of neural network.

Guzman and Peralta [8] applied artificial neural networks to classify the grain samples of Philippine rice grains based on size, shape and 52 varieties of rice grains belonging to 5 varietal groups in the Philippines by using image processing techniques. The system used 3 data sets containing 110 rice grains for each size, shape and variety of rice grain identification. They achieved a precision rate of 98.76% for sizes and 96.67% for shape. The precision rate based on individual rice varietal types were 85.81, 94.58, 96.16 and 97.39% for the lowland irrigated, lowland rainfed, saline prone, cool elevated, and upland rice groups, respectively. The overall accuracy was 70% for 52 varieties of rice grains classification.

OuYang et al. [14] developed the system to identify different varieties of rice seeds. The neural network technique was applied to classify five varieties of rice seeds based on color and appearance quality. The precision rates for five varieties were 99.99% for No.5 “Xiannong”, 99.93% for “Jinyougui”, 98.89% for “You166”, 82.82% for No.3 “Xiannong” and 86.65% for “Medium you 463”. The average precision was 93.66%.

Lilhare and Bawane [11] applied two layers of the feed forward neural network to classify varieties of paddy rice seed into 3 groups which were large, medium and small based on morphological features. The results showed that only two features (minor axis and area) were provided the sufficient information to classify varieties of paddy rice.

Silva and Sonnadara [22] applied neural network to classify 9 different varieties of rice based on morphological, color and texture features. There were thirteen, six and fifteen features for morphological, color and texture features, respectively. The system used individual feature sets and combined feature sets in the different neural network models. It was found that the texture features produced higher accuracy than the morphological and color features. The overall accuracy rate was 92% for the combined feature sets. The accuracy rates based on different varieties of rice seeds were 94, 98, 84, 100,
Gujar and Siddappa [7] applied neural network to identify six varieties of basmati rice seeds in India based on morphological and color features. Nine morphological features and six color features were used to classify rice seeds. The accuracy rates were 90, 88, 95, 82, 74 and 80% for six varieties of basmati rice seeds.

Zhao-yan and Fang [24] applied neural network to identify six varieties (ey7954, syz3, xs11, xy5968, xy9308, z903) rice seeds in Zhejiang province, China based on color and morphological features. Seven color and fourteen morphological features were used to identify rice seed varieties. The training data set contained two hundred and forty kernels while the testing data set contained sixty kernels. The precision rates were 90, 88, 95, 82, 74 and 80% for ey7954, syz3, xs11, xy5968, xy9308 and z903, respectively.

Shantaia and Ansari [21] applied neural networks to identify six varieties rice seeds in Chhattisgarh region by using color, morphological and textural features. Nine colors, nine morphological and textural features were used in discriminant analysis. The data set contained 60 sample images for training and 60 sample images for testing data set. The precision rates were 90, 88, 95, 82, 74 and 80% for six varieties of rice seeds.

Mladenov and Dejanov [13] developed the system for seed germination assessment by using computer vision. Neural network for germinated seed image segmentation based on color and texture models was applied. The germinated seed image segmented into the background, seed, germs and root zones. The precision rates were based on the standard of RBFN (Radial Basis Function Network) and the modification of RBFN networks.

For biological techniques, germination testing was considered an important step for measuring seed quality in the planting value of seed lot in the normal conditions. This research employed the standard germination test of seed based on the top of paper method in ISTA (1996). Many researchers used Biological techniques in their studies as follows:

1. Dell” Aquila [6] developed the computer system for monitoring the seed imbibition integrated with the standard germination test. The data set contained broccoli, radish, lentil, lettuce and carrot. The system monitored image analysis based on size (area, perimeter, length and width) and shape (roundness factor) features. The increase of area and roundness factors was used to determine the timing of radicle emergence. These two features were useful to estimate the radicle elongation rate in the germination.

2. Chaugule [5] reviewed the survey of the application of image processing in seed technology, seed germination and vigor methods which use computer-aided image analysis in order to monitor the seed growth and vigor for the automated seed quality tests.

Therefore, it can be seen that there are many studies of an automatic system to classify or identify varieties of rice seeds for various purposes. For computer techniques, in the classification and recognition system, many researchers applied different patterns for different purposes. For example, [10, 15, 16] applied Statistical pattern recognition. [1, 12, 18, 20] applied Structural or syntactic pattern recognition. [7, 8, 11, 13, 14, 21, 22, 24] applied Neural-based pattern recognition.

For the biological techniques, [5, 6] applied a germination testing technique of the seed germination by using computer vision. However, in this research, the RSGA applied six varieties rice seed species by using neural network technique for predicting rice seed images for crop germination test. The details of the system are presented in the next section.

