PATTERN RECOGNITION TEXTURE OF DIAMOND CUT

PEERAPAT SRIANGSUTHANANON

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Thesis
entitled

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……………………………………
Mr. Peerapat Sriangsuthananon
Candidate

……………………………………
Asst. Prof. Supaporn Kiattisin,
Ph.D. (Electrical and Computer Engineering)
Major advisor

……………………………………
Asst. Prof. Adison Leelasatitham,
Ph.D. (Electrical Engineering)
Co-advisor

……………………………………
Lect. Waranyu Wongseree,
Ph.D. (Electrical Engineering)
Co-advisor

……………………………………
Prof. Banchong Mahaisavariya,
M.D., Dip Thai Board of Orthopedics
Dean
Faculty of Graduate Studies
Mahidol University

……………………………………
Asst. Prof. Supaporn Kiattisin,
Ph.D. (Electrical and Computer Engineering)
Program Director
Master of Science Program in Technology of Information System Management
Faculty of Engineering
Mahidol University

Thesis
entitled

PATTERN RECOGNITION TEXTURE OF DIAMOND CUT

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on
December 26, 2013

………………………………………
Mr. Peerapat Sriangsuthananon
Candidate

………………………………………
Asst. Prof. Bunlue Emaruechi,
Ph.D. (Environmental Systems Engineering)
Chair

………………………………………
Asst. Prof. Werapon Chiracharit,
Ph.D. (Electrical and Computer Engineering)
Member

………………………………………
Asst. Prof. Supaporn Kiattisin,
Ph.D. (Electrical and Computer Engineering)
Member

………………………………………
Lect. Waranyu Wongseree,
Ph.D. (Electrical Engineering)
Member

………………………………………
Asst. Prof. Adison Leelasantitham,
Ph.D. (Electrical Engineering)
Member

………………………………………
Prof. Banchong Mahaisavariya,
M.D., Dip Thai Board of Orthopedics
Dean
Faculty of Graduate Studies
Mahidol University

………………………………………
Mr. Worawit Isarangkul Na Ayuttaya
M.S. (Technical Management)
Dean
Faculty of Engineering
Mahidol university

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Peerapat Sriangsuthananon

PATTERN RECOGNITION TEXTURE OF DIAMOND CUT

PEERAPAT SRIANGSUTHANANON 5438243 EGTI/M

M.Sc. (TECHNOLOGY OF INFORMATION SYSTEM MANAGEMENT)

THESIS ADVISORY COMMITTEE : SUPAPORN KIATTISIN, Ph.D., ADISON LEELASATITHEM, Ph.D., WARANYU WONGSEREE, Ph.D.

ABSTACT

There are many types of diamond cuts in the world. However, many people still does not know anything about them. Diamond recognition can use the four C’s, which are diamond clarity, carat, color, and cut, and in this research the diamond cut was used for recognition of the diamond, in which the texture of the diamond was classified, because it is the single most important factor of the four C’s. So, the diamond cut needs to be recognized using the texture of those diamonds. A good solution would be to use the image to recognize the texture, so texture recognition from an image has therefore been researched. The best way of recognizing the diamond cut is to find the value, which can be classified as feature extraction. The wavelet transform is one form of algorithm which can perform feature extraction and obtain more features from texture. For this reason, a wavelet transform is appropriate for texture feature extraction, and the subsequent performance of the feature extraction is displayed as statistical properties of the coefficients. The statistical properties of the coefficients are standard deviation, median absolute deviation, and mean absolute deviation of horizontal, vertical, and diagonal from wavelet transforms, which are used for those coefficients for achieving success in texture recognition.

KEY WORDS: PATTERN RECOGNITION / WAVELET TRANSFORM / DIAMOND CUT / TEXTURE CLASSIFICATION

51 Pages

การเรียนรู้จดจำพื้นผิวลายเจียระไนเพชร

PATTERN RECOGNITION TEXTURE OF DIAMOND CUT

พีรภัทร์ ศรีอังศุธนานนท์ 5438243 EGTI/M

วท.ม. (เทคโนโลยีการจัดการระบบสารสนเทศ)

คณะกรรมการที่ปรึกษาวิทยานิพนธ์ : สุภาภรณ์ เกียรติสิน, Ph.D., อดิศร ลีลาสันติธรรม, Ph.D., วรัญญู วงษ์เสรี, Ph.D.

บทคัดย่อ

ลายเจียระไนเพชรในโลกนี้นั้นมีหลากหลายรูปแบบมากมาย แต่อย่างไรก็ตามก็ยังมีผู้คนมากมายที่ไม่รู้จักลายเจียระไนเพชรเหล่านี้ การเรียนรู้จดจำเพชรนั้นสามารถใช้ 4's C ในการจดจำ ก็คือ ความชัดเจนของเพชร(Clarity) น้ำหนักของเพชร(Carat) น้ำของเพชร(Color) ลายเจียระไนของเพชร(Cut) และในบทความนี้จะใช้ลายเจียระไนของเพชรในการเรียนรู้จดจำเป็นพื้นผิวของเพชรเพราะว่านี่เป็นตัวแปรสำคัญที่สุดจากทั้งหมดใน 4's C. ดังนั้น ลายเจียระไนเพชรจำเป็นที่จะถูกจดจำโดยพื้นผิวของลายเพชรต่างๆ ซึ่งจะเป็นการดีถ้าหากใช้รูปภาพในการจดจำเพชรและเรียนรู้จดจำพื้นผิวจากรูปภาพที่ได้รับการวิจัย. วิธีการที่ดีที่สุดในการเรียนรู้จดจำคือการค้นหาตัวแปรซึ่งสามารถจำแยกออกมาได้จากการทำการสกัดตัวแปร. เวฟเลตทรายฟอร์มเป็นหนึ่งในกระบวนการทั้งหลายที่สามารถทำการสกัดตัวแปรได้และยังสามารถได้ตัวแปรมากมายอีกด้วย. ด้วยเหตุผลนี้เวฟเลตทรายฟอร์มจึงเหมาะสมในการสกัดตัวแปรจากพื้นผิวและประสิทธิภาพของการสกัดตัวแปรนั้นถูกแสดงออกมาทางค่าสัมประสิทธิของตัวแปรสถิติด้วย ซึ่งประกอบไปด้วย ส่วนเบี่ยงเบนมาตรฐาน ค่ามัธยฐานความเบี่ยงเบนแน่นอน และค่าเฉลี่ยส่วนเบี่ยงเบนแน่นอนของแนวนอน แนวตั้ง และแนวทแยงของรูปแบบจากการใช้เวฟเลตทรานฟอร์ม ซึ่งค่าสัมประสิทธิเหล่านี้จะทำให้บรรลุเป้าหมายการรู้เรียนจดจำพื้นผิว

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CHAPTER I
INTRODUCTION

1.1 Background and significance of the problems

The Diamond is very valuable material and many people want to have it as their assets. So, the diamond was often stolen or was copied to fake diamond. It is very difficult to protect it if the protection or careful observation is not good enough and the fake diamond verification is also difficult too because the diamond verification processes need the diamond expert for verifying. However, sometimes the verification may take a long time and low accuracy if that expert's experience is not good enough. It will charge very high cost if we decided to use the diamond tester for verification.

On the other hand, there are only few people who really have the knowledge about the diamond if they are not interested in or learn in details such as diamond clarity, diamond carat, diamond color and diamond cut. Especially in the diamond cut which is a style or design guide used to shape a diamond for polishing. The diamond cut is also the calling name for the types of diamond which have many names separated by diamond sharp following the diamond's lapidary made it. In fact, the people cannot know what the name of that diamond. So, the best way to know that is to ask the expert. It will be great if we have some remarkable signs which is easy to recognize the name of diamond from diamond cut without any cost or time.

Texture analysis is often used in image processing and pattern recognition processes widely. It was the beginning of the introduction into the desired target. If the analysis is not enough, the desired results would not be shown as well. E.g. In the feature extraction, if the texture has no features appear at all, it is impossible or the result is incorrect.

Texture classification is very important in image processing and pattern recognition areas. The methods known are Fourier transform, Linear transforms, Chain code, Shape Matrix, Region moments, Gabor filtering and Co-occurrence approach but there are many methods to be use with and include Wavelet transform too. According to the abstract, the wavelet transform is a method which used to analyze the texture because the wavelet transform can help to solve problems in diamond quality by analyzing the differentiation between defective and flawless diamond. Because of the each image of the diamond has difference texture. The wavelet transform has 6 features to operate the feature extraction which refers to the statistical property coefficients more than feature extraction by Fourier transform with less response time, reliable, better technique and localized in time and frequency. Then classification use coefficients from wavelet transform such as standard, median, mean, standard deviation, median absolute deviation and mean absolute deviation of Approximate, horizontal, vertical and diagonal coefficient of wavelet transform which can be described by the tree diagrams to display result of classification.

1.2 Research objectives

1.2.1 To learn about wavelet transform algorithm for feature extraction.

1.2.2 Find factor from wavelet transform for pattern recognition

1.3 Delimitation of the research

1.3.1 Use clearly 8 diamond cut image in texture recognition is Round Brilliant, Oval, Marquise, Pear, Heart, Emerald, Princess and Radiant with top-view of diamond image.

1.3.2 Use two dimension wavelet transform for diamond cut texture analyze with Biorthogonal wavelet mother of order 2.2 in level 1

1.3.3 Use factor of horizontal, vertical and diagonal image from wavelet transform of standard deviation, Median absolute deviation and mean absolute deviation only and analyzing by decision tree J48.

1.4 Expected outcomes and benefits

1.4.1 The people can recognize the name of diamond cut.

1.4.2 Can be applied with real diamond.

1.4.3 Can be used factor’s result for pattern recognition of diamond cut

CHAPTER II
REVIEW OF RELATED LITERATURE AND RESEARCH

2.1 Diamond

Figure 2.1 Diamonds

A diamond (from the ancient Greek ἀδάμας – adámas, meaning "unbreakable," "proper," or "unalterable") is one of the best-known and most sought-after gemstones. Diamonds have been known to mankind and used as decorative items since ancient times; some of the earliest references can be traced to India.

The hardness of diamond and its high dispersion of light – giving the diamond its characteristic "fire" – make it useful for industrial applications and desirable as jewelry. Diamonds are such a highly traded commodity that multiple organizations have been created for grading and certifying them based on the four Cs, which are color, cut, clarity, and carat. Other characteristics, such as presence or lack of fluorescence, also affect the desirability and thus the value of a diamond used for jewelry.

