UNDERGRADUATE THESIS

DOT DETECTION ON BRAILLE IMAGE USING CIRCLE HOUGH TRANSFORM WITH SAUVOLA THRESHOLDING

SILVANUS PRIHANTONO
NPM 20081010223

THESIS ADVISORS
Fetty Tri Anggraeny, S.Kom., M.Kom
Andreas Nugroho Sihananto, S.Kom., M.Kom

MINISTRY OF HIGHER EDUCATION, SCIENCE, AND TECHNOLOGY
UNIVERSITAS PEMBANGUNAN NASIONAL VETERAN JAWA TIMUR
FACULTY OF COMPUTER SCIENCE
INFORMATICS STUDY PROGRAM
SURABAYA
2026

APPROVAL SHEET

"DOT DETECTION ON BRAILLE IMAGE USING CIRCLE HOUGH TRANSFORM WITH SAUVOLA THRESHOLDING"

"DETEKSI TITIK PADA CITRA BRAILLE MENGGUNAKAN CIRCLE HOUGH TRANSFORM DENGAN SAUVOLA THRESHOLDING"

By :
SILVANUS PRIHANTONO
NPM. 20081010223

Has been defended before, and accepted by, the Board of Assessors of the Thesis Examination of the Informatics Study Program, Faculty of Computer Science, Universitas Pembangunan Nasional Veteran Jawa Timur, on August 26, 2026:

Approved,

Fetty Tri Anggraeny, S.Kom., M.Kom.
NIP. 19820211 202121 2 005 ..... **(Advisor I)**

Andreas Nugroho Sihananto, S.Kom., M.Kom
NIP. 19900412 202406 1 003 ..... **(Advisor II)**

Dr. Rizky Parlika, S.Kom, M.Kom
NIP. 19840518 202121 1 003 ..... **(Head Assessor)**

Achmad Junaidi, S.Kom., M.Kom
NIP. 19781110 202521 1 048 ..... **(Assessor I)**

Acknowledge by,

Dean of the Faculty of Computer Science

Prof. Dr. Ir. Novirina Hendrasarie, MT

NIP. 19681126 199403 2 001

APPROVAL SHEET

"DOT DETECTION ON BRAILLE IMAGE USING CIRCLE HOUGH TRANSFORM WITH SAUVOLA THRESHOLDING"

"DETEKSI TITIK PADA CITRA BRAILLE MENGGUNAKAN CIRCLE HOUGH TRANSFORM DENGAN SAUVOLA THRESHOLDING"

By:
SILVANUS PRIHANTONO
NPM. 20081010223

Approved to proceed to the Thesis Examination

Approved by,

Coordinator of Informatics Study Program
Faculty of Computer Science

Dr. Intan Yuniar Purbasari S.Kom. MSc.

NIP. 19800602 202521 2 029

STATEMENT OF ORIGINALITY

I am the undersigned:

Student Name	:	SILVANUS PRIHANTONO
NPM	:	20081010223
Degree Program	:	Bachelor (S1)
Study Program	:	Informatics
Faculty	:	Faculty of Computer Science

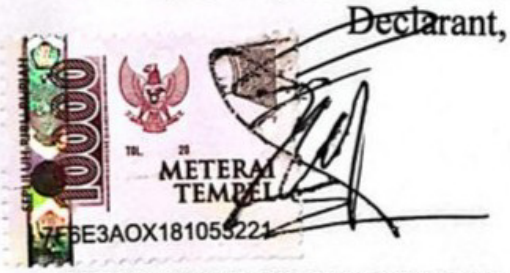
Hereby declares that this undergraduate thesis contains no part of any other scientific work that has been submitted to obtain an academic degree at any higher education institution. Furthermore, it does not contain any work or opinions previously written or published by others, except for those which are explicitly cited in this thesis and listed completely in references.

And I declare that this scientific document is free from elements of plagiarism. If in the future indications of plagiarism are found in this Thesis, I am willing to accept sanctions in accordance with the applicable laws and regulations.

Thus, I made this statement without any coercion from anyone and to be used as it should.