Materials and Methods

The experiment was conducted by using the following computer hardware specifications:

1. CPU Intel(R) Core(TM) i5-2400 CPU @ 3.10GHz
2. Memory DDR3 4 GB and
3. Hard disk 500 GB.

For the computer software, Microsoft Windows 7 (Microsoft Corp.; Redmond, WA, USA) was used as the operating system. For the development tool, MATLAB R2013a (The Math Works Inc.; Natick, MA, USA) was used. Analysis and design were described by using the system conceptual diagram and system structure chart. The details of each element are described below.

System Conceptual Diagram

First, the images of many rice seeds are taken by a digital camera. Next, the images of the rice seeds are transferred into the RSGA for predicting rice seed image for crop germination which involves RSGA comparing the features of testing rice seed image data sets with training rice seed image data sets by using artificial neural network technique. Finally, RSGA displays the rice seed germinating prediction results to the user as shown in Figure 1.

![Figure 1: Rice Seed Germination Analysis System Conceptual Diagram](image)

System Structure Chart

The RSGA structure chart elaborates on how each model works is shown in Figure 2. The RSGA consists of five main process modules:

1. image acquisition,
2. image preprocessing,
3. feature extraction,
2.4) quality control analysis and
2.5) quality results.

Each process module has the following details.

![Rice Seed Germination Analysis System Structure Chart](image)

**Figure 2: Rice Seed Germination Analysis System Structure Chart**

**Image Acquisition**
In the first module, many rice seeds image was taken in a bird-eyes-view angle as an input of RSGA. The seeds are placed on a white polypropylene sheet with the distance between seeds and camera of 17 inches.

**Image Preprocessing**
In the second module, the image preprocessing module consists of four sub modules which are:
- 2.2.1) whole seed image binarization,
- 2.2.2) whole seed image enhancement,
- 2.2.3) whole seed image segmentation, and
- 2.2.4) seed image binarization.

**Whole Seed Image Binarization**
RSGA changes an RGB color image to a binarization image (as shown in Figure 3(a)-3(b)). First, RSGA changes true color image RGB to double precision. Then RSGA converts the image to a binary image using a binarization technique.

![Sample of whole rice seed image binarization](image)

**Figure 3:** Sample of whole rice seed image binarization. Figure 3 (a) represents whole rice seed images. Figure 3 (b) represents a binarization image.

**Whole Seed Image Enhancement**
RSGA performs morphological closing to close any opening area in the whole seed image. Then RSGA fills holes and removes noise to get an enhanced binary image.

**Whole Seed Image Segmentation**
RSGA labels the eight connected components of whole rice seed binarization image. Then, RSGA builds the rectangle which can cover and fit to each size of the seed on each label seed. Finally, RSGA segments the whole seed into each seed following the label of seed. The result of this step is shown in Figure 4.

![Sample of whole rice seed image segmentation](image)

**Figure 4:** Sample of whole rice seed image segmentation

**Seed Image Binarization**
RSGA changes an RGB color image to a gray-scale image as shown in Figure 5(a)-5(b). Then, RSGA transforms the grayscale image into a binary image as shown in Figure 5(c). Finally, RSGA converts the binary image to a binarization image as shown in Figure 5(d).

![Sample of seed image binarization](image)

**Figure 5:** Sample of seed image binarization

**Features Extraction**
In the third module, this feature extraction module consists of four seed features which are:
- 2.3.1) color,
- 2.3.2) shape,
- 2.3.3) size, and
- 2.3.4) texture. Each feature has the following details.

**Color Feature**
The color features consist of three features which are:
1) average red color,
2) average green color and
3) average blue color.

The details of color features calculation in Figure 5(a) is shown below.
Average red color = 148.4075  
Average green color = 129.0601  
Average blue color = 115.8955

Size feature
The size features measure image regions based on ellipse shape-based consisting of five features which are orientation, major axis length, minor axis length, eccentricity and area. The details of size features calculation in Figure 5(d) is shown below.
Orientation = 75.8977  
Major axis length = 85.7503  
Minor axis length = 24.6090  
Eccentricity = 0.9579  
Area = 1640

Shape feature
The shape features measure seed shape. Shape feature consists of two features which are roundness and aspect ratio. Roundness used to measure the similarity of the seed to the roundness which can be calculated in equation (1). Aspect ratio was calculated from the major axis length divided by the minor axis length which can be calculated in equation (2).

\[
Roundness = \frac{4\pi \cdot \text{area}}{\text{perimeter}^2}
\]  
\[
\text{Aspect Ratio} = \frac{\text{Major Axis Length}}{\text{Minor Axis Length}}
\]

The details of shape features calculation in Figure 5(d) is shown below.
Roundness = 0.4968  
Aspect ratio = 85.7503/24.6090 = 3.4845

Texture feature
RSGA uses gray level co-occurrence matrices (GLCM) for measuring the seed surface texture. The GLCM in this research applied four texture features which are contrast, correlation, entropy and homogeneity. Each texture feature calculated based on equation 3-6 [2]. RSGA applied GLCM in two directions which are horizontal and vertical direction.

