CHAPTER 5

CONCLUSION

5.1 Conclusion

This research presented a comprehensive method for determining the optical properties of the ruby stone using the CCD tomography approach. Objective 1 included examining the light intensity of ruby stones based on their theoretical value. Optical properties, such as the absorption attenuation and index refraction of ruby stones, were obtained from the databases of Gemology Software Tools. LabVIEW programming software was then used to provide a mathematical expression of the light intensity of ruby stones. This objective is a crucial point since the CCD sensor is a photodetector that is very sensitive to light, resulting in voltage form that will be applied on the three-dimensional images.

The mathematical expression obtained from Objective 1 was then evaluated using two image reconstruction systems. System A was equipped with a laser as a light source while System B was not equipped with a laser. The voltages obtained as light passed through the ruby stones, with different refractive indices, and image reconstruction systems were compared. The light penetrated two mediums: the air and the ruby stone.

Based on the mathematical expression of the optical properties of ruby stones, System A produced a lower light intensity ratio than System B. This was because System A took the light absorption coefficient into consideration but System B did not.

The absorption attenuation in System A was due to the penetration of the laser from one medium to the other, thereby reducing the initial light intensity. The importance of knowing the final mathematical expression for both systems is to produce the block diagram of graphical coding in LabVIEW to generate the 3D image for further clarity analysis.

Objective 2 included designing a conceptual model of the CCD tomography technique with the help of the LabVIEW software. This objective could be fulfilled when the research established the octagon orientation concept for CCD and ruby stone placement for conceptual modeling. Earlier studies indicated an octagonal arrangement of the emitters and receivers was optimal for the medium under study. This process involved simulations using data from Gemology Tools Professional and real-time experiments.

The research used the LBP for the 3D image reconstruction algorithm; it is very accessible and user-friendly, and it generates clear tomograms. Statistical analysis was used to investigate the effect of different refractive indices of ruby stones on the reconstructed image. The Z-axis of the image reconstruction presents the pixel values, representing the multiplication of sensitivity maps for the 160 views with CCD normalized voltage value. A different transparency level of ruby stone will offer a different Z-axis; a higher transparency level generates a lower Z-axis, while a higher opacity generates a higher Z-axis. The comparison made of the 3D image produced by System A and B validated that the system with a laser that produced a higher number of pixels. The image is clearer in image reconstruction of System A; therefore, System A was selected for further analysis.

The third objective was to validate the optical properties of ruby stones based on the simulation and experimental images. These two values were compared and analyzed using statistical and relative error analyses. In this study, this research collected 8 samples from the ruby stone z. The mean voltages and pixel values of the eight samples were statistically analyzed and compared to theoretical outputs. The experimental and theoretical values were then used to validate the CCD tomography system's ability to measure the clarity of different ruby stones. The relative error analysis of the experimental and theoretical mean pixel values was 10.15%. This verified the competency of the proposed conceptual modeling of CCD tomography system to quantify the grade of ruby stone based on the light intensity values.

5.2 Research Significance

The most fundamental contribution of this present study was to overcome human error when grading the ruby stones, which is prevalent among existing methods that rely entirely on the experience and eyes of the jewelry appraiser. The pixel values (z-axis) gain from the 3D images were analyzed using the statistical engineering approach. Each of the pixel values represented the transparency level of the ruby stone which is a crucial criterion (clarity) that could not be distinguished easily through human vision.

The standardized grading method proposed is also a low-cost conceptual model that anyone can afford. The Malaysian government should gain significant income if it were to adopt the proposed CCD tomography system for ruby grading. This system can be commercialized and advertised to outsiders and other countries as this is a novel ruby stone grading system.

The conceptual model proposed in this study could improve the development-oriented policies which could support entrepreneurship, innovation, creativity, improve productive activities and lead to job creation, thereby indirectly acknowledging the target and objectives of Sustainable Development Goals and its role in promoting economic growth. Essentially, the development of quantitatively grading ruby stones can foster productive employment through new advancements in the gemological field.

Lastly, good economic growth contributes to a stable and trusted government. In a way, stable and financially-sound lives are due to the substantial income because of government policies. Therefore, the proposed quantitative method of grading ruby stones significantly improves the gemology tool industry and has a fundamental impact on the government and societal contentment.

5.3 Recommendations for Future Studies

i. The research presented a few recommendations for future research as follows:
ii. Introduce a filtration algorithm to reduce smearing effects that could adversely destruct the effective pixel value of the reconstructed images.
iii. Increase the number of views to provide high resolution of image reconstruction.
iv. Use an area array CCD to capture a wide range of subject focus.
v. A high sampling rate from the data acquisition system (DAS) (i.e., >250 k samples /second) is suggested to be used to optimize the capability of proposed design to generate high accuracy of image reconstruction