Perhaps the most famous use of the diamond in jewelry is in engagement rings, which became popular in the early to mid-20th century due to an advertising campaign by the De Beers company, though diamond rings have been used to symbolize engagements since at least the 15th century. The diamond's high value has also been the driving force behind dictators and revolutionary entities, especially in Africa, using slave and child labor to mine blood diamonds to fund conflicts.

2.2 The Four C's of diamonds

When you are planning on purchasing a diamond it is important that you know as much as possible about how diamonds are classified. There are four topics you need to become familiar with Cut, Color, Clarity, and Carat Weight.

2.2.1 Cut

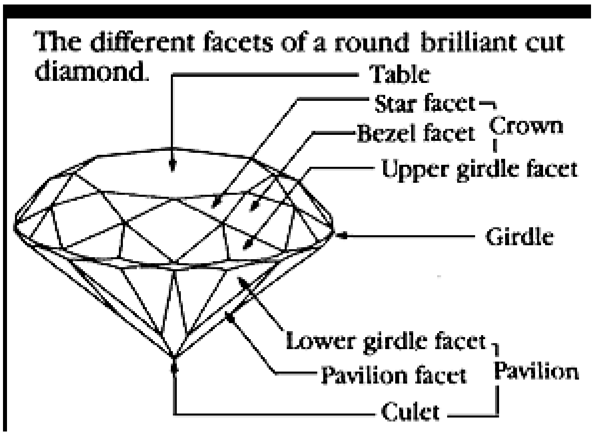


Figure 2.2 The different facets of round brilliant cut diamond

When we speak of cut we are more interested in the proportions of the diamond as opposed to its shape (Round Brilliant, Marquise, Pear, Princess, etc.) Every diamond regardless of its shape gets it brilliancy and scintillation by cutting and polishing the diamond facets to allow the maximum amount of light that enters through its top to be reflected and dispersed back through its top. A correctly cut, "well made", stone is pictured in Figure 2.3 (1).

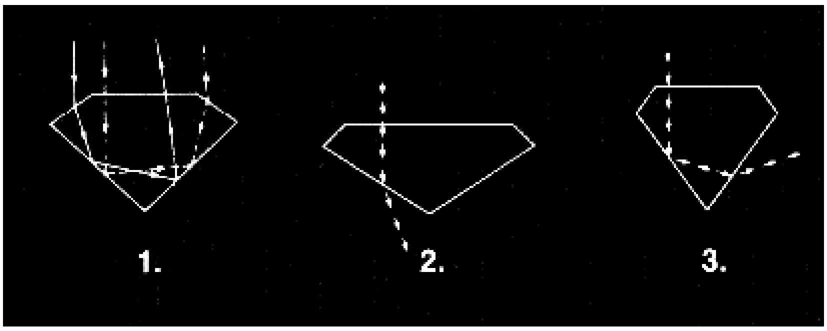


Figure 2.3 A cut stone

As you can see if the angles are correct the light that enters is dispersed properly back through the diamond's top facets. When a stone is cut too shallow in Figure 2.3 (2) or too deep in Figure 2.3 (3) the light that enters through the top is allowed to escape through the diamond's bottom and does not allow the maximum beauty of the diamond to be realized.

2.2.2 Color

Diamonds come naturally in every color of the rainbow. However most people are concerned with diamonds in the white range. The Gemological Institute of America (GIA) rates the body color in white diamonds from D (colorless) to Z (light yellow) shown in Figure 2.4

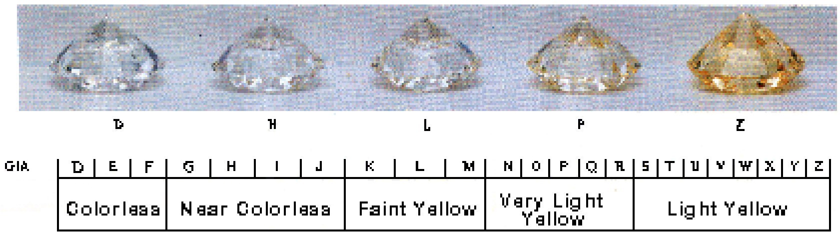


Figure 2.4 The Gemological Institute of America (GIA) rates

The best color for a diamond is no color at all. A totally colorless diamond allows light to pass through it easily, resulting in the light being dispersed as the color of the rainbow. Colors are graded totally colorless to light yellow. The differences from one grade to the other are very subtle and it takes a trained eye and years of experience to color grade a diamond.

2.2.3 Clarity

The clarity of a diamond is determined by the amount and location of flaws, or blemishes, in the diamond when viewed under 10 power (10x) magnification. GIA rates clarity grades in diamonds from Flawless to Imperfect 3 (Figure 2.5). The Diamond Shopping Network offers you diamonds from the Imperfect 1 grade through Flawless.

Most diamonds contain very tiny birthmarks known as "inclusions." An inclusion can interfere with the light passing through the diamond. The fewer the inclusions, the more beautiful the diamond will be.

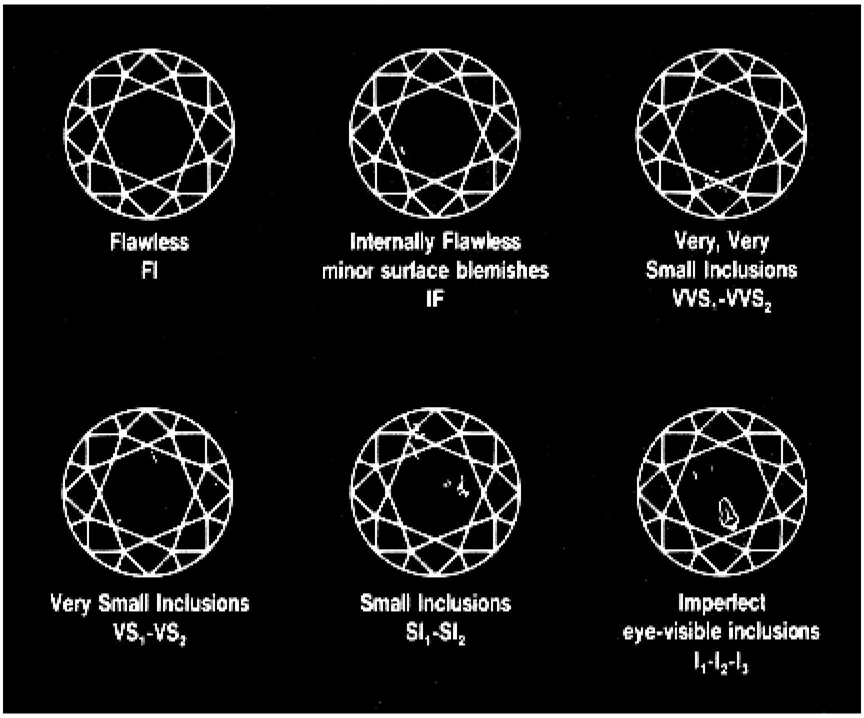


Figure 2.5 GIA rates clarity grades

Diamonds have the capability of producing more brilliance than any other gemstone. A diamond that is free of inclusions and surface blemishes is very rare and therefore very valuable.

2.2.4 Carat

This is the weight of a diamond measured in carats. As the carat weight of a diamond increases so does its rarity and therefore its price.

One carat is divided into 100 "points," so that a diamond of 75 points weights .75 carats. The carat-weight of a diamond is the easiest measurement to determine. Most importantly, two diamonds can be of equal carat-weight, but their value can differ greatly due to their cut, color, and clarity.

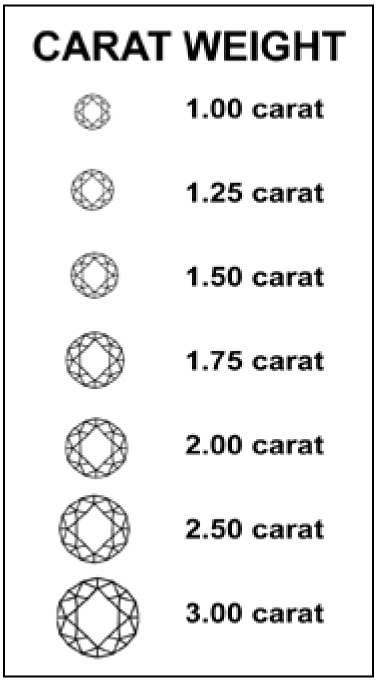


Figure 2.6 Carat weight

2.3 Diamond Cut

Cut refers not to a diamond's shape (e.g. round, oval, pear, etc.) but to a diamond's proportions, symmetry and polish. The beauty of a diamond depends more on cut than any other factor. Though extremely difficult to analyze and quantify, diamond cut has three primary effects on appearance: brilliance (the brightness created by the combination of all the white light reflections from the surface and the inside of a polished diamond), fire (the dispersion of light into the colors of the visible spectrum, seen as flashes of color), and scintillation (the flashes of light and dark, or sparkle, when a diamond or light source is moved).

When a diamond is fashioned from a rough stone, the cutter must balance optimal cut (and therefore appearance) against maximum yield (cutting the diamond to maintain as much carat weight from the rough stone as possible). Because many customers are willing to pay more for a larger, fair-cut cut diamond than for a slightly smaller, well-cut diamond, there is pressure on the cutter to sacrifice appearance for weight. This is why the Cut grade is so important; it allows the purchaser to identify those stones that were cut Fair to Poor in an effort to gain carat weight.

Figure 2.7 Rough stone

In Figure 2.7, the same rough stone (shown in blue) can yield one of two potential diamonds:

A too deep cut diamond (orange) would yield a significantly larger diamond, earning the diamond cutter a larger profit on his investment.

A smaller, well cut diamond (white) may sell for less in total than the larger diamond, but it will command a higher price-per-carat not only because of its superior appearance, but also due to decreased yield from the rough stone (which therefore makes the diamond more expensive to create).

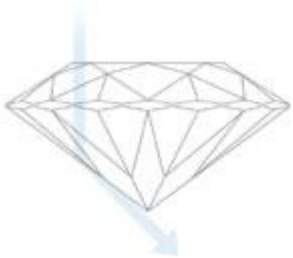
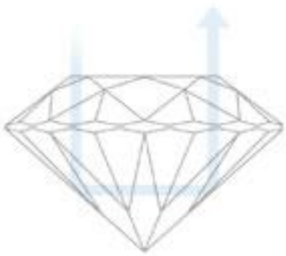
2.3.1 Diamond cut proportions

Diamond proportion refers to the relationship between the size, shape, and angle of each facet of a diamond. A wide range of combinations are possible, ultimately determining the diamond's interaction with light.

