CHAPTER V
CONCLUSION

This chapter presents conclusions summary and derived from parameter sensitivity investigation and system evaluation conducted throughout this research. This chapter also along with suggestions for future studies to further improve proposed Braille dot detection system, Sauvola Thresholding, Circle Hough Transform method and other thresholding method.

5.1. Conclusions

Based on the parameter sensitivity investigation and comparative evaluation conducted in this research, the following conclusions are drawn in accordance with the research problem statements:

1. Parameters combination of window_size and k in Sauvola adaptive thresholding positively influences Braille dot detection performance on this pipeline with this dataset. Optimal configuration of window_size=13 and k=0.049 identified through a joint full Cartesian grid search achieves a mean Precision of 0.8047, mean Recall of 0.7809, and mean F1-Score of 0.7925. Both parameters exhibit a clear optimal region, with performance degrading sharply when either parameter deviates too far in either direction.
2. CHT *param2* parameters is sole variable with meaningful influence on detection performance when operating on binarized images. *Param1* was empirically confirmed to have no effect on binary input and was fixed at 1 but proved solid when used to grayscale image solely without binarization. Identified Optimal *param2* value of 3 on interger and 2.51-3.49 on float or double data type as they both have same value through a grid search from 0.1 to 8.0, achieves a mean F1-Score of 0.7925, representing best balance between Precision and Recall across full dataset. Parameter *param1* value of 130 was considered as optimal value when using CHT directly to grayscale image value without binarization preprocess.

3. Combined Sauvola and CHT pipeline under optimal configuration of window_size=13, k=0.049, and param2=3 achieves a mean F1-Score of 0.7925. This results outperforming all compared methods. In comparative evaluation, CHT without binarization ranks second at F1=0.7387, Niblack combined with CHT ranks third at F1=0.7065, and Otsu combined with CHT ranks last at F1=0.4565 due to global thresholding being unable to handle local contrast variation in Braille document images. This observed research add hypothesis that binarization technique could potentially increase performance with proper selection of binarization method and parameter configuration.

Interesting occurrence happens in this research when working with near zero of *param2* value for example below *param2*<0.4 it behaves strangely. OpenCV library used to run Circle Hough Transform couldn't work with absolute 0 value but could work with *param2* as float number but then rounding it up to nearest integer value. However, it didn't work with *param2* value less than 0.4 which not rounding up to 1 nor rounding down to 0 but instead rounding up to 0.1. Which raise potential research of how OpenCV Hough Transform works especially Circle Hough Transform variant enumerator HOUGH_GRADIENT. OpenCV CHT variant enumerator of HOUGH_GRADIENT use method 21HT [40] that mentioned in OpenCV documentations [41].

5.2. Suggestions

Based on this research findings and limitations identified in this research, these following recommendations are proposed for future studies.

1. Subsequent studies may benefit from applying more advanced optimization strategies such as Bayesian Optimization or genetic algorithms to explore the parameter space more efficiently, potentially identifying finer optimal configurations with fewer total evaluations.
2. Further development can extend the detection system toward a complete Braille recognition pipeline by integrating the dot detection stage with a character mapping module, enabling the system to translate detected dot

patterns into readable Braille characters and ultimately into text, which would expand its practical utility as an assistive technology.