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IOT-Based Gemstone Detection and Analysis System

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ABSTRACT

"A gemstone is a mineral stone that be formed from the result of geological processes and has a hardness above 7 Mohs" [2]. [1] This current research is undertaken to create a system that can identify the gemstones of the Corundum Family. According to [2], there are four characteristics that can be used to identify the type of gemstone based on physical aspects. These four aspects are refraction of light, the color, density, and hardness of the mineral contained in the stone.

One of the countries that produce the most gemstones and has the highest proportion of gemstones is Sri Lanka. There are 200 diverse types of gemstones around the globe, but only about 75 distinct kinds of coloured and colourless gemstones from 10 primary families could be discovered in Sri Lanka. Although Sri Lanka is naturally rich in the gemstone industry, the methods or techniques that are used to verify and validate gemstones are yet manual and traditional. The gemstone trade continues to thrive as miners and traders are far more knowledgeable about the different varieties of gemstone families. The method of verifying gemstones is fraught with challenges for both clients and traders.

This research is conducted to invent an Internet of Things (IoT) based gemstone detector that can identify gemstones based on their refractive index, colour, and Cut-Shape, it is possible to effectively address the issues that customers and traders both confront. The refractive index, colour, and Cut-Shape of the gemstone will be determined via image processing, and the IoT device will be utilized to cluster the other elements.

Keywords— Gemstone, Corundum, Image Processing, IOT, Convolutional Neural Network

I. INTRODUCTION

A natural gemstone is a mineral, stone, or organic matter that can be cut and polished or otherwise treated for use as jewelry or other ornament [1] Sri Lanka is naturally rich in gemstones. During early times Sri Lanka was once quite fittingly referred to as "Rathna-dweepa" which connotes the meaning "The Island of Gemstones" [3] Famous gemstones from Sri Lanka range in variety. Especially notable are blue sapphire, pink sapphire or ruby, and yellow sapphire; alexandrite and cat's-eye chrysoberyl; and almandine and hessonite garnet. Spinel, tourmaline, zircon, moonstone, and quartz are also relatively common; they share their country of origin with several rarer gemstones as well. [4]

There are numerous gem families, and for this research project, the "Corundum family" has been selected as the gemstone family. There are seven distinct types of gems in the corundum family: Ruby, Padmaraga, Blue sapphire, yellow sapphire, pink sapphire, purple sapphire, and green sapphire. the reason for selecting the Corundum family It is highly valued and popular. The corundum family of gemstones consists of some of the most valuable and popular gemstones including ruby and sapphire. [5]

According to [2] there are four characteristics that can be used to identify the type of gemstone based on physical aspects. These four are hardness, density, refraction of light and the colour of the mineral contained in the stone. The value of a gemstone is determined by the famous 4 big C's: Colour Clarity Cut or shape (or the potential for cutting) Carat (or the carat after cutting). [2] Carat weight has a very specific definition; one carat is equal to 200 milligrams, or one-fifth of a gram. Carat weight has an important impact of the price of a gemstone. The higher the carat weight, the more expensive the gem will be. Gemstones are frequently priced per carat meaning that gemstones of a known quality are sold by their actual weight. [2] There are number of devices to identify a gemstone such as: Loupe, Microscope, Refractometer, Dichroscope, Polariscope, Spectroscope, Lighting and Stands. Measuring the Refractive Index (RI) of gems will be a high priority. It can do this with a microscope, but a refractometer is the best tool. Besides measuring the RI, a refractometer will give the birefringence and optic sign of a gemstone [6]. This research will use an image recognition models and methods where a gemstone image is used as an input data to the image processing model, to identify the Refractive index value, colour and the shape of a gemstone in the gem industry. One of the tools gemmologists use to identify diverse types of gems is a spectroscope. This tool allows the gemmologist to determine the spectra of a gemstone which shows which wavelengths are absorbed. It is a powerful identification test and serves to illustrate the above example. Below are the specters from Ruby and Tsavorite with the lines showing which colours are absorbed [7].