When light strikes a diamond, approximately 20% immediately reflects off the surface (as glare). Of the 80% that enters, a portion will escape through the bottom of the diamond (where the observer cannot appreciate it). A well-proportioned diamond will have each facet properly placed and angled so as to maximize the amount of light that reflects back out of the crown (top) of the diamond, to the eye of the observer. This reflected light is perceived as scintillation, fire and brilliance.

In the table 2.1 as below, three common light patterns are shown. When light meets any facet of a diamond, it will either reflect (bounce back) or refract (bend while passing through the facet). The angle that the light hits the facet determines whether the majority of light reflects or refracts, which is why cut is so important.

Table 2.1 common light patterns

No	Pattern	Description
1		If the diamond cut is too shallow, entering light strikes the pavilion facet at a low angle and passes through the facet (refracts), escaping through the bottom of the diamond.
2		If the diamond cut is too deep, entering light strikes the first pavilion facet at an angle sharp enough to reflect to the second pavilion. But the light strikes the second pavilion at too low an angle, causing the light to refract (pass through the facet), escaping through the bottom of the diamond.
3		In a well cut diamond, the light strikes each pavilion facet at an angle which allows most of the light to reflect back to the crown (top). As it passes through the crown facets at a low angle, the light refracts upon exit. In this case, refraction is a good thing, as the bent light travels to the observer's eye and is perceived as a lively fire.

Every Diamond comes with a GIA Grading Report or Dossier certificate, most of which include a proportion diagram. The proportion diagram is a graphic representation of the diamond's actual proportions.

The proportion diagram shows the diamond's girdle size, culet size, table and depth percentages, as well as other measurements, such as the crown and pavilion angles.

Each angle and dimension is measured electronically using a light scanner. The proportion diagram is a "fingerprint" of your diamond.

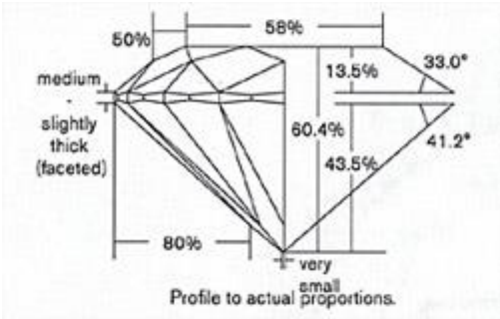


Figure 2.8 GIA Diamond Proportion Diagram

2.4 Diamond Type

The diamond cut is using in this research have 8 types as

2.4.1 Round Brilliant

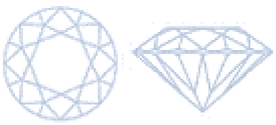


Figure 2.9 Round Brilliant Diamond

The round cut diamond is the most popular diamond shape, representing approximately 75% of all diamonds sold. Due to the mechanics of its shape, the round diamond is generally superior to fancy shapes at the proper reflection of light, maximizing potential brightness.

2.4.2 Oval

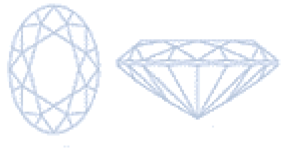


Figure 2.10 Oval Diamond

Because the oval diamond is a modified brilliant-cut (like virtually all round cut diamonds), the two diamond shapes possess a similar fire and brilliance. However, oval cut diamonds have the added advantage of an elongated shape, which can create the illusion of greater size.

2.4.3 Marquise

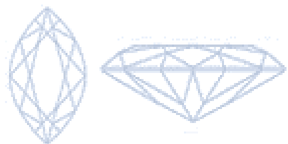


Figure 2.11 Marquise Diamond

The marquise cut diamond is a football-shaped, modified brilliant-cut. Because the marquise diamond is long and narrow, it can also create the illusion of greater size. Carat for carat, the marquise diamond has one of the largest surface areas of any diamond shape, making it a good choice when trying to maximize perceived size.

2.4.4 Pear

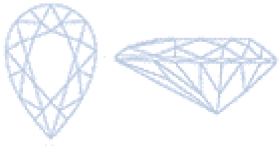


Figure 2.12 Pear Diamond

The modified brilliant-cut pear shaped diamond is a combination of a round and a marquise shape, with a tapered point on one end. Ideally, a pear shaped diamond should possess excellent or very good symmetry. The point should line up with the apex of the rounded end. The shoulders and wings (the upper and lower curves on the right and left side of the diamond) should form uniform, symmetrical curves.

2.4.5 Heart

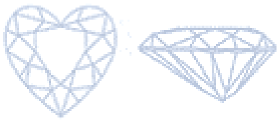


Figure 2.13 Heart Diamond

The modified brilliant-cut heart shaped diamond is a unique and unmistakable symbol of love, popular in solitaire pendants as well as rings. Heart shaped diamonds less than .50 carats may not be a good choice, since the heart shape is more difficult to perceive in smaller diamonds, especially after they are set in prongs.

2.4.6 Emerald

Figure 2.14 Emerald Diamonds

The unique look of the emerald cut diamond is due to the step cuts of its pavilion and its large, open table. Instead of the sparkle of a brilliant-cut, emerald cut diamonds produce a hall-of-mirrors effect, with the interplay of light and dark planes. Often, inclusions or body color are easier to see in an emerald cut diamond.

2.4.7 Princess

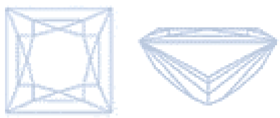


Figure 2.15 Princess Diamond

The princess cut diamond, first created in 1980, is the most popular fancy diamond shape, especially for engagement rings. Like round cut diamonds, princess cut diamonds are a good choice for their flexibility in working in almost any style of ring.

2.4.8 Radiant

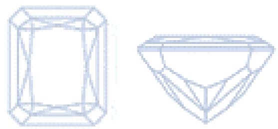


Figure 2.16 Radiant Diamond

The radiant cut diamond is the first rectangular cut to have a complete brilliant-cut facet pattern applied to both the crown and pavilion, creating a vibrant and lively diamond. The modified square shape is a nice bridge between a cushion and a princess cut, and for that reason looks beautiful set with both rounded or square cornered diamonds.

2.5 Wavelet Transform

The wavelet Transform is normally used in decomposition and reconstruction. Figure as below is shown the methodology of decomposition what used in two dimension discrete wavelet transform.

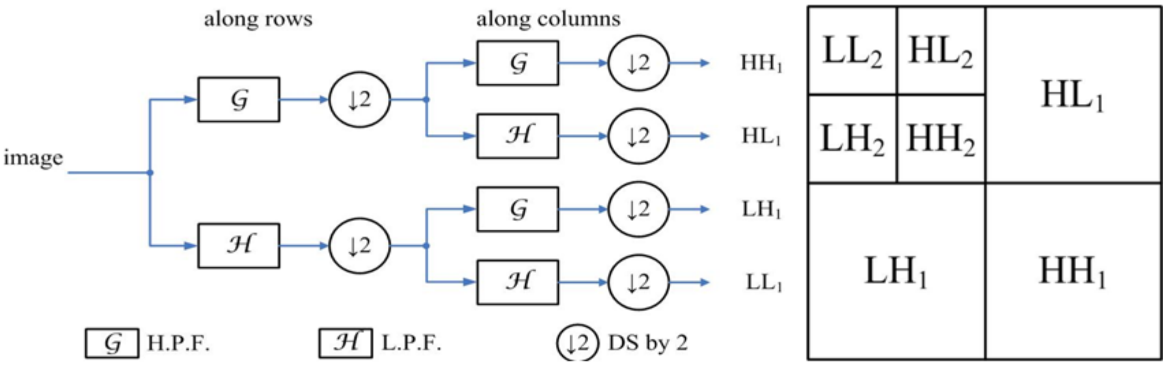


Figure 2.17 Wavelet transform process

The (continuous) wavelet transform of one dimension is defined as,

$$Wf_a(b) = \int f(t)\,\Psi_{a,b}(t)\,dt = \langle f, \Psi_{a,b} \rangle, a \neq 0$$

Where the wavelet $\Psi_{a,b}$ is computed from the mother wavelet Ψ

$$\Psi_{a,b}(t) = \frac{1}{\sqrt{a}}\Psi\left(\frac{t-b}{a}\right)$$

And can be discretized by restraining a and b to a discrete lattice.

For feature extraction, the decomposition step is used for finding the factor which takes in texture pattern recognition by high frequency pass filter and low frequency pass filter with the original image called filters bank. That is usually performance by using a product of one dimension filters can defined as,

$$L_n(b_i, b_j) = \left[H_x[H_y L_{n-1}]_{\downarrow 1,2}\right]_{\downarrow 1,2}(b_i, b_j)$$

$$D_{n1}(b_i, b_j) = \left[H_x[G_y L_{n-1}]_{\downarrow 1,2}\right]_{\downarrow 1,2}(b_i, b_j)$$

$$D_{n2}(b_i, b_j) = \left[G_x[H_y L_{n-1}]_{\downarrow 1,2}\right]_{\downarrow 1,2}(b_i, b_j)$$

$$D_{n3}(b_i, b_j) = \left[G_x[G_y L_{n-1}]_{\downarrow 1,2}\right]_{\downarrow 1,2}(b_i, b_j)$$

The filters bank is four different image which pass low and high filter called approximation, horizontal, vertical and Diagonal. The filters bank can be explained following Fig.4 as the approximation image which is got form original image by passing low-pass filter and then passed low-pass filter again. This image must use in second time or next time as soon as possible, the horizontal image is passed high-pass filter, the Vertical image is passed low-pass filter and passed high-pass filter again, the diagonal image is passed high-pass filter and passed low-pass filter again and image's result is shown as Figure 2.19 as below.

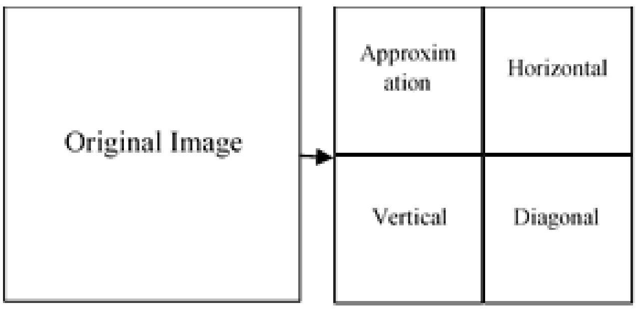


Figure 2.18 Result of wavelet transform

The statistical property coefficients can get form those image. As mentioned above, the approximation image cannot use it. Therefore, the only three images are horizontal image, vertical image, diagonal image which are used in feature extraction for pattern recognition and the statistical property coefficients which are used in this methodology is standard deviation, median absolute deviation and mean absolute deviation of those three images. According to the feature extraction, we will get them from two dimensions discrete wavelet transform have totally nine features and are suitable features for texture classification

The original image which is used in two dimension discrete wavelet transform must be chosen by the best size of height or row and width or column of image which is 2n pixel of both size when n is 1, 2, … such as 512 pixel or 1024 pixel which is 29 and 210 as sequence. Because of the pass wavelet transform in first filter once time, the size of columns is decreased by a half with keeping the even index of columns. Then, when pass again in second filter the size of rows is decreased by a half too with keeping the even index of rows. So, the size of image will be decreased by a half when passed wavelet transform once time and decrease again when passed it again time by the size when passed wavelet transform is $\frac{2^n}{x}$ when x is total time or called “subband”. It will get a good coefficients if we choose the good size of image for analyze. Although, wavelet transform can used in rotation and scaling.