Surabaya, August 26th, 2026

Declarant,



SILVANUS PRIHANTONO

NPM. 20081010223

ABSTRACT

Student Name / NPM	:	SILVANUS PRIHANTONO / 20081010223
Thesis Title in Bahasa Indonesia	:	DETEKSI TITIK PADA CITRA BRAILLE MENGGUNAKAN CIRCLE HOUGH TRANSFORM DENGAN SAUVOLA THRESHOLDING
Thesis Title in English	:	DOT DETECTION ON BRAILLE IMAGE USING CIRCLE HOUGH TRANSFORM WITH SAUVOLA THRESHOLDING
Advisor	:	1. Fetty Tri Anggraeny, S.Kom., M.Kom. 2. Andreas Nugroho Sihananto, S.Kom., M.Kom

This research investigates parameter sensitivity of Braille dot detection pipeline combining Sauvola adaptive thresholding and Circle Hough Transform applied to a selected Braille document image dataset. Automated detection of Braille dots presents a unique challenge in document image processing due to low-relief embossed nature of Braille cells and the susceptibility of captured images to local illumination variation and surface texture irregularities making choice of binarization and detection parameters a critical determinant of system performance. Proposed pipeline processes each image through Sauvola adaptive thresholding as a binarization stage, whose output is passed directly to Circle Hough Transform for circular dot detection. To identify optimal configuration for each stage, a joint full Cartesian grid search was conducted over Sauvola parameters *window_size* and *k* with all evaluated parameter combinations assessed against ground truth annotations using Precision, Recall, and mean F1-Score across all images in dataset. Results are visualized as two-dimensional heatmaps and individual sensitivity curves for each parameter. Sauvola grid search identified an optimal configuration of *window_size*=13 and *k*=0.049, achieving a mean Precision of 0.8047, mean Recall of 0.7809, and mean F1-Score of 0.7925. For the Circle Hough Transform, internal Canny threshold parameter param1 was empirically validated to have no meaningful influence on detection performance when applied to pre-binarized images and was fixed at 1. Accumulator threshold *param2* was identified as sole variable of interest, with an optimal value of 3 producing the same peak mean F1-Score of 0.7925. These findings confirm that Sauvola adaptive thresholding combined with Circle Hough Transform constitutes an effective and quantitatively validated approach to Braille dot detection with optimal parameter configurations and their performance boundaries documented through heatmap and sensitivity curve visualizations as a practical reference for datasets sharing similar image characteristics.

Keywords : Braille Dot Detection, Sauvola Thresholding, Circle Hough Transform, Parameter Sensitivity Analysis, Computer Vision.

ACKNOWLEDGEMENTS

All praise, glory, and deepest gratitude be to our Lord and Saviour Jesus Christ, whose boundless grace, mercy, and guidance have sustained me as author throughout every stage of this research and have made it possible to bring this undergraduate thesis entitled **"DOT DETECTION ON BRAILLE IMAGE USING CIRCLE HOUGH TRANSFORM WITH SAUVOLA THRESHOLDING"** or **"DETEKSI TITIK PADA CITRA BRAILLE MENGGUNAKAN CIRCLE HOUGH TRANSFORM DENGAN SAUVOLA THRESHOLDING"** towards completion. I am also extending special heartfelt devotion to Saint Mary, Holy Mother of God, whose intercession and maternal care have accompanied me in moments of difficulty and perseverance throughout this journey. During this research process, author received invaluable assistance, guidance, support, and encouragement. Therefore, I would like to express sincere and deep gratitude to:

1. Our Lord and Saviour Jesus Christ and Saint Mary, Holy Mother of God, for their grace, protection, and constant presence that gave me strength and clarity of mind to complete this research.
2. My beloved parents and family, who have continuously provided prayers, unconditional support, encouragement, and endless sacrifices throughout entire educational journey.
3. Prof. Dr. Ir. Novirina Hendrasarie, M.T., as Faculty of Computer Science Dean, Universitas Pembangunan Nasional "Veteran" Jawa Timur.
4. Dr. Intan Yuniar Purbasari, S.Kom., M.Sc., as The Head of Informatics Study Program, Faculty of Computer Science, Universitas Pembangunan Nasional "Veteran" Jawa Timur.
5. The Author's thesis advisor, Fetty Tri Anggraeny, S.Kom., M.Kom., and Andreas Nugroho Sihananto, S.Kom., M.Kom who has dedicated time, effort, and thought in providing guidance, direction, and motivation throughout the process of completing this undergraduate thesis.