Several types of gemstones vary in density. In gemology, the density or *specific gravity* of a gemstone is computed as the ratio of the density of the material to the density of water. The density is expressed as a

number which indicates how much heavier the gemstone is compared to an equal volume of water [8]

One most important attributes of a gem material are its colour [9]. As mentioned above, colour is important to both identification of a gem as well as to determine the value of a gemstone. Colour is a combination of hue, tone, and saturation. Hue is the colour portion of the model, expressed as a number from 0 to 360 degrees. Tone describes how dark or light the colour is or whether your gem's tone light, medium, dark, or somewhere in between. Next judge the strength or intensity of the colour (saturation) in one of six grades ranging from dull through strong to vivid. To assess saturation, first note whether your stone's colour falls in the warm (yellows, oranges, reds) or cool (purples, blues, greens) colour family.

As mentioned above colour of the gemstone plays a key role in the gem industry. And at present in Sr Lanka the colour of the gemstone is identified using our naked eye or printed colour charts. As current technological developments are fast-paced, and advancements are making it easier to identify the colour of the gemstone. Image processing is one type of technology. By taking existing Hue, Saturation wand Value (HSV) colour in images of gemstone, the colour of the gemstone can be detected through image processing [10].

We discovered throughout this research's fieldwork in Rathnapura that a gem's kind can vary depending on its refractive index. A detailed chart was presented to us, highlighting various gemstones and their refractive indices. The gem would vary within its family despite the little variations in refractive indexes. Refractometers were used to determine a certain gemstone's refractive index. One step in the process of finding gems is using their refractive index.

The gem traders claimed that while some gemstones could be identified simply by looking at them and others by using the tools they own, such as refractometers and spectroscopes, others were more challenging to identify. As a result, these stones are delivered to the gem laboratory. Additionally, they noted that utilizing a refractometer is difficult due to the instrument's high cost and the requirement that a liquid known as the "Refractive index liquid" be required alongside it in order to function properly. It can injure skin if used improperly or if a droplet falls on it. Additionally, the Refractive Index is too expensive to be purchased. Customers frequently fall victim to fraud because they are unaware of it because gems are very expensive things. The Cut-Shape and colour of gems tend to be similar, although they could be whole unrelated gems. Gems vary according to their value as well.

II. RELATED WORK

In related work, the authors did not find research that used a similar title but instead adopted some of the associated prior research as references.

The first reference is Development of a Gemstone Type Identification System Based on HSV Space Colour Using an Artificial Neural Network Back Propagation Algorithm by V. A. H. S. H. Ismatul Maula [11] They have used HSV color model to distinguish the color and Artificial Neural Network (ANN) back propagation algorithm to determine whether a gem is a Ruby, Emerald, or Sapphire. But this research paper has used only 15 images to train the model and 15 images to test the model.

The second reference is An Image Processing Technique for Color Detection and Distinguish Patterns with Similar Color: An aid for Color Blind People by S. K. V. S. B. S. Bhagya R Navada [12], IMAQ color detection is used for detecting the color after training it to n colors to develop an aid for color blind people for recognizing color and the edges of images. They have used 64 images to test the model.

The third reference is Specific Color Detection in Images using RGB Modelling in MATLAB by T. J. S. K. Vishesh Goel [13], it gives an approach to recognize colors in a two-dimensional image using color thresh-holding technique in MATLAB with the help of RGB color model to detect a selected color by a user in an image

In our research study, we are using the HSV color model to detect the colors. The reason we use HSV color space for color detection over RGB is that HSV is more robust towards external lighting changes. This means that in cases of minor changes in external lighting (such as pale shadows) Hue values vary lesser than RGB values. CNN (Convolutional Neural Network) (Convolutional Neural Network) has Very High accuracy in image recognition problems, and it automatically detects the key features without any human supervision than ANN.

By automating the gemstone detection process with an IoT device, this research hopes to reduce excessive expenditure, while also improving accuracy and efficiency. The colour of the gemstone is one of the most crucial determining factors for determining the proper gemstone; colour charts are used in gem labs to discover the proper gemstone. A distinct weighting strategy is essential to implement the carat weight. The cut-shape of a gemstone has a direct impact on both its market value and appearance. To identify the cut-shape of gemstones, we use a variety of techniques, including classification algorithms, image segmentation techniques, decision trees, etc. A programmed microcontroller connects the weight sensor, LED lights, and other components. Through Wi-Fi, the device is linked to a mobile application and the cloud. Through the mobile application, it measures the Refractive index using image processing and displays all the information that has been determined about a certain gemstone, such

as the weight of the gem, the true colour of the gem, the Refractive Index, cut, and shape. This gem information detecting device is primarily focused on cost reduction, automating the human gem detection process, and making the process simpler and easier by integrating several different devices into a single device.

