DESIGN AND PERFORMANCE EVALUATION OF SOIL NITROGEN TESTER

Design Project

JC JOSEPH R. ORTIZ
KAZELLE ANNE A. SALLEGUE

College of Engineering and Information Technology
CAVITE STATE UNIVERSITY
Indang, Cavite

June 2019

DESIGN AND PERFORMANCE EVALUATION OF SOIL NITROGEN TESTER

Undergraduate Design Project
Submitted to the Faculty of the
College of Engineering and Information Technology
Cavite State University
Indang, Cavite

In partial fulfilment
of the requirements for the degree
Bachelor of Science in Electronics and Communications Engineering

00079505

Design and performance evaluation of soil nitrogen tester
620.2 Ort 2019
DP-681

JC JOSEPH R. ORTIZ
KAZELLE ANNE A. SALLEGUE
June 2019

ABSTRACT

ORTIZ, JC JOSEPH R. and SALLEGUE, KAZELLE ANNE A. Design and performance evaluation of Soil Nitrogen Tester. Undergraduate Design Project. Bachelor of Science in Electronics and Communications Engineering. Cavite State University, Indang, Cavite. June 2019. Adviser: Engr. Nemilyn A. Fadchar

The general objective of the study was to design and evaluate the performance of a soil nitrogen tester. Specifically, it aimed to design and assemble a portable soil nitrogen tester. It also targeted to test and evaluate the precision and sensitivity of the system. Moreover, it intended to conduct a cost analysis of the device.

The design project was composed of Arduino Uno R3 which served as the microcontroller unit. Its ports were used to interface input and output devices such as the photodiode, infrared proximity sensor, infrared light emitting diodes (IR LEDs), LED indicators, stepper motor, motor driver, and piezo buzzer. The application software was programmed and developed using the matrix laboratory (MATLAB) App Designer. Artificial neural network and support vector machine were the learning algorithms used to determine which model was appropriate for soil nitrogen level prediction.

The project was tested by the researchers at Bancod, Indang, Cavite. The evaluation was conducted at the Engineering Science Building, Cavite State University, Indang, Cavite and at the Department of Agricultural and Food Engineering, Cavite State University, Indang, Cavite. The performance of the soil nitrogen tester was evaluated by scanning distinct soil samples with low, medium, and high levels of nitrogen. Throughout the three phases of evaluation, the artificial neural network model had precision percentages of 33.33 percent, 66.67 percent, and 77.78 percent. On the other hand, the

support vector machine had performance percentages of 55.56 percent, 100 percent, and 100 percent. Hence, support vector machine had the better prediction and was implemented as the final predictive model for the application software.

Based on the results of the evaluation, the design project met the given objectives. The system was able to operate in accordance to its intended function. The overall performance of the system is satisfactory. The total cost of the system amounted to P20,216.39 and the break-even point was calculated to be 213 samples.

TABLE OF CONTENTS

	Page
BIOGRAPHICAL DATA	iii
ACKNOWLEDGMENT	v
ABSTRACT	xi
LIST OF TABLES	xvi
LIST OF FIGURES	xvii
LIST OF APPENDIX TABLES	xix
LIST OF APPENDIX FIGURES	xx
LIST OF APPENDICES	xxvi
INTRODUCTION	1
Statement of the Problem	3
Objectives of the Study	3
Significance of the Study	3
Time and Place of the Study	4
Scope and Limitations of the Study	4
Definition of Terms	5
REVIEW OF RELATED LITERATURE	8
METHODOLOGY	21
Soil Sampling	21
Preparation of soil samples	21
Scanning of soil samples on near-infrared spectroscopy (NIRS) device	22

Design Considerations..... 23

Selection of microcontroller unit..... 23

Selection of light source..... 23

Selection of light sensor..... 24

Selection of motor..... 24

Selection of motor driver..... 24

Materials..... 25

Instrumentation..... 28

Design and construction of the soil nitrogen (N) tester..... 28

Integrating the Arduino Uno, photodiode, infrared light emitting diodes (IR LEDs), and motor driver for the device..... 29