6. Dr. Rizky Parlika, S.Kom, M.Kom, and Achmad Junaidi, S.Kom., M.Kom, as thesis examiners, who have provided constructive criticism, suggestions, and feedback for the improvement of this undergraduate thesis.
7. All lecturers, academic staff of Informatics Study Program, Faculty of Computer Science, Universitas Pembangunan Nasional "Veteran" Jawa Timur, who have imparted knowledge, experience, and valuable learning throughout author's academic journey, as well.
8. My best friends
9. Other friends and fellow students of Informatics Study Program class of 2020, who have continuously provided support, encouragement, and companionship throughout academic journey and process of completing this undergraduate thesis.

The author acknowledges that this undergraduate thesis remains imperfect. Constructive criticism and suggestions are sincerely welcomed for future improvement. Through this thesis, I hope that this research may provide meaningful contribution to future research

Credo in Deum Patrem omnipotentem, Creatorem caeli et terrae. Et in Iesum Christum, Filium eius unicum, Dominum nostrum, qui conceptus est de Spiritu Sancto, natus ex Maria Virgine, passus sub Pontio Pilato, crucifixus, mortuus, et sepultus, descendit ad inferos, tertia die resurrexit a mortuis, ascendit ad caelos, sedet ad dexteram Dei Patris omnipotentis, inde venturus est iudicare vivos et mortuos. Credo in Spiritum Sanctum, sanctam Ecclesiam catholicam, sanctorum communionem, remissionem peccatorum, carnis resurrectionem, vitam aeternam. Amen.

Ave Maria, gratia plena, Dominus tecum. Benedicta tu in mulieribus, et benedictus fructus ventris tui, Iesus. Sancta Maria, Mater Dei, ora pro nobis peccatoribus, nunc et in hora mortis nostrae. Amen.

Surabaya, August 10th, 2026

Thesis Author,

SILVANUS PRIHANTONO

NPM. 20081010223

TABLE OF CONTENTS

APPROVAL SHEET ..... **iii**
APPROVAL SHEET ..... **v**
STATEMENT OF ORIGINALITY ..... **vii**
ABSTRACT ..... **ix**
ACKNOWLEDGEMENTS ..... **xi**
TABLE OF CONTENTS ..... **xiii**
LIST OF FIGURES ..... **xvii**
LIST OF TABLES ..... **xix**
CHAPTER I INTRODUCTION **21**
1.1. Study Background 21
1.2. Problem Statement and Formulation 24
1.3. Research Objectives 24
1.4. Significance of the Study 25
1.5. Scope and Limitations 26
CHAPTER II LITERATURE REVIEW **27**
2.1. Previous Research 27
2.2. Images and Digital Images Definition 31
2.2.1. Digital Image Processing 31
2.3. Braille 32
2.4. Grayscale Conversion 33
2.5. Sauvola Thresholding Binarization 34
2.6. Images Degradation Characteristic and Morphology Operation 35
2.7. Circle Hough Transform (CHT) 36
2.8. Sensitivity Analysis 38
2.9. Ground Truth Concepts and Detection Results 39
2.10. Performance Evaluation Metric 40
CHAPTER III RESEARCH METHODOLOGY **43**
3.1. System Requirement 43
3.1.1. Hardware 43

3.1.2. Software 44
3.2. Research Stages 44
3.3. Dataset Source and Acquisition 45
3.3.1. Dataset Enrichment 46
3.4. Design Modeling 47
3.5. Implementation 49
3.6. Sauvola and CHT Calculation 49
3.6.1. Notation Definition for Sauvola Thresholding 50
3.6.2. Sauvola Thresholding Detection Simulation 50
3.6.3. Notation Definition for CHT 55
3.6.4. Circle Hough Transform Detection Simulation 56
3.7. Testing and Analysis 59
3.8. Trial Scenario 60
CHAPTER IV RESULTS AND DISCUSSION 63
4.1. Dataset Analysis and Test environment 63
4.2. Sauvola Thresholding Parameter Test 65
4.2.1. Sauvola Parameter Configuration and Initial Sampling 66
4.2.2. Sauvola Heatmap Analysis 67
4.2.3. Window Size Parameter Analysis Result 68
4.2.4. K Parameter Analysis Result 72
4.2.5. Sauvola Optimal Parameter Result 75
4.3. Circle Hough Transform Test 77
4.3.1. CHT Parameter Configuration and Initial Sampling 79
4.3.2. CHT Heatmap Analysis 82
4.3.3. *Param2* Sensitivity Analysis Result 87
4.3.4. CHT Optimal Parameter Results 93
4.3.5. CHT Without Binarization 98
4.4. Comparison to Niblack 99
4.4.1. Niblack Heatmap Analysis 100
4.4.2. Niblack Sensitivity Analysis and Optimal Results 102
4.5. Comparative Result 105
CHAPTER V CONCLUSION 111