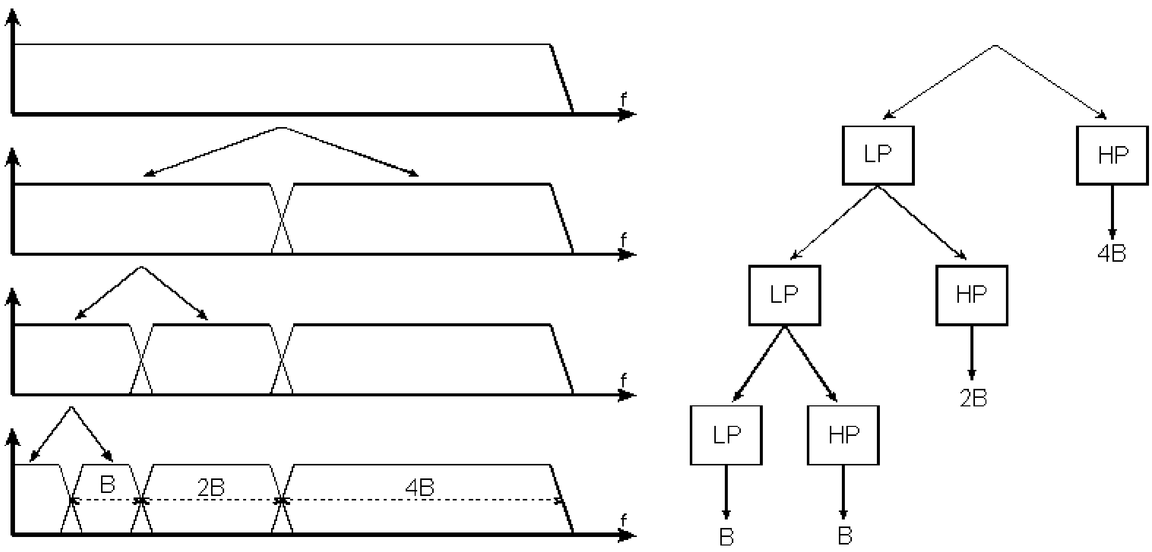


Figure 2.19 Subband of wavelet transform

2.6 Decision Tree

The automated classification of objects from large catalogues or survey projects is an important task in many astronomical surveys. Faced with various classification algorithms, astronomers should select the method according to their requirements. Here we describe several kinds of decision trees for finding active objects by multi wave length data, such as REPTree, Random Tree, Decision Stump, Random Forest, J48, NBTree, AdTree.

All decision tree approaches investigated are in the WEKA package. The classification performance of the methods is presented. In the process of classification by decision tree methods, the classification rules are easily obtained, moreover these rules are clear and easy to understand for astronomers. As a result, astronomers are inclined to prefer and apply them, thus know which attributes are important to discriminate celestial objects. The experimental results show that when various decision trees are applied in discriminating active objects (quasars, BL Lac objects and active galaxies) from non-active objects (stars and galaxies), ADTree is the best only in terms of accuracy, Decision Stump is the best only considering speed, J48 is the optimal choice considering both accuracy and speed.

2.6.1 J48

J48 is slightly modified C4.5 in WEKA. The C4.5 algorithm generates a classification-decision tree for the given data-set by recursive partitioning of data. The decision is grown using Depth-first strategy. The algorithm considers all the possible tests that can split the data set and selects a test that gives the best information gain. For each discrete attribute, one test with outcomes as many as the number of distinct values of the attribute is considered. For each continuous attribute, binary tests involving every distinct values of the attribute are considered. In order to gather the entropy gain of all these binary tests efficiently, the training data set belonging to the node in consideration is sorted for the values of the continuous attribute and the entropy gains of the binary cut based on each distinct values are calculated in one scan of the sorted data. This process is repeated for each continuous attributes. For a deeper introduction of this method, readers can refer to (Mitchell 1997; Quinlan 1986).

CHAPTER III
MATERIALS AND METHODS

3.1 Materials and Schedule

3.1.1 Schedule

Schedule of this research has start at September and use 4 months for research with any topic in table 3.1

Table 3.1 Schedule of research

Task\Month	September	October	November	December
Learning diamond	■			
Learning Wavelet		■		
Use Matlab with Wavelet Transform		■	■	
Analyze data			■	■
Use decision tree for recogize			■	■

3.1.2 Tools

List of tools for process pattern recognition of diamond has

3.1.2.1 Hardware

- Personal Computer: Intel Core i5, RAM 8 GB, HDD 1 TB.

3.1.2.2 Software

- Matlab version for using image processing with wavelet transform.

- Weka version for using pattern recognition with decision tree.
- Microsoft Windows 8 for Operating System of personal computer.
- Microsoft Excel 2012 for using database to keep data form Matlab and input data to Weka.

3.1.3 Data

The Data of Diamond cut that used in this research, will used the image of diamond cut as Figure 3.1 in 8 types only. But the real diamond cut image is difficult for analyze because reflect of light have more or other problem, it is a problem when learning data.

Figure 3.1 Real diamond cut image

So for eliminate those problems. This research is used diamond cut image in clearly image as Fig 3.2 by each image will have scaling in 0.5x, 1x, 2x pixel and rotating in every 90 degree angle

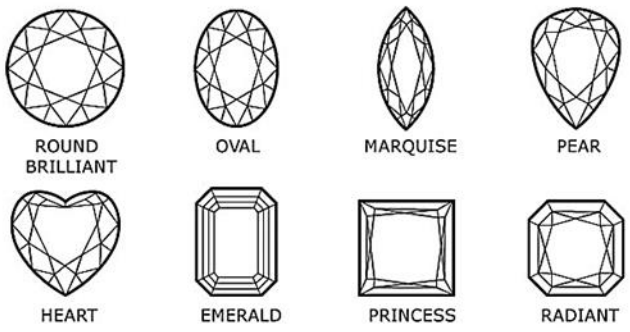


Figure 3.2 Clear diamond cut image

Some clearly image have different size in same image but some image in rotating is not different that can guess in same size the data must like in every angle too.

3.2 Method

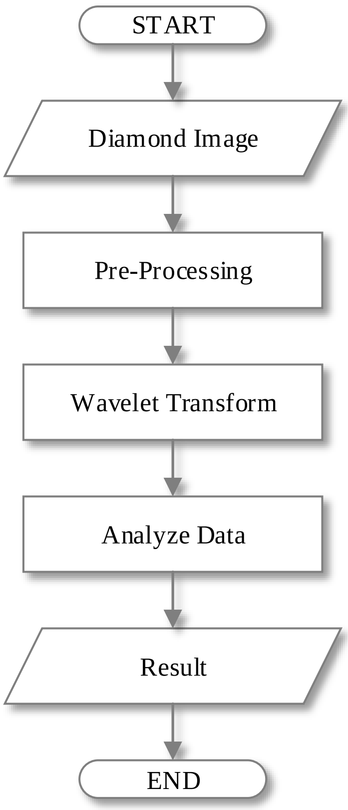


Figure 3.3 Flow process diagram

3.2.1 Initial

The diamond image is used in this processing totally 8 types but before process with wavelet transform. The diamond image will be pass pre-processing to edge detection for get line of diamond cut.

3.2.2 Processing

When the diamond image is passed in pre-processing. The diamond image that clearly and ready to use. That image must have edge of diamond cut and then take it into wavelet transform processing each image in Matlab. The statistic coefficient data will show for each image. Use those data to find important factor for pattern recognition.

3.2.3 Result

After get the static coefficient data, those data is used to factor and used all factor from each data take into Weka and use decision tree function for create a tree that show the result form data which important data for pattern recognition will show in tree.

CHAPTER IV
ANALYSIS AND RESULTS

4.1 Analysis

The clearly diamond cut image data in chapter 3, every image in scaling at 0.5x (64x64 pixel), 1x (128x128 pixel) , 2x (256x256 pixel) and rotating at 0°, 90°, 180°,270° will take it into Matlab with "**wavemenu**" command. And used 2D wavelet transform for analyze the image by use bior 2.2 as mother wavelet transform on level 1.

When each image input into processing wavelet transform, the statistic coefficient will showed as result in Fig4.1 – 4.8 and data in table 4.1 – 4.8 that is "feature extraction". It is the factor for use in pattern recognition by this research, the factor of standard deviation, median absolute deviation and mean absolute deviation is focused because those value is deviation of image.