So, in this way when we compare the proposed system with the existing research papers, we can conclude that the proposed system will have a high accuracy rate in detecting the color.

Gemstone cut-shape identification and analysis is a topic that discussed since a long ago. Number of attempts have been made for discovering new technologies and methods to detect gemstones all over the world. From the past to the present-day researchers have launched several experiments regarding detecting gemstones not only with the automation processes but also with laboratory processes. The present subject matters disclose aspects related to gemstone identification automation. Bertrand Devouard and Franck Notari conducted research and found that measurements of optical and physical properties, combined with acute observation using various illumination techniques, are usually sufficient to determine the nature of a gem [15]. So, they improved identification mechanism use in laboratory environment enhancing spectroscopic laboratory techniques [15]. Rahul Mahendrakumar and Munjalkumar Dhirajlal conducted research to detect synthetic gemstones using image processing with the help of a laser beam and the refraction pattern of gemstone [16]. In that they have analyzed physical and optimal properties for detection. Peter C. Zwaan has conducted research for detect blue sapphire and red ruby in Sri Lanka which are belongs to Corundum family [17].

But he hadn't used any computerized method for that. He has analyzed lapidary treatments, cutting gemstones, inclusions and characteristics of Corundum family. Saulius Sinkevicius, Arunas Lipnickas and Kestas Rimkus together have identified amber gemstones using color and shape [18]. they have used technologies like image processing, matching, image classification techniques [18]. Adriano A. Mol, Luiz S. MartinsFilh and Jose Demisio S. da Silva together launched research to detect parameters estimation in gemstones cut design using ANN [19]. They have used computer-aided-design technology (CAD)
[19].

III. METHODOLOGY

The proposed system-based Corundum Gem Detector has a capability of identifying the gemstones of the corundum family and detect the exact color of the gemstone, refractive index, the cut shape of it, and its weight and send data to the connected mobile application and save to the cloud.

A. Proposed Smart Device

There is a proposed system to identify the essential details of a gemstone automatically to be used by the user. The process of the implementation of the functionalities is based on controlling the automated components of the device using IoT technologies. Those are the measure the weight of a particular gem accurately, optimal image capturing and image processing, measure the Refractive index of a particular gem, send collected information to the mobile application, which is to the device via Wi-Fi, display gem information to the user including colour, refractive index, cut and shape, weight (in grams and carat), send, and save collected information in the cloud. The above functionalities are included so that a user interface will be provided to the user using a mobile application to consume the detected data and save them for future usage. One of the main objectives of this research is to reduce the cost of a smart device rather than using expensive machines. Hence, to implement the smart device prototype it is included Arduino-based technologies. The block diagram of the gemstone identification system can be seen in Figure 1.

B. Block Diagram of the Smart Device

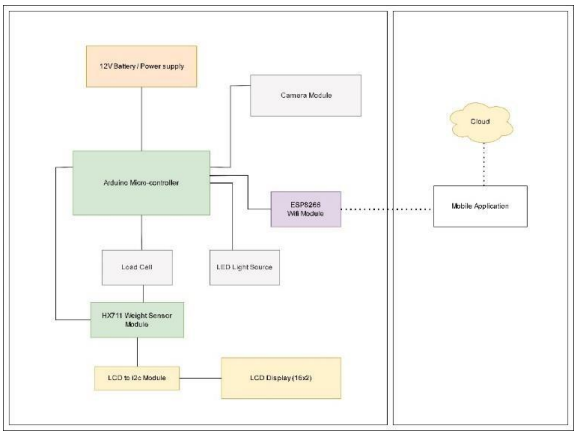

Figure 1

The device is using Arduino-based technologies. Arduino UNO micro-controllers are included which control the functionalities to measure the weight of a gemstone and display values to the user using an LCD display unit, control artificial light sources, and send gathered data to the connected mobile application using the ESP8266 Wi-Fi module. An electronic weighing machine uses a load cell to measure the weight produced by the load, here most load cells are following the method of a strain gauge, which converts the pressure into an electrical signal, these load cells have four strain gauges that are hooked up in a Wheatstone bridge formation. A cell is an amplifier that senses the weight and supplies an electrical analogue voltage to HX711 Load Amplifier Module. Then this amplified value is fed to the Arduino where the output of HX711 is converted into the weight values in grams. The output result is displayed on the 16x2 Liquid Crystal

Display unit [08]. LCD adapter is a device containing a micro-controller PCF8574 chip. This micro-controller is an I/O expander, which communicates with other micro-controller chips with two wire communication protocol. Using this adapter anyone can control a 16x2 LCD with only two wires. (SDA, SCL) [10]. Then all the values will be sent into the connected mobile application via ESP8266 Wi-Fi.