Developing the program and application software for the soil N tester..... 31

Chemical analysis of soil samples..... 31

Performance Parameters..... 34

Data Analysis..... 34

Establishing multivariate calibration model..... 34

Validation of multivariate calibration model..... 34

Testing and Evaluation..... 34

Principles of operation..... 34

Preliminary testing..... 35

Evaluation..... 35

Cost of Fabrication..... 35

Cost and Return Analysis..... 36

RESULTS AND DISCUSSION 38

Preparation of Soil Samples 38

Near-infrared Spectroscopy (NIRS) Device Testing 39

Principles of Operation of the Soil Nitrogen Tester 39

Circuit Design and Assembly 41

Application Software Development 44

Deployment of the Application Software 47

Calibration of the Device 49

Preliminary Testing 54

Evaluation 56

Cost of Soil Nitrogen Tester 59

Cost and Return Analysis 60

SUMMARY, CONCLUSION, AND RECOMMENDATIONS 62

Summary 62

Conclusion 64

Recommendations 65

REFERENCES 66

APPENDICES 70

LIST OF TABLES

Table		Page
1	Preparation of soil samples with nitrogen (N) concentration (Group 1).....	22
2	Preparation of soil samples without N concentration (Group 2).....	22
3	Summary of specifications.....	26
4	Decision making capabilities of the device.....	33
5	N levels of the soil samples through soil test kit (STK).....	50
6	Preliminary testing of the device.....	55
7	Preliminary evaluation.....	57
8	Final evaluation.....	57
9	Validation.....	59
10	Comparison of artificial neural network (ANN) and support vector machine (SVM) models (Precision).....	59
11	Bill of materials for the construction of the device.....	59

LIST OF FIGURES

Figure		Page
1	Near-infrared (NIR) in the electromagnetic spectrum.....	13
2	General near-infrared (NIR) spectrometer configuration.....	13
3	A simple artificial neural network (ANN).....	15
4	Possible hyperplane for support vector machine (SVM).....	15
5	Soil nitrogen (N) tester design.....	28
6	Block diagram of the system.....	29
7	Soil nitrogen (N) tester schematic diagram.....	30
8	Program flowchart.....	32
9	Nitrogen (N) color chart.....	33
10	Absorbance spectrum from near-infrared (NIR) device of the soil sample S_BR_1.....	41
11	Printed circuit board (PCB) design for photodiode and infrared light emitting diodes (IR LEDs) – (a) schematic diagram, (b) PCB layout.....	42
12	Printed circuit board (PCB) design for the 5V and ground (GND) terminals – (a) schematic diagram, (b) PCB layout.....	43
13	Internal view of the actual device – (a) open lid design, (b) circuit assembly.....	43
14	External view of the actual device.....	44
15	Soil nitrogen tester application software.....	45
16	Flowchart of the software application – (a) main flow of program...	46
16	Flowchart of the software application – (b) refresh button, (c) stop button.....	47

17 Flowchart of the Arduino program..... 48

18 Soil_Nitrogen_Tester installer..... 49

19 Artificial neural network (ANN) model regression curve..... 52

20 Training history for support vector machine (SVM)..... 52

21 Support vector machine (SVM) area under the curve-receiver operating characteristic (AUC-ROC) curve..... 53

22 Cubic support vector machine (SVM) model confusion matrix..... 53

23 Soil_Nitrogen_Tester with dropdown options for artificial neural network (ANN) and support vector machine (SVM)..... 55

24 Soil samples with low, medium, and high nitrogen (N) levels (from left to right)..... 56

25 Additional samples gathered with high, low, and medium nitrogen (N) levels (from left to right)..... 58

LIST OF APPENDIX TABLES

Table		Page
1	Collection of soil samples.....	72
2	Training dataset for both artificial neural network (ANN) and support vector machine (SVM).....	72
3	Testing dataset for both artificial neural network (ANN) and support vector machine (SVM).....	74
4	Preliminary testing results acquired from SNT_Scan_Data.csv.....	75
5	Preliminary evaluation results acquired from SNT_Scan_Data.csv..	75
6	Final evaluation results acquired from SNT_Scan_Data.csv.....	76
7	Validation results acquired from SNT_Scan_Data.csv.....	76

LIST OF APPENDIX FIGURES

Appendix Figure		Page
1	Arduino Uno R3	78
2	SFH 4248 940/950 nm IR LED	78
3	OIS-330 1050 nm IR LED	79
4	OIS-330 1300 nm IR LED	79
5	OIS-330 1550 nm IR LED	80
6	FCI-InGaAs-1000 InGaAs Photodiode	80
7	Stepper Motor 28BYJ-48 with ULN2003 driver	81
8	Soil B tester design (front view – closed)	81
9	Soil N tester design (top view – open)	82
10	Soil N tester design (top view – closed)	82
11	Soil N tester design (side view – open)	83
12	Soil N tester design (rear view – open)	83
13	Soil Test Kit	84
14	STK for N analysis	84
15	Freshly dug soil	85
16	First day of settling method	85
17	Third day of settling method	86
18	46-0-0 Urea fertilizer	86
19	Air-drying of soil samples with various N concentrations	87
20	Air-drying of soil samples without N concentrations	87