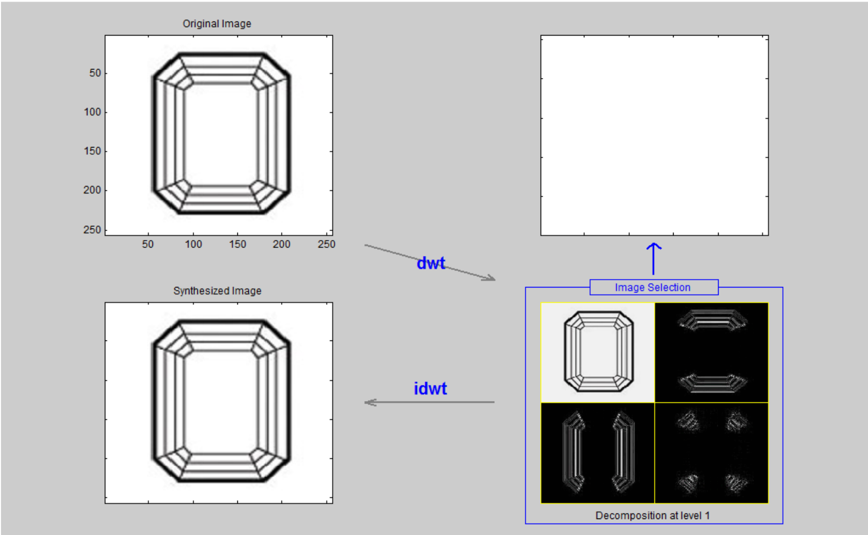


Figure 4.1 Emerald image output

Table 4.1 Emerald data output

Scale	Angle	Horizontal			Vertical			Diagonal		
		Std Dev.	Med Abs Dev.	Mea Abs Dev.	Std Dev.	Med Abs Dev.	Mea Abs Dev.	Std Dev.	Med Abs Dev.	Mea Abs Dev.
1x	0°,180°	23.70	0.00	7.92	30.90	0.00	12.22	7.02	0.00	1.97
2x	0°,180°	7.58	0.00	2.60	9.22	0.00	3.61	0.82	0.00	0.24
0.5x	0°,180°	37.02	0.06	17.27	50.95	0.13	27.79	16.16	0.00	4.99
1x	90°,270°	30.91	0.00	12.14	25.32	0.00	9.29	7.04	0.00	1.93
2x	90°,270°	9.24	0.00	3.60	7.58	0.00	2.58	0.82	0.00	0.23
0.5x	90°,270°	50.70	0.06	27.63	42.27	0.06	19.63	16.40	0.00	5.10

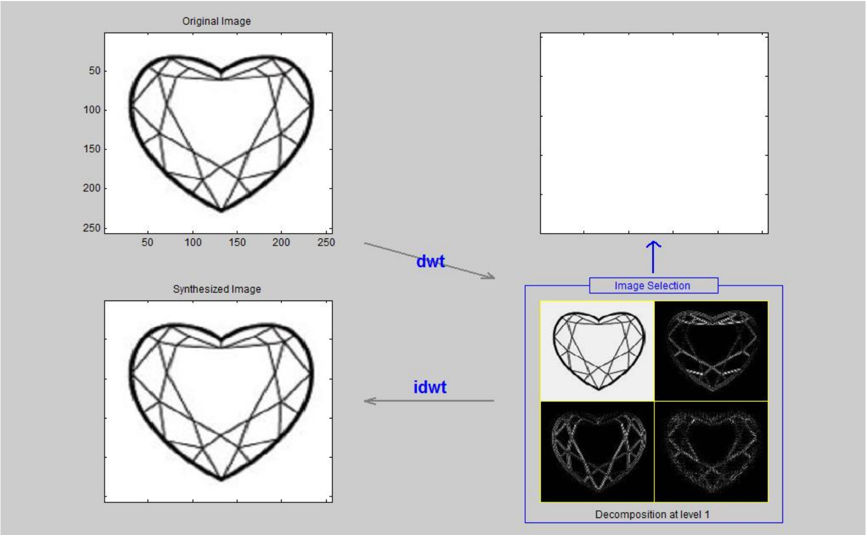


Figure 4.2 Heart image output

Table 4.2 Heart data output

Scale	Angle	Horizontal Std Dev.	Horizontal Med Abs Dev.	Horizontal Mea Abs Dev.	Vertical Std Dev.	Vertical Med Abs Dev.	Vertical Mea Abs Dev.	Diagonal Std Dev.	Diagonal Med Abs Dev.	Diagonal Mea Abs Dev.
1x	0°	24.59	0.31	9.81	26.04	0.38	10.98	10.15	0.25	4.22
2x	0°	7.60	0.13	3.03	7.90	0.06	3.34	1.16	0.00	0.52
0.5x	0°	40.55	1.34	19.41	45.60	1.22	21.60	23.03	0.75	11.27
1x	90°	26.46	0.38	11.25	24.43	0.38	9.95	9.94	0.25	4.27
2x	90°	7.99	0.13	3.40	7.64	0.13	3.06	1.19	0.00	0.53
0.5x	90°	46.72	1.88	23.44	42.61	1.66	20.73	22.44	1.00	11.48
1x	180°	24.51	0.38	9.86	25.85	0.44	10.92	9.84	0.25	4.21
2x	180°	7.64	0.13	3.05	7.92	0.13	3.35	1.15	0.00	0.51
0.5x	180°	40.83	1.47	19.54	44.73	1.50	21.94	23.33	1.00	11.65
1x	270°	25.90	0.44	11.18	24.98	0.38	10.12	9.93	0.25	4.20
2x	270°	7.99	0.13	3.39	7.63	0.13	3.05	1.19	0.00	0.53
0.5x	270°	45.61	1.63	22.12	40.66	1.63	19.86	22.97	1.13	11.37

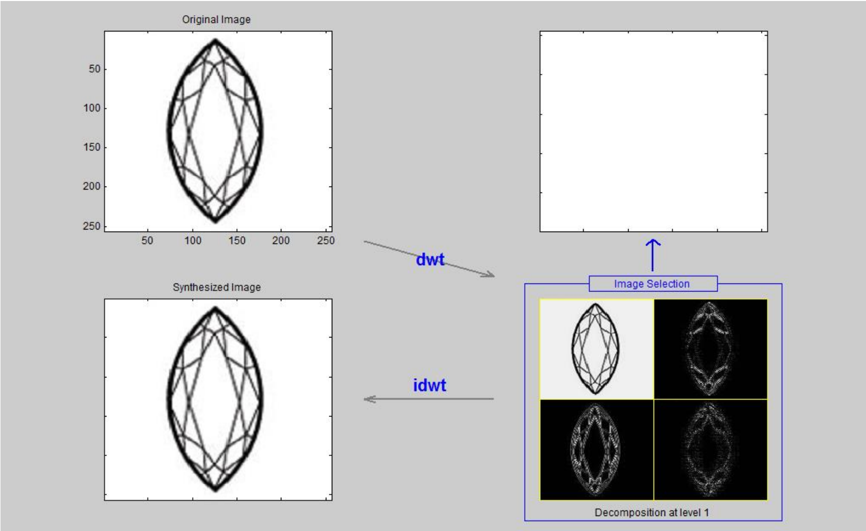


Figure 4.3 Marquise image output

Table 4.3 Marquise data output

Scale	Angle	Horizontal			Vertical			Diagonal		
		Std Dev.	Med Abs Dev.	Mea Abs Dev.	Std Dev.	Med Abs Dev.	Mea Abs Dev.	Std Dev.	Med Abs Dev.	Mea Abs Dev.
1x	0°,180°	12.35	0.00	3.99	29.86	0.00	11.67	7.04	0.00	2.50
2x	0°,180°	3.89	0.00	1.27	8.92	0.00	3.39	0.84	0.00	0.31
0.5x	0°,180°	18.53	0.00	7.23	46.89	0.00	20.79	16.83	0.00	6.50
1x	90°,270°	29.37	0.00	11.61	11.59	0.00	3.90	7.63	0.00	2.65
2x	90°,270°	8.93	0.00	3.40	3.88	0.00	1.28	0.87	0.00	0.31
0.5x	90°,270°	46.30	0.00	20.53	19.07	0.00	7.42	17.24	0.00	6.88

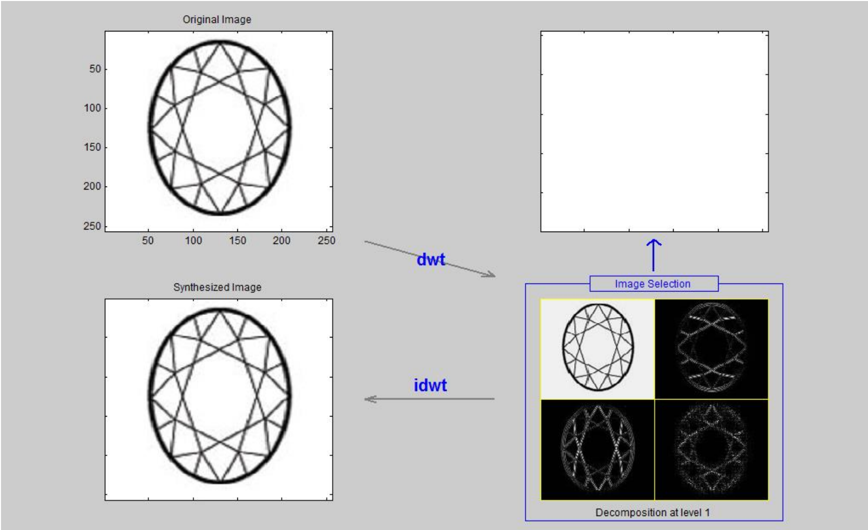


Figure 4.4 Oval image output

Table 4.4 Oval data output

Scale	Angle	Horizontal Std Dev.	Horizontal Med Abs Dev.	Horizontal Mea Abs Dev.	Vertical Std Dev.	Vertical Med Abs Dev.	Vertical Mea Abs Dev.	Diagonal Std Dev.	Diagonal Med Abs Dev.	Diagonal Mea Abs Dev.
1x	0°,180°	22.55	0.19	8.54	28.74	0.19	12.30	8.00	0.13	3.31
2x	0°,180°	6.81	0.00	2.53	8.64	0.00	3.59	0.98	0.00	0.42
0.5x	0°,180°	37.71	1.16	16.43	50.51	1.06	25.62	20.00	0.75	9.25
1x	90°,270°	28.26	0.13	11.87	21.88	0.14	8.21	8.53	0.00	3.46
2x	90°,270°	8.72	0.00	3.64	6.80	0.00	2.56	1.01	0.00	0.43
0.5x	90°,270°	50.48	1.19	25.47	36.63	0.97	15.90	20.16	0.75	9.37