In the mobile application user interface, there is a separate signup and login for each user. The main objective of developing a mobile application is display the weight of a gemstone, capture high quality images of a gemstone using mobile phone camera and proceed them using image processing models and techniques and display the colour, shape, and the refractive index value. Another main objective of this research study is to save number of analyzed gemstone information to the cloud to be used in the future. The application included the ability to save gathered and analyzed information to the firebase cloud and display each of them separately when needed. Firebase is a developed by google which can use as a non-relational cloud database, can read or transfer data from database. This proposed system uses Wi-Fi communication between all around the scope to transfer data between each component.

Light causes colour and the absorption of different wavelengths of that light by different minerals cause our eyes to perceive distinct colours accordingly [09]. Therefore, another highlighted component of this proposed device is light sources. The device includes three types of LED light sources: yellow, ultra-violet, and blue. These 3 types of light sources are directed to the place where the gem is placed on the device. Then it can direct each light source to the gemstone and capture the images.

C. Refractive Index

Setting up the components of an IoT device is extremely important as shown in the figure [2], just as determining the refractive index is necessary for gem recognition. An Arduino camera connected to an Arduino UNO board will be used to measure the refractive index as the IoT device's components are assembled. The Arduino camera will be integrated above the gem stage/holder in the canter of the apparatus. To find the gem's refraction, a laser light will be utilized. The refracted ray will fall in a solid plane, such as a solid wooden or plain surface plane that is not transparent (so that it would not refract again), after the laser light strikes the gem and refracts in the gem. Using image processing, a virtual ruler (which displays a ruler in the camera itself) will be implemented in the Arduino camera, and the camera will be able to determine the position of the laser pointer using the virtual ruler. Using this, the mobile application's WIFI module will be used to identify and send the value of the ruler that the laser pointer is aimed at.

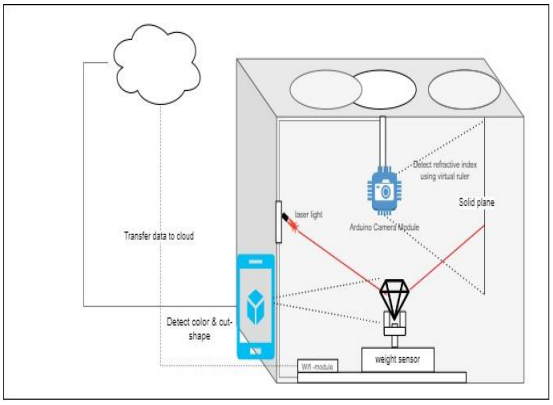

Figure 2

When the phone receives the refractive index, it will compare it to the published refractive index chart that is seeded to the database and identify the appropriate gem.

By converting the captured frames to HSV color code, specifying the brightest and dimmest light, and locking it using the OpenCV library's "cv2.minMaxLoc(mask)" technique, the laser light is recognized. By doing this, the camera will be able to recognize and identify the bright point in the video frame. A tiny circle is also made using the OpenCV library to locate the bright light's focal point. As a result, the laser light will be used to identify the bright light spot, and the refractive index will be determined by the value parallel to the light. to which the mobile device will receive.

E. Colour of the Gemstone

In this section, will be show about research methodology, block diagram of the system, image processing workflow (pre-process), CNN training workflow and identification workflow

Before the processing part we have gathered data sets and, we have collected knowledge from gemmologists about the techniques they use at currently to detect the colour. For this purpose, we have interviewed Gemmologists via questionnaires, and we gathered the required information through literature reviews.

CNN Training and Identification Workflow

After inputting pre-processed value then we must define the training target value. After that we can begin the training process by defining the epoch value, error value, show rate value etc. Below flow chart demonstrates the identification workflow.