21	Soil samples with N concentration.....	88
22	Soil samples without N concentrations.....	88
23	Soil samples with various N concentrations stored in storage bags...	89
24	Soil samples without N concentrations stored in storage bags.....	89
25	NIR spectrometer.....	90
26	NIR device interface.....	90
27	Absorbance spectrum for S_AR_1 from NIR spectrometer (1).....	91
28	Absorbance spectrum for S_AR_1 from NIR spectrometer (2).....	91
29	Absorbance spectrum for S_AR_1 from NIR spectrometer (3).....	92
30	Absorbance spectrum for S_AR_2 from NIR spectrometer (1).....	92
31	Absorbance spectrum for S_AR_2 from NIR spectrometer (2).....	93
32	Absorbance spectrum for S_AR_2 from NIR spectrometer (3).....	93
33	Absorbance spectrum for S_AR_3 from NIR spectrometer (1).....	94
34	Absorbance spectrum for S_AR_3 from NIR spectrometer (2).....	94
35	Absorbance spectrum for S_AR_3 from NIR spectrometer (3).....	95
36	Absorbance spectrum for S_BR_1 from NIR spectrometer (1).....	95
37	Absorbance spectrum for S_BR_1 from NIR spectrometer (2).....	96
38	Absorbance spectrum for S_BR_1 from NIR spectrometer (3).....	96
39	Absorbance spectrum for S_BR_2 from NIR spectrometer (1).....	97
40	Absorbance spectrum for S_BR_2 from NIR spectrometer (2).....	97
41	Absorbance spectrum for S_BR_2 from NIR spectrometer (3).....	98
42	Absorbance spectrum for S_BR_3 from NIR spectrometer (1).....	98
43	Absorbance spectrum for S_BR_3 from NIR spectrometer (2).....	99

44	Absorbance spectrum for S_BR_3 from NIR spectrometer (3).....	99
45	Absorbance spectrum for S_CR_1 from NIR spectrometer (1).....	100
46	Absorbance spectrum for S_CR_1 from NIR spectrometer (2).....	100
47	Absorbance spectrum for S_CR_1 from NIR spectrometer (3).....	101
48	Absorbance spectrum for S_CR_2 from NIR spectrometer (1).....	101
49	Absorbance spectrum for S_CR_2 from NIR spectrometer (2).....	102
50	Absorbance spectrum for S_CR_2 from NIR spectrometer (3).....	102
51	Absorbance spectrum for S_CR_3 from NIR spectrometer (1).....	103
52	Absorbance spectrum for S_CR_3 from NIR spectrometer (2).....	103
53	Absorbance spectrum for S_CR_3 from NIR spectrometer (3).....	104
54	Final look of the etched PCB.....	104
55	STK results of Group 1 soil samples.....	105
56	STK results of Group 2 soil samples.....	105
57	Open lid status of the device.....	106
58	Standby status of the device.....	106
59	Scanning status of the device.....	107
60	LED indicators at the USB ports lighted during power on.....	107
61	Soil_Nitrogen_Tester result for S_1R_1-D obtained from ANN model.	108
62	Soil_Nitrogen_Tester result for S_1R_1-D obtained from SVM model.	108
63	Soil_Nitrogen_Tester result for S_1R_2-D obtained from ANN model.	109
64	Soil_Nitrogen_Tester result for S_1R_2-D obtained from SVM model.	109
65	Soil_Nitrogen_Tester result for S_1R_3-D obtained from ANN model.	110
66	Soil_Nitrogen_Tester result for S_1R_3-D obtained from SVM model.	110