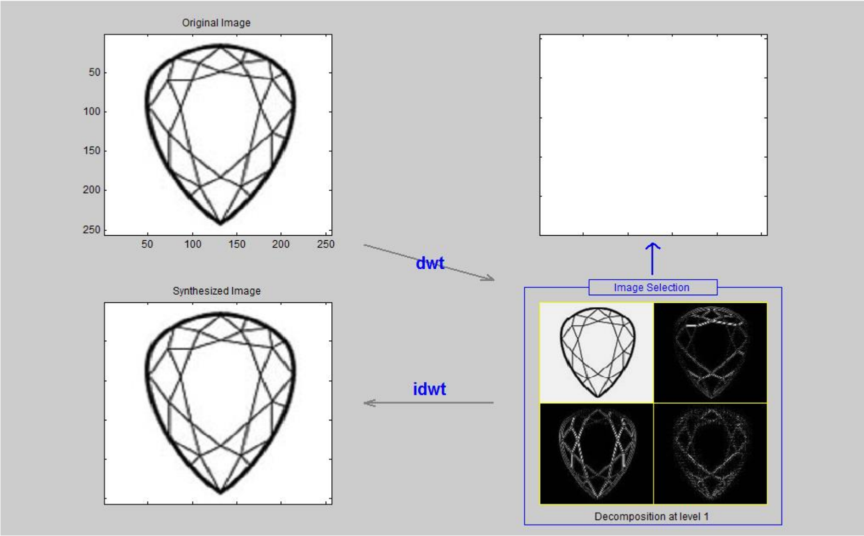


Figure 4.5 Pear image output

Table 4.5 Pear data output

Scale	Angle	Horizontal Std Dev.	Horizontal Med Abs Dev.	Horizontal Mea Abs Dev.	Vertical Std Dev.	Vertical Med Abs Dev.	Vertical Mea Abs Dev.	Diagonal Std Dev.	Diagonal Med Abs Dev.	Diagonal Mea Abs Dev.
1x	0°	21.74	0.13	7.93	27.84	0.13	11.53	8.86	0.13	3.58
2x	0°	6.63	0.00	2.46	8.76	0.00	3.60	1.05	0.00	0.44
0.5x	0°	34.05	0.81	15.14	49.28	0.81	23.31	21.00	0.63	9.56
1x	90°	28.08	0.19	11.94	21.04	0.19	7.99	8.71	0.13	3.63
2x	90°	8.84	0.00	3.65	6.63	0.00	2.46	1.08	0.00	0.46
0.5x	90°	48.17	0.81	23.03	33.63	0.75	15.36	21.75	0.63	9.78
1x	180°	20.52	0.13	7.89	29.29	0.19	12.42	9.00	0.13	3.72
2x	180°	6.60	0.00	2.44	8.76	0.00	3.59	1.05	0.00	0.44
0.5x	180°	33.96	0.75	15.18	48.77	0.75	23.51	21.59	0.63	9.95
1x	270°	29.57	0.25	12.41	21.79	0.19	7.99	8.84	0.13	3.68
2x	270°	8.83	0.00	3.67	6.65	0.00	2.47	1.08	0.00	0.46
0.5x	270°	50.18	0.88	24.21	34.65	0.88	16.15	20.71	0.50	9.20

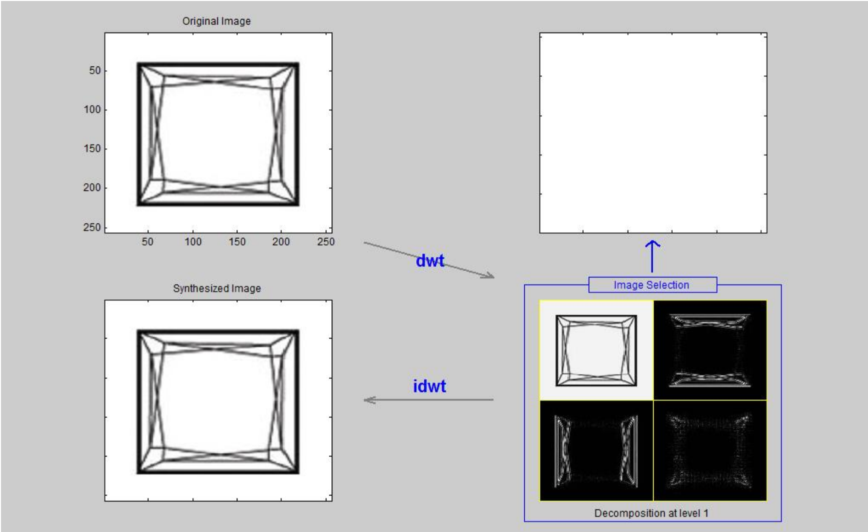


Figure 4.6 Princess image output

Table 4.6 Princess data output

Scale	Angle	Horizontal Std Dev.	Horizontal Med Abs Dev.	Horizontal Mea Abs Dev.	Vertical Std Dev.	Vertical Med Abs Dev.	Vertical Mea Abs Dev.	Diagonal Std Dev.	Diagonal Med Abs Dev.	Diagonal Mea Abs Dev.
1x	0°,90°, 180°,270°	24.65	0.00	8.78	25.88	0.00	9.27	3.54	0.00	0.97
2x	0°,90°, 180°,270°	7.74	0.00	2.71	7.72	0.00	2.76	0.47	0.00	0.16
0.5x	0°,90°, 180°,270°	38.20	0.13	17.07	45.62	0.25	17.77	7.21	0.00	2.49

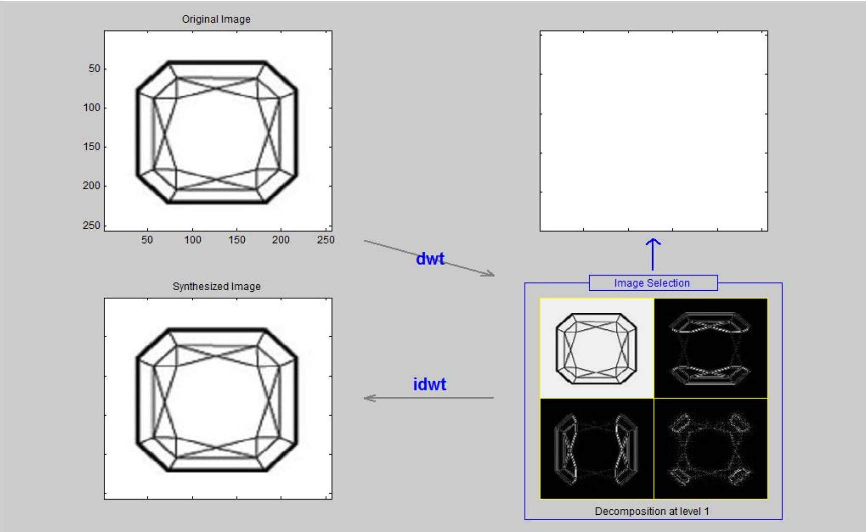


Figure 4.7 Radiant image output

Table 4.7 Radiant data output

Scale	Angle	Horizontal			Vertical			Diagonal		
		Std Dev.	Med Abs Dev.	Mea Abs Dev.	Std Dev.	Med Abs Dev.	Mea Abs Dev.	Std Dev.	Med Abs Dev.	Mea Abs Dev.
1x	0°,90°, 180°,270°	27.07	0.00	10.37	24.62	0.00	9.87	6.49	0.00	2.24
2x	0°,90°, 180°,270°	8.14	0.00	2.95	7.76	0.00	2.97	0.82	0.00	0.31
0.5x	0°,90°, 180°,270°	40.29	0.38	19.48	45.82	0.50	22.61	15.65	0.25	6.45

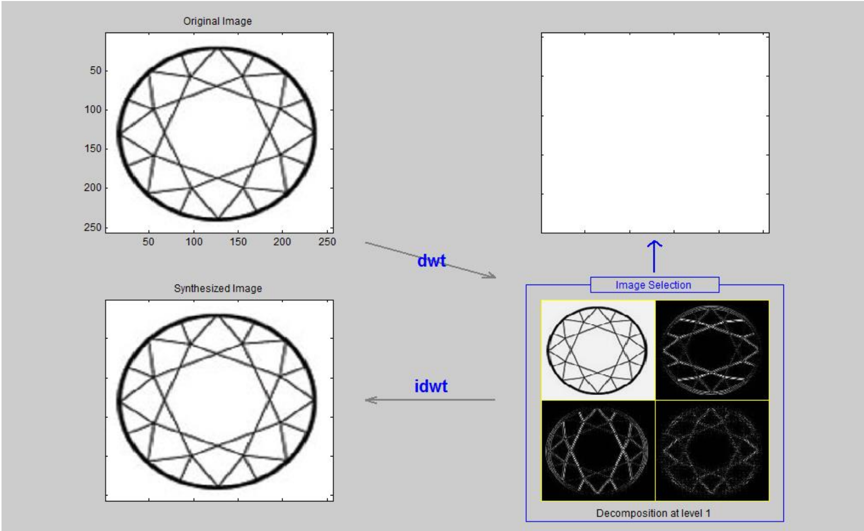


Figure 4.8 Round Brilliant image output

Table 4.8 Round Brilliant data output

Scale	Angle	Horizontal			Vertical			Diagonal		
		Std Dev.	Med Abs Dev.	Mea Abs Dev.	Std Dev.	Med Abs Dev.	Mea Abs Dev.	Std Dev.	Med Abs Dev.	Mea Abs Dev.
1x	0°,90°, 180°,270°	28.64	1.19	12.47	27.55	1.31	12.44	9.86	0.75	4.50
2x	0°,90°, 180°,270°	8.78	0.50	3.82	8.34	0.44	3.72	1.15	0.13	0.56
0.5x	0°,90°, 180°,270°	48.11	3.53	24.62	46.71	3.31	24.01	23.20	2.13	12.08

4.2 Results

From data factor output of wavelet transform as shown in table 4.1 – 4.8, the data is familiar in rotating but in scaling factor data have different upon scaling.

For the data that will use to find the important factor, it need to use the data is stable. For data is stable which need to average those data as shown in Table 4.9 – 4.16.

Table 4.9 Statistical property coefficients of Round Brilliant

Type	Std dev.	Med abs dev.	Mean abs dev.
Horizontal	28.67	1.375	12.58
Vertical	27.57	1.5	12.54
Diagonal	9.876	0.875	4.58

Table 4.10 Statistical property coefficients of Oval

Type	Std dev.	Med abs dev.	Mean abs dev.
Horizontal	22.58	0.25	8.576
Vertical	28.78	0.1875	12.34
Diagonal	8.002	0.125	3.324

Table 4.11 Statistical property coefficients of Marquise

Type	Std dev.	Med abs dev.	Mean abs dev.
Horizontal	12.36	0	4.02
Vertical	29.89	0	11.72
Diagonal	7.041	0	25.26

Table 4.12 Statistical property coefficients of Pear

Type	Std dev.	Med abs dev.	Mean abs dev.
Horizontal	21.76	0.3125	8.012
Vertical	27.88	0.3125	11.61
Diagonal	8.86	0.125	3.622

Table 4.13 Statistical property coefficients of Heart

Type	Std dev.	Med abs dev.	Mean abs dev.
Horizontal	24.63	0.5	9.898
Vertical	26.05	0.5	11.07
Diagonal	10.16	0.25	4.284

Table 4.14 Statistical property coefficients of Emerald

Type	Std dev.	Med abs dev.	Mean abs dev.
Horizontal	23.72	0	7.974
Vertical	30.92	0	12.25
Diagonal	7.021	0	2

Table 4.15 Statistical property coefficients of Princess

Type	Std dev.	Med abs dev.	Mean abs dev.
Horizontal	24.64	0	8.812
Vertical	25.91	0	9.324
Diagonal	3.555	0	1.004

Table 4.16 Statistical property coefficients of Radiant

Type	Std dev.	Med abs dev.	Mean abs dev.
Horizontal	27.09	0.0625	10.43
Vertical	24.65	0.125	9.931
Diagonal	6.507	0	2.29

CHAPTER V
CONCLUSION AND DISCUSSION

This object of this research is to find factor from wavelet transform for recognition diamond's cut. The research used decision tree J48 for find factor which can used in recognition by used WEKA application in create decision tree from data in table 4.9 - 4.16 for find final factor that can recognize diamond cut.