Contrast texture feature
The contrast texture feature measures the local variations in the GLCM. The contrast texture can be calculated in equation 3.

\[
\sum_{i,j=0}^{N-1} P_{i,j} (i - j)^2
\]

Correlation texture feature
The correlation texture feature measures the linear dependency of gray levels on those of neighboring pixels. The correlation texture can be calculated in equation 4.

\[
\sum_{i,j=0}^{N-1} P_{i,j} \frac{(i - \mu_i)(j - \mu_j)}{\sigma_i \sigma_j}
\]

Entropy texture feature
The entropy texture feature is a statistical measure of randomness that is used to characterize the texture of the input image. The entropy texture can be calculated in equation 5.

\[
\sum_{i,j=0}^{N-1} P_{i,j} (-\ln P_{i,j})
\]

Homogeneity texture feature
The homogeneity texture feature measures the closeness of the distribution of elements in the GLCM to the GLCM diagonal. The homogeneity texture can be calculated in equation 6.

\[
\sum_{i,j=0}^{N-1} \frac{P_{i,j}}{1 + (i - j)^2}
\]

The details of texture features calculation in Figure 5(b) is shown below.
Contrast horizontal = 0.2577  
Correlation horizontal = 0.9177  
Entropy horizontal = 1.8826  
Homogeneity horizontal = 0.8856  
Contrast vertical = 0.1225  
Correlation vertical = 0.9610  
Entropy vertical = 1.6838  
Homogeneity vertical = 0.9388

Quality Control Analysis
In the fourth module, RSGA applied neural network (NN) technique in order to predict rice seed image for crop germination.

Artificial Neural Network Technique
The artificial neural network (ANN) classifies the rice images by using the neural network structure: 18-13-2 as shown in Figure 6. The 18 input nodes are equal to 18 features of each seed image and the 2 output nodes are equal to 2 kinds of satisfied seed quality and unsatisfied seed quality of rice seed images in the training data set. The hidden nodes are 2/3 of
average between input nodes and output nodes which is the rule of thumb [3].

![Figure 6: RSGA Artificial Neural Network Structure](image)

### Quality Result

The quality result module shows rice seed germinating prediction results. The graphic user interface (GUI) of the system is shown in Figure 7 as follows.

1. **Image box**—there are two image boxes which are the input unknown rice image (Figure 7 label number 1) and the germination analysis image box (Figure 7 label number 2). The germination analysis results contain the red mark that represents for non-germination rice seed result.
2. **Text box**—there are one textbox which is the browse image file location text box (Figure 7 label number 3).
3. **Command button**—there are two command buttons which are the browse image button (Figure 7 label number 4) and the result button (Figure 7 label number 5).

### Results and Discussion

The RSGA process employs six Thai rice seed species which are:

1. CP111,
2. RD41,
3. Chiang Phatthalung,
4. Sang Yod Phattalung,
5. Phisanulok 2 and
6. Chai Nat 1 from Bureau of Rice Seed, Ministry of Agriculture and Cooperatives, Rice Department of Thailand.

The experiment was conducted on 34735 rice seeds in 144 trays (petri dishes) and varied in Bangkok and Chiangmai. The germination testing method was based on top of paper method as shown in Figure 8. Figure 8(a) shows the preparation of rice seed for crop germination based on top of paper method. Figure 8(b) shows the rice seed germination test based on the top of paper method results. Figure 8(c) shows the zooming of the germinated rice seed result. The precision rates that varied between locations were 96.05 and 88.60 % for Bangkok and Chiangmai respectively (Table 1). The precision rates that varied between species were 98.92, 81.13, 84.67, 85.63, 83.53 and 80.92 % for CP111, RD41, Chiang Phatthalung, Sang Yod Phattalung, Phitsanulok 2 and Chai Nat 1 respectively (Table 2). The precision rate was 93.06 %. The average access time was 8.31 seconds per image.