5.1. Conclusions 111
5.2. Suggestions 112
BIBLIOGRAPHY 115

LIST OF FIGURES

Figure 2.1 Braille Structure and Specification 32
Figure 3.1 Research Flowchart 45
Figure 3.2 Flowchart Model 48
Figure 3.3 Sample pixel of Window size 3x3 51
Figure 3.4 Flowchart Sauvola 51
Figure 4.1 Ground Truth Custom App with Annotated image 64
Figure 4.2 Sauvola Heatmap Sampling 66
Figure 4.3 Sauvola Heatmap Result 68
Figure 4.4 Window size to F1-Score Chart 69
Figure 4.5 Window Size to Precision Chart 70
Figure 4.6 Window Size to Recall Chart 71
Figure 4.7 Window Size Combined Chart 72
Figure 4.8 *k* Parameter to F1-Score 73
Figure 4.9 *k* Parameter to Precision 74
Figure 4.10 *k* Parameter to Recall 74
Figure 4.11 *k* Parameter Combined Chart 75
Figure 4.12 Image Sampling of Best F1-Score Sauvola Parameter Combination 77
Figure 4.13 CHT Heatmap Sampling 81
Figure 4.14 CHT Heatmap Result 83
Figure 4.15 CHT Integer Only Heatmap Result 86
Figure 4.16 *Param2* to F1-Score Non-Truncate 87
Figure 4.17 *Param2* to F1-Score Truncated 88
Figure 4.18 *Param2* to Precision Truncated 89
Figure 4.19 *Param2* to Precision Non-Truncate 90
Figure 4.20 *Param2* to Recall Truncated 90
Figure 4.21 *Param2* to Recall Non-Truncate 91
Figure 4.22 *Param2* to Combined Chart Truncated 92
Figure 4.23 *Param2* to Combined Non-Truncate 92
Figure 4.24 *Param2* Integer Value to F1-Score 94
Figure 4.25 *Param2* Integer Value to Precision 94

Figure 4.26 *Param2* Integer Value to Recall 95
Figure 4.27 Image Sampling of Best F1-Score CHT Parameter Combination..... 97
Figure 4.28 Niblack Sampling Heatmap..... 99
Figure 4.29 Niblack Formal Heatmap..... 101
Figure 4.30 Niblack Parameter *K* to *F1-Score*..... 102
Figure 4.31 Niblack Parameter *K* Combined Chart 103
Figure 4.32 Niblack to *window_size* parameter 104
Figure 4.33 Niblack *window_size* Combined Chart..... 105
Figure 4.34 Algorithm Line Chart Comparison..... 106

LIST OF TABLES

Table 3.1 Sample Grayscale Calculation 52
Table 3.2 CHT Vote Calculation 57
Table 3.3 Trial Scenario Summary 62
Table 4.1 Test Environment and Specification 65
Table 4.2 Sauvola Sampling Configuration 66
Table 4.3 Sauvola Formal Configuration 67
Table 4.4 Highest F1-Score Parameter Combination by Mean 76
Table 4.5 CHT Sampling Configuration 80
Table 4.6 Revised CHT Formal Grid Search Configuration 82
Table 4.7 Highest F1-Score Parameter Combination by Mean 85
Table 4.8 Highest Mean F1-Score of Integer *Param2* value 96
Table 4.9 Highest Mean F1-Score of Integer *Param1* value 98
Table 4.10 Niblack Sampling Configuration 99
Table 4.11 Niblack Formal Configuration 100
Table 4.12 Highest F1-Score Parameter Combination of Niblack by Mean 105
Table 4.13 Algorithm Comparative Table 106