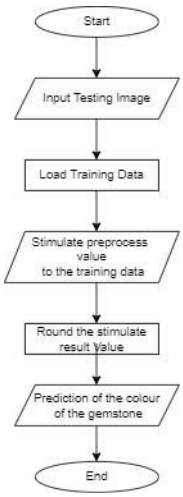

Figure 3: Identification Workflow

F. Cut-Shape Analysis

As the first step we collected information and data regarding gemstones in our field visit to Rathnapura. We also gathered Corundum gemstones data from sources such as NGJA (National Gem & Jewelry Authority, GJRTI (Gem & Jewelry Research Training Institute). We discussed with vendors and lapidaries about gemology, gemstones, and gem industry. How do they find gemstones, how do they analyze gems, how to assess, how do they classify various gemstones, what are the characteristics and qualities of gemstones, the way they cut and polish gemstones, current problems in gem industry Sri Lanka? We analyzed collected data to identify direct and indirect factors which are influencing to identify cut-shape of gemstones. We also gathered datasets for training and testing purposes. Then processed the dataset and created a CNN model using image processing for detect the cut-shape of gemstone. We trained the model with 500 images and tested with 200 images. In the model implementation, I used some well-known techniques such as contrast enhancement, adjusting image intensity, trace region boundaries and separating each shape from the background. After creating the model to detect the shape of gemstone, we took real time images of gemstones using capturing device on the IOT device as inputs for the model. Then modified the model to analyze input images comparing to trained data. After successfully completed the detection part the output is sent to the developed mobile application. So, the user can identify the cut-Shape of the selected gemstone easily. In this scenario, we have used python as the programming language for handling the image processing algorithms and OpenCV framework, TensorFlow, keras libraries.

V. RESULT AND DISCUSSION

The refractive index of the gemstone is calculated by capturing the incident and refracted rays and by applying Snell's law we calculated the refractive index. By the calculated refractive index, we can uniquely identify the type of the gemstone. In the trained model to detect the color of the gemstone, there is an accuracy rate of 86% and this model uses 161 images for the training process to extract the color feature of the gemstone. Each gemstone image was cropped in different positions. Each cropping will be performed to extract the color feature in the pre-processing stage. In the train model to detect the cut shape there is an accuracy rate of 67%. The training images are put through an augmentation for maximizing number of training data. After training the above models, we have fed the models to the mobile app that we have implemented. A user can do a real time scanning or else they can choose the image from gallery and once they scan, the output is visible as shown in the figure <7.4>. As we mentioned in our user manual, user must take separate captures for identification of refractive index and other optimal characteristics. After retrieving the result on mobile interface, user can convert the result to pdf and share with social media such as WhatsApp, telegram or share using email. As we implemented a user can view all previous scan history.

When the laser light was triggered and the gem was set in the gem holder or stage, the laser light was refracted by the gem and the refracted ray fell on the solid plane, allowing the camera to capture the laser light at that precise time. As the image processing in the camera formed the virtual ruler, the value was determined and transmitted to the mobile app, and the mobile app presented the gemstone name along with its data. After that, the gem was tested manually, and it was able to retrieve the same result. We performed user acceptance testing and analyzed user experience with real time user interactivity. We visited several gem stores and conducted awareness sessions for users. We analyzed certain gemstones using our device with the mobile application and most of them provided accurate results. This approach verified our system's correctness and validity in front of real customers.

IV. CONCLUSION

This study demonstrates an Internet of Things (IoT) device that can identify a specific sort or kind of gem using machine learning, image processing, and a few hardware components that are linked to a mobile application. This study demonstrated and developed the manual gem detecting procedure, which had been carried out for decades. Additionally, adopting this tool

could help to address consumer disputes and cost eliminations.

This paper presented an image processing and Convolutional Neural Network technique to identification of the colour of gemstones by taking the Hue value on the image. In the fact one gemstone have many Varian colour. Using this proposed system, we can determine the exact colour of the gemstones in the Corundum family. For example, consider Blue Sapphire, we can determine whether its Royal Blue or Cornflower Blue etc.

To increase its accuracy, future developments should include the ability to measure the hardness of stones in addition to its spectrum. With it, costs would be further reduced and there would be no need to buy numerous gadgets or ship the gems to labs for additional testing. As we were unable to implement them because we were unable to locate specific equipment and as we completed this project under a short deadline, adding multiple torch lights to validate the color changes would also be an added benefit to the device. However, the device can be improved further with new ideologies.

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