5.1 Conclusion

From chapter 4, the wavelet transform can exact the feature from diamond cut image that shown many factor but the factor used have totally 9 factor is

- Standard deviation in Horizontal
- Median absolute deviation in Horizontal
- Mean absolute deviation in Horizontal
- Standard deviation in Vertical
- Median absolute deviation in Vertical
- Mean absolute deviation in Vertical
- Standard deviation in Diagonal
- Median absolute deviation in Diagonal
- Mean absolute deviation in Diagonal

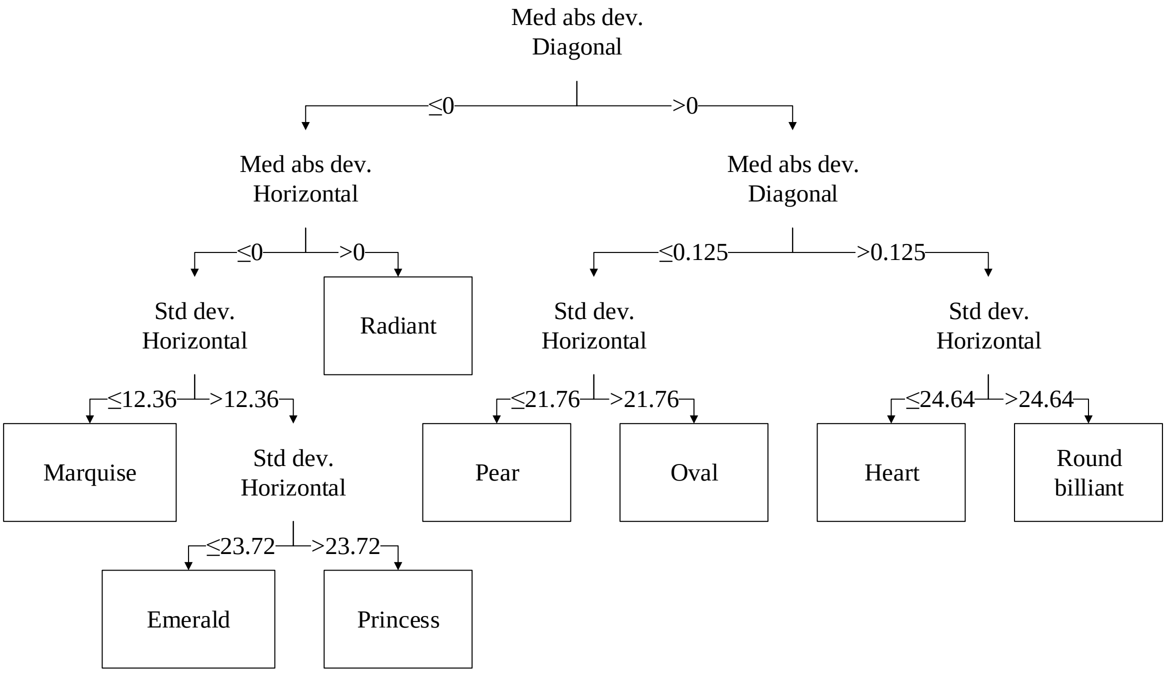


Figure 5.1 Tree model

In Figure 5.1 shown is the result of pattern recognition by used those 9 factor and use decision tree J48 in pattern recognition. So, the final result of factor for pattern recognition have just enough 3 factor only that can recognition is

- Median absolute deviation in Diagonal
- Median absolute deviation in Horizontal
- Standard deviation in Horizontal

And test tree model with image in rotate, can show correct output target and get accuracy rate equal 100 % although use other degree as 30 degree, 45 degree, 60 degree or other , accuracy is still 100 %.

But in scaling image is tested within range from 0.5x to 2x size, the accuracy is absolutely not equal 100% by upon scaling if scale of image is near range origin 1x size accuracy will near 100% but if scale of image is wide range, the accuracy will decrease or output result wrong if so wide.

5.2 Discussion

5.2.1 This research of pattern recognition of diamond cut should be collected data from many image of rotating and scaling.

5.2.2 This all research used biorthonogal mother wavelet transform in one order only, next time should be use another mother wavelet transform and other order, will be get the better data form this research.

5.2.3 In next time should be used other diamond cut than 8 types in this research for improve this research than better.

5.2.4 In next time should be used other view of diamond cut image for improve this research.

5.2.5 In next time should be change diamond cut image to real image for recognize form real diamond.

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APPENDIX

Texture Classification of Diamond Cut

Peerapat Sriangsuthananon, Adisorn Leelasantitham, Supaporn Kiattisin
Technology Information System Management Program
Faculty of Engineering, Mahidol University
25/25 Puttamonthon, Nakorn Pathom 73170, Thailand
applepandora9@gmail.com, adisorn.lee@mahidol.ac.th, supaporn.kit@mahidol.ac.th

Abstract—The diamond cut, there are many types in the world. However, many people still does not know about those types. The diamond classification can be used in four C's which are diamond clarity, diamond carat, diamond color and diamond cut and this paper used diamond cut for classifying the diamond which is texture of diamond because this is the single most important factor of the four C's. So, the diamond cut need to classify by texture of those diamonds. It will be good if we use the image for classify texture and the texture classification from image which has been researched. The best way for classification is to find the value which can classify from feature extraction. The wavelet transform is the one from all of algorithm which can do feature extraction and get more features form texture. For this reason, the wavelet transform was appropriate for texture feature extraction and the performance of feature extraction was shown as Statistical property coefficients. The Statistical property coefficients was standard deviation, median absolute deviation and mean absolute deviation of horizontal, vertical and diagonal form wavelet transform which used those coefficients for achieving a success in texture classification.

Keywords—Pattern Recognition; wavelet transform; diamond cut; texture classification

I. Introduction

The Diamond is very valuable material and many people want to have it as their assets. So, the diamond was often stolen or was copied to fake diamond. It is very difficult to protect it if the protection or careful observation is not good enough and the fake diamond verification is also difficult too because the diamond verification processes need the diamond expert for verifying. However, sometimes the verification may take a long time and low accuracy if that expert's experience is not good enough. It will charge very high cost if we decided to use the diamond tester for verification.

On the other hand, there are only few people who really have the knowledge about the diamond if they are not interested in or learn in details such as diamond clarity, diamond carat, diamond color and diamond cut. Especially in the diamond cut which is a style or design guide used to shape a diamond for polishing[1]. The diamond cut is also the calling name for the types of diamond which have many names separated by diamond sharp following the diamond's lapidary made it. In fact, the people cannot know what the name of that diamond. So, the best way to know that is to ask the expert. It will be great if we have some remarkable signs which is easy to recognize the name of diamond from diamond cut without any cost or time.

Texture analysis is often used in image processing and pattern recognition processes widely. It was the beginning of the introduction into the desired target. If the analysis is not enough, the desired results would not be shown as well. E.g. In the feature extraction, if the texture has no features appear at all, it is impossible or the result is incorrect.

Texture classification is very important in image processing and pattern recognition areas. The methods known are Fourier transform, Linear transforms, Chain code, Shape Matrix, Region moments, Gabor filtering and Co-occurrence approach [4,7] but there are many methods to be use with and include Wavelet transform too. According to the abstract, the wavelet transform is a method which used to analyze the texture because the wavelet transform can help to solve problems in diamond quality by analyzing the differentiation between defective and flawless diamond. Because of the each image of the diamond has difference texture [3]. The wavelet transform has 6 features to operate the feature extraction which refers to the statistical property coefficients more than feature extraction by Fourier transform with less response time, reliable, better technique and localized in time & frequency[2,6]. Then classification use coefficients from wavelet transform such as standard, median, mean, standard deviation, median absolute deviation and mean absolute deviation of

Approximate, horizontal, vertical and diagonal coefficient of wavelet transform which can be described by the tree diagrams to display result of classification.

II. Method

The method for texture classification of diamond cut in this paper is used a flow diagram that shown in Fig.1 as below

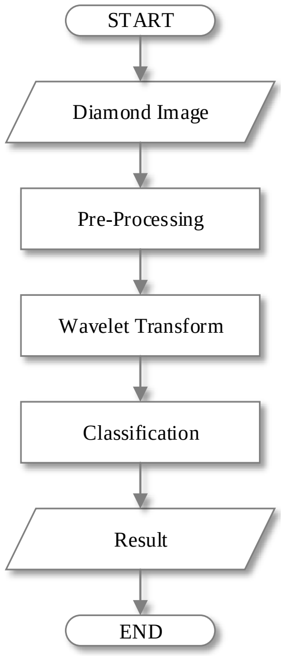

Fig.1 Flow diagram for classify diamond cut

This diagram in Fig.1 is shown the flow for analyzing texture classification by wavelet transform. The first, Diamond image is a clear top-view diamond image and eight types of diamond cut as mentioned above in Fig.2. After that, in pre-processing is used algorithm for transforming to the edge line following the line of diamond cut as shown in Fig.3. Next, we will use the two dimensions discrete wavelet transform for decomposition to analyze the diamond image and get the Statistical property coefficients from it to be feature (feature extraction) and to use those coefficients for classifying result which will show specific feature of that diamond cut.

Fig.2 clear top-view diamond image

In texture analyze, the diamond image is used in texture analysis with two dimensions greyscale image level by edge transform from three dimensions color image in top-view diamond cut. The diamond cut which is used in the paper can define following the images as round brilliant, oval, marquise, pear, heart, emerald, princess and radiant and each diamond cut is used 10 sample images in rotating and scaling with Similar size.

