CHAPTER V
CONCLUSION

5.1 Conlusion

Based on the research results and discussion on the multi-method comparative study for *Retinex*-based cardiac ultrasound image quality improvement, the following conclusions can be drawn:

1. The process of improving cardiac ultrasound image quality using the *Retinex* method (*SSR*, *MSR*, and *MSRCR*) combined with *Bilateral Filter* and *Median Filter* preprocessing has proven able to improve the visual quality of the image. Compared to the original image, the enhancement result image displays better contrast and higher information content (*Entropy*), so that anatomical structures of the heart such as the walls and chambers become more visible.

2. Based on the performance comparison of the three *Retinex* variants, *SSR* consistently produces the highest *PSNR* and *SSIM* values (K1 = 11.69 dB and *SSIM* 0.0924; K4 = 12.37 dB and *SSIM* 0.0954), showing its ability to preserve structural similarity relative to the reference image. In contrast, *MSRCR* produces the highest *CII* (K3 = 1.3591), indicating the strongest contrast improvement, but accompanied by a sharp decrease in *PSNR* and *SSIM* (a negative *SSIM* value) due to structural distortion. *MSR* occupies a middle position across all metrics as a form of *trade-off* between detail and structural stability.

3. The use of *Bilateral Filter* and *Median Filter* preprocessing produces a consistent pattern: *Median Filter* excels on the *PSNR* and *SSIM* metrics because it is more aggressive at suppressing noise so that the base image is closer to the reference image, while *Bilateral Filter* excels on the *Entropy* and *CII* metrics because it preserves object edges, giving *Retinex* more room to bring out detail and contrast. Because *Entropy* and *CII* are more relevant to the cardiac ultrasound image enhancement objective, the Bilateral path is considered to provide a more suitable preprocessing foundation.

4. The comparison of the *Retinex*-based method with the non-*Retinex* method (*CLAHE*) resulted in a 2–2 tied score: *CLAHE* excels on *PSNR* (24.32 dB) and *SSIM* (0.5383) because it is processed directly from the dataset without

additional preprocessing, while *Retinex* excels on *Entropy* (average 7.07) and *CII* (average 1.22). Because *Entropy* and *CII* better represent the objective of this research, namely bringing out structural detail and improving image contrast, the *Retinex*-based method overall is considered superior to *CLAHE* for improving cardiac ultrasound image quality.

5. Based on the aggregate score of the ranking of the four metrics, the stability level (standard deviation), and the percentage of images with a *CII* value greater than 1, combination K1 (*Bilateral Filter* + *Single Scale Retinex*) is established as the most optimal combination. K1 obtained the lowest aggregate score (2.50), the highest *Entropy* value (7.3040), a *CII* > 1 percentage reaching 95.95%, and a low standard deviation (0.1663) indicating consistent performance. Visual evaluation also confirms that K1 improves contrast smoothly and evenly without artifacts that would interfere with clinical interpretation.

5.2 Suggestions

Based on the research results that have been carried out, there are several suggestions that can be considered for the development of future research:

1. Combination K1 (*Bilateral Filter* + *Single Scale Retinex*) is recommended as the optimal *Retinex* method for improving cardiac ultrasound image quality, while *CLAHE* can be used as a quick comparison baseline or an alternative when a preprocessing stage is not available.

2. Testing needs to be carried out on cardiac ultrasound image datasets with different modalities or acquisition devices to test the generalization of the optimal combination obtained.

3. It is recommended to carry out a broader exploration of *SSR*, *MSR*, and *MSRCR* parameters (for example, variations in *Gaussian* scale and color-restoration parameters) to further optimize the enhancement results.

4. Further evaluation needs to be carried out on the impact of enhancement on the performance of automatic classification or segmentation of cardiac ultrasound images, as well as a comparison with deep-learning-based enhancement methods as a direction for future development.

5. Visual validation of the results (edge sharpness, visibility of heart chambers, and presence or absence of artifacts) still needs to be carried out before application in a real clinical context.