![Figure 8: Sample of rice seed germination testing based on top of paper method](image)

### Table 1: Experimental results based on Bangkok and Chiangmai City

<table>
<thead>
<tr>
<th>Location</th>
<th>Amount</th>
<th>Germination</th>
<th>Non-germination</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bangkok</td>
<td>20801</td>
<td>15792</td>
<td>136</td>
</tr>
<tr>
<td>Chiangmai</td>
<td>13934</td>
<td>9809</td>
<td>249</td>
</tr>
<tr>
<td>Total</td>
<td>34735</td>
<td>25601</td>
<td>385</td>
</tr>
</tbody>
</table>

Where \( GP \) = Germinated Prediction, \( N-GP \) = Non-germinated Prediction
In previous studies about rice seed classification and recognition systems, a semantic identification method was applied to classify a rice seed quality image based on shape, size, color and texture features [7, 8, 11, 13-16, 18, 20-22, 24]. Some researchers [8, 10, 14, 15, 20] applied the method to recognize a rice seed quality image by using identification method to retrieve a rice seed image into seed database and, finally, compared each seed image to the system database. The researchers can theoretically classify the rice seed based on shape, size and color, but practically the satisfied rice seed sometimes cannot be used for real germination. Therefore, the RSGA has applied texture features in order to improve the accuracy compared to the previous works by applying four main features based on color, size, shape and texture features. This research can contribute to building a computer system which can classify the germination and non-germination rice seeds in order to predict rice images for crop germination by using image processing techniques for many purposes including: the study of interesting rice seed species, the study of seed germination test and the effect on variations between rice species and locations. This research also applied the simple ANN technique with a simple computer system. It is possible to implement the RSGA on mobile phone which is suitable for users or researchers who want to measure the germination rate.

The following topics deserve consideration for future development of the RSGA: increase variation rice seed species in the system database, increase variation locations of Thailand in the system database, process the standard germination test based on other methods, for example, sand and soil, and implement the package on an online client-server web services.

## Conclusion

The RSGA fulfilled the research objective by extracting four main features which is based on color, size, shape and texture features in order to predict the rice seed crop germination test by using image processing technique. Based on the experimental results, the RSGA employed the ANN techniques to predict the crop seed germination image with the precision rates of 93.06 %. The precision rates based on location variations were 96.05 and 88.60 % for Bangkok and Chiangmai respectively. The precision rates based on rice species variations were 98.92, 81.13, 84.67, 85.63, 83.53 and 80.92 % for CP111, RD41, Chiang Phatthalung, Sang Yod Phattalung, Phitsanulok 2 and Chai Nat 1 respectively. The average access time was 8.31 seconds per image. There are a lot of rice seed species in the world. However, for this research only Bangkok and Chiangmai were the selected locations. Therefore, in this research only six rice seed species (CP111, RD41, Chiang Phatthalung, Sang Yod Phattalung, Phitsanulok 2 and Chai Nat 1) were used for this study and 34735 rice seed images were in the RSGA database. To increase the prediction precision rate, the RSGAIP needs to access more features in prediction for quality control analysis and contains more rice seed species images of Thailand in the system database. Finally, the RSGA needs to be implemented on the online client-server web services which will help to predict germination rate of rice seed quality.

## Acknowledgments

The authors would like to thank the Bureau of Rice Seed, the Ministry of Agriculture and Cooperatives; the Rice Department of Thailand; and Faculty of Science, Mahidol University for supplying rice seed species and facilities to the research.

## References


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Table 2: Experimental results based on variation of rice species

<table>
<thead>
<tr>
<th>Species (SP)</th>
<th>Amount</th>
<th>GP Amount</th>
<th>N-GP Amount</th>
<th>GP</th>
<th>N-GP</th>
</tr>
</thead>
<tbody>
<tr>
<td>CP111 (SP1)</td>
<td>21550</td>
<td>10642</td>
<td>273</td>
<td>59</td>
<td>4676</td>
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<tr>
<td>RD41 (SP2)</td>
<td>3000</td>
<td>1913</td>
<td>472</td>
<td>94</td>
<td>521</td>
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<tr>
<td>Chiang Phatthalung (SP3)</td>
<td>3000</td>
<td>2073</td>
<td>402</td>
<td>58</td>
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<tr>
<td>Sang Yod Phattalung (SP4)</td>
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<td>2130</td>
<td>360</td>
<td>69</td>
<td>426</td>
</tr>
<tr>
<td>Phitsanulok 2 (SP5)</td>
<td>3000</td>
<td>2064</td>
<td>431</td>
<td>63</td>
<td>442</td>
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<td>Chainat 1 (SP6)</td>
<td>1200</td>
<td>777</td>
<td>187</td>
<td>42</td>
<td>192</td>
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<td>Total</td>
<td>34735</td>
<td>25601</td>
<td>2125</td>
<td>385</td>
<td>6724</td>
</tr>
</tbody>
</table>

Where GP = Germinated Prediction, N-GP = Non-germinated Prediction


**BIOGRAPHY**

Benjaporn Lustwut received her B.S. in ICT and M.S. in computer science from Mahidol University, Bangkok, Thailand. She is currently a Ph.D. candidate in computer science in the faculty of Information and Communication Technology, Mahidol University, Bangkok, Thailand. Her research interests include image processing, image segmentation, machine learning, and pattern recognition.

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