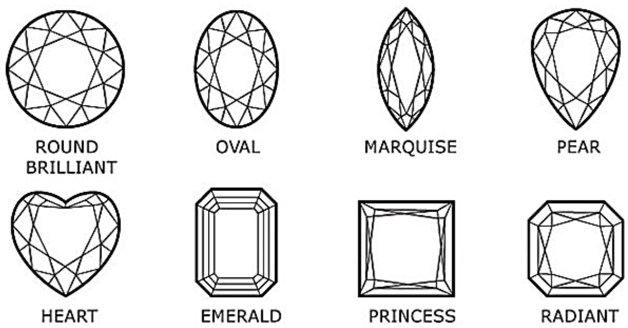

Fig.3 Top view's edge of diamond cut

The wavelet Transform is normally used in decomposition and reconstruction. Figure as below is shown the methodology of decomposition what used in two dimension discrete wavelet transform.

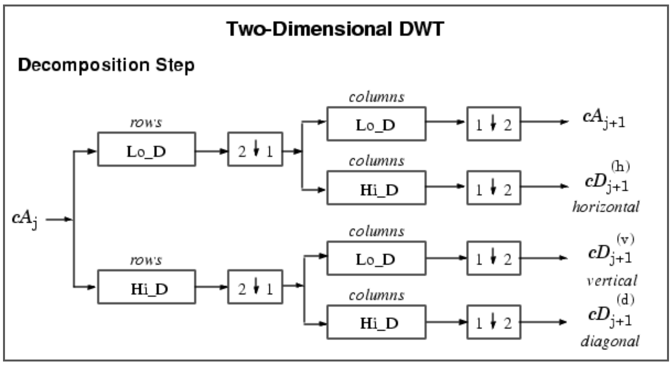

Fig.4 Decomposition step of two dimension discrete wavelet transform

The (continuous) wavelet transform of one dimension is defined as,

$$Wf_a(b) = \int f(t)\,\Psi_{a,b}(t)dt = \langle f, \Psi_{a,b}\rangle, a \neq 0$$

Where the wavelet $\Psi_{a,b}$ is computed from the mother wavelet Ψ

$$\Psi_{a,b}(t) = \frac{1}{\sqrt{a}}\Psi\left(\frac{t-b}{a}\right)$$

And can be discretized by restraining a and b to a discrete lattice.

For feature extraction, the decomposition step is used for finding the factor which takes in texture pattern recognition by high frequency pass filter and low frequency pass filter with the original image called filters bank. That is usually performance by using a product of one dimension filters can defined as,

$$L_n(b_i, b_j) = \left[H_x\left[H_y L_{n-1}\right]_{\downarrow 1,2}\right]_{\downarrow 1,2}(b_i, b_j)$$

$$D_{n1}(b_i, b_j) = \left[H_x\left[G_y L_{n-1}\right]_{\downarrow 1,2}\right]_{\downarrow 1,2}(b_i, b_j)$$

$$D_{n2}(b_i, b_j) = \left[G_x\left[H_y L_{n-1}\right]_{\downarrow 1,2}\right]_{\downarrow 1,2}(b_i, b_j)$$

$$D_{n3}(b_i, b_j) = \left[G_x\left[G_y L_{n-1}\right]_{\downarrow 1,2}\right]_{\downarrow 1,2}(b_i, b_j)$$

The filters bank is four different image which pass low and high filter called approximation, horizontal, vertical and Diagonal. The filters bank can be explained following Fig.4 as the approximation image which is got form original image by passing low-pass filter and then passed low-pass filter again. This image must use in second time or next time as soon as possible, the horizontal image is passed high-pass filter, the Vertical image is passed low-pass filter and passed high-pass filter again, the diagonal image is passed high-pass filter and passed low-pass filter again and image's result is shown as Fig.5 as below.

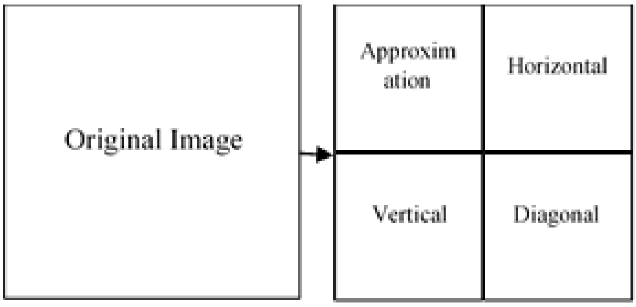

Fig.5 Result of wavelet transform

The statistical property coefficients can get form those image. As mentioned above, the approximation image cannot use it. Therefore, the only three images are horizontal image, vertical image, diagonal image which are used in feature extraction for pattern recognition and the statistical property coefficients which are used in this methodology is standard deviation, median absolute deviation and mean absolute deviation of those three images. According to the feature extraction, we will get them from two dimensions discrete wavelet transform have totally nine features and are suitable features for texture classification [4].

The original image which is used in two dimension discrete wavelet transform must be chosen by the best size of height or row and width or column of image which is 2^n pixel of both size when n is 1, 2, … such as 512 pixel or 1024 pixel which is 2^9 and 2^{10} as sequence. Because of the pass wavelet transform in first filter once time, the size of columns is decreased by a half with keeping the even index of columns. Then, when pass again in second filter the size of rows is decreased by a half too with keeping the even index of rows. So, the size of image will be decreased by a half when passed wavelet transform once time and decrease again when passed it again time by the size when passed wavelet transform is $\frac{2^n}{x}$ when x is total time or called "subband". It will get a good coefficients if we choose the good size of image for analyze. Although, wavelet transform can used in rotation and scaling.

So, the diamond image is taken as top-view type for diamond cut's name. The wavelet transform uses the two dimension discrete wavelet transform in first order for analyzing that image to find result classification.

III. Experiment & Discussion

In this experiment, it will start after pre-processing methodology which will be used the edge of diamond cut image as Fig.3 for completed analyzing with two dimensions discrete wavelet transform to do the feature extraction with size of each edge's image in 128x128 pixels by the diamond cut which is in center of image.

Then, we use those images to analyze with Biorthogonal Wavelet of order 2.2 and level 1. So, the Statistical property coefficients is got from image as below by get the value of mean deviation (MD) signature as texture feature. The mean deviation is defined as,

$$MD_{ni} = \frac{1}{N}\sum_{j,k} | D_{ni}(b_j, b_k) |$$

When N is the total number of wavelet coefficients in D_{ni} which is a sub image.

Table I Statistical property coefficients of round

Round Brilliant			
Type	Std dev.	Med abs dev.	Mean abs dev.
Horizontal	28.67	1.375	12.58
Vertical	27.57	1.5	12.54
Diagonal	9.876	0.875	4.58

Table II Statistical property coefficients of oval

Oval			
Type	Std dev.	Med abs dev.	Mean abs dev.
Horizontal	22.58	0.25	8.576
Vertical	28.78	0.1875	12.34
Diagonal	8.002	0.125	3.324

Table III Statistical property coefficients of marquise

Marquise			
Type	Std dev.	Med abs dev.	Mean abs dev.
Horizontal	12.36	0	4.02
Vertical	29.89	0	11.72
Diagonal	7.041	0	25.26

Table IV Statistical property coefficients of pear

Pear			
Type	Std dev.	Med abs dev.	Mean abs dev.
Horizontal	21.76	0.3125	8.012
Vertical	27.88	0.3125	11.61
Diagonal	8.86	0.125	3.622

Table V Statistical property coefficients of heart

Heart			
Type	Std dev.	Med abs dev.	Mean abs dev.
Horizontal	24.63	0.5	9.898
Vertical	26.05	0.5	11.07
Diagonal	10.16	0.25	4.284

Table VI Statistical property coefficients of emerald

Emerald			
Type	Std dev.	Med abs dev.	Mean abs dev.
Horizontal	23.72	0	7.974
Vertical	30.92	0	12.25
Diagonal	7.021	0	2

Table VII Statistical property coefficients of princess

Princess			
Type	Std dev.	Med abs dev.	Mean abs dev.
Horizontal	24.64	0	8.812
Vertical	25.91	0	9.324
Diagonal	3.555	0	1.004

Table VIII Statistical property coefficients of radiant

Radiant			
Type	Std dev.	Med abs dev.	Mean abs dev.
Horizontal	27.09	0.0625	10.43
Vertical	24.65	0.125	9.931
Diagonal	6.507	0	2.29

Finally, the classification will use the value from feature extraction follow TABLE I-VIII when Std dev. is standard deviation, Med abs dev. is median absolute deviation and Mean abs dev. is mean absolute deviation of horizontal, vertical and diagonal image which are totally nine features that are average from each image in same diamond cut. The classification uses the one of top three in classification and performance of decision tree is J48 [5] for classifying those values and show as Fig.6 is below

IV. RESULT & CONCLUSION

The Result of classification from the decision tree can be summarized as follow, the features of image which is used in classify diamond cut have three features which are 1.median absolute deviation of diagonal 2.median absolute deviation of horizontal 3.standard deviation of horizontal by value condition as Fig.6. So, the three features can identify eight types of diamond cut

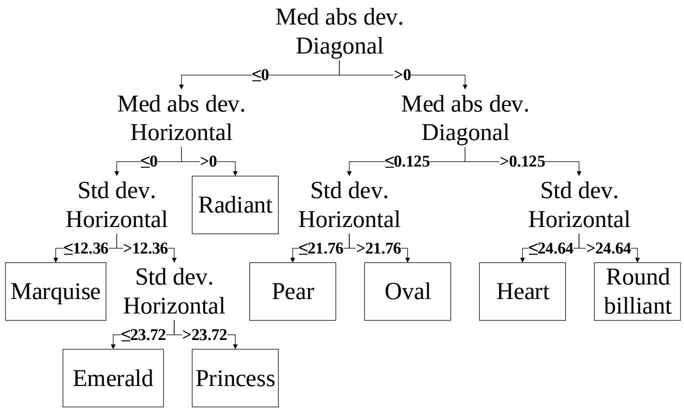

Fig.6 Result of classification

In the future, the diamond cut image would be useful for the real diamond image. If we use the real diamond image which is taken the pre-processing for getting edge image which may be different one from this experiment.

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BIOGRAPHY

NAME	Mr. Peerapat Sriangsuthananon
DATE OF BIRTH	10 August 1988
PLACE OF BIRTH	Bangkok, Thailand
INSTITUTIONS ATTENDED	University of Thai Chamber of Commerce, 2007-2011
	Bachelor of Engineering (Computer Engineering)
	Mahidol University, 2011-2013
	Master of Science (Technology of Information System Management)
RESEARCH GRANTS	Grant to Support Graduate Students in Academic Presentations in Thailand Academic Year 2013
HOME ADDRESS	293/55 Pracha Uthit Road, Bang Mod, Thungkhru, Bangkok, Thailand, 10140
	Tel. 085-515-7920
	E-mail : sriangsuthananon@hotmail.com
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