67 Soil_Nitrogen_Tester result for S_2R_3-D obtained from ANN model. 111

68 Soil_Nitrogen_Tester result for S_2R_3-D obtained from SVM model. 111

69 Soil_Nitrogen_Tester result for S_3R_1-D obtained from ANN model. 112

70 Soil_Nitrogen_Tester result for S_3R_1-D obtained from SVM model. 112

71 STK results for five soil samples used for testing..... 113

72 Soil_Nitrogen_Tester result for S_BR_3-E - ANN model (1)..... 113

73 Soil_Nitrogen_Tester result for S_BR_3-E - SVM model (1)..... 114

74 Soil_Nitrogen_Tester result for S_BR_3-E - ANN model (2)..... 114

75 Soil_Nitrogen_Tester result for S_BR_3-E – SVM model (2)..... 115

76 Soil_Nitrogen_Tester result for S_1R_2-E – ANN model (1)..... 115

77 Soil_Nitrogen_Tester result for S_1R_2-E – SVM model (1)..... 116

78 Soil_Nitrogen_Tester result for S_1R_2-E – ANN model (2)..... 116

79 Soil_Nitrogen_Tester result for S_1R_2-E – SVM model (2)..... 117

80 Soil_Nitrogen_Tester result for S_1R_2-E – ANN model (3)..... 117

81 Soil_Nitrogen_Tester result for S_1R_2-E – SVM model (3)..... 118

82 Soil_Nitrogen_Tester result for S_1R_1-E – ANN model (1)..... 118

83 Soil_Nitrogen_Tester result for S_1R_1-E – SVM model (1)..... 119

84 Soil_Nitrogen_Tester result for S_1R_1-E – ANN model (2)..... 119

85 Soil_Nitrogen_Tester result for S_1R_1-E – SVM model (2)..... 120

86 Soil_Nitrogen_Tester result for S_1R_1-E – ANN model (3)..... 120

87 Soil_Nitrogen_Tester result for S_1R_1-E – SVM model (3)..... 121

88 Soil_Nitrogen_Tester result for S_BR_3-E – ANN model (1)..... 121

89 Soil_Nitrogen_Tester result for S_BR_3-E – SVM model (1)..... 122

90 Soil_Nitrogen_Tester result for S_BR_3-E – ANN model (2)..... 122

91 Soil_Nitrogen_Tester result for S_BR_3-E – SVM model (2)..... 123

92 Soil_Nitrogen_Tester result for S_1R_2-E – ANN model (1)..... 123

93 Soil_Nitrogen_Tester result for S_1R_2-E – SVM model (1)..... 124

94 Soil_Nitrogen_Tester result for S_1R_2-E – ANN model (2)..... 124

95 Soil_Nitrogen_Tester result for S_1R_2-E – SVM model (2)..... 125

96 Soil_Nitrogen_Tester result for S_1R_1-E – ANN model (1)..... 125

97 Soil_Nitrogen_Tester result for S_1R_1-E – SVM model (1)..... 126

98 Soil_Nitrogen_Tester result for S_1R_1-E – ANN model (2)..... 126

99 Soil_Nitrogen_Tester result for S_1R_1-E – SVM model (2)..... 127

100 Collection of additional soil samples..... 127

101 Soil_Nitrogen_Tester result for S_4R_1-E – ANN model (1)..... 128

102 Soil_Nitrogen_Tester result for S_4R_1-E – SVM model (1)..... 128

103 Soil_Nitrogen_Tester result for S_4R_1-E – ANN model (2)..... 129

104 Soil_Nitrogen_Tester result for S_4R_1-E – SVM model (2)..... 129

105 Soil_Nitrogen_Tester result for S_4R_1-E – ANN model (3)..... 130

106 Soil_Nitrogen_Tester result for S_4R_1-E – SVM model (3)..... 130

107 Soil_Nitrogen_Tester result for S_4R_2-E – ANN model (1)..... 131

108 Soil_Nitrogen_Tester result for S_4R_2-E – SVM model (1)..... 131

109 Soil_Nitrogen_Tester result for S_4R_2-E – ANN model (2)..... 132

110 Soil_Nitrogen_Tester result for S_4R_2-E – SVM model (2)..... 132

111 Soil_Nitrogen_Tester result for S_4R_2-E – ANN model (3)..... 133

112 Soil_Nitrogen_Tester result for S_4R_2-E – SVM model (3)..... 133

113 Soil_Nitrogen_Tester result for S_4R_3-E – ANN model (1)..... 134

114 Soil_Nitrogen_Tester result for S_4R_3-E – SVM model (1)..... 134

115 Soil_Nitrogen_Tester result for S_4R_3-E – ANN model (2)..... 135

116 Soil_Nitrogen_Tester result for S_4R_3-E – SVM model (2)..... 135

117 Soil_Nitrogen_Tester result for S_4R_3-E – ANN model (3)..... 136

118 Soil_Nitrogen_Tester result for S_4R_3-E – SVM model (3)..... 136

LIST OF APPENDICES

Appendix		Page
1	Tables	71
2	Figures	77
3	Computations	137
4	Specification sheets	142
5	Forms	168

DESIGN AND PERFORMANCE EVALUATION OF SOIL NITROGEN TESTER

JC Joseph R. Ortiz
Kazelle Anne A. Sallegue

An undergraduate design project submitted to the faculty of the Department of Computer and Electronics Engineering, College of Engineering and Information Technology, Cavite State University, Indang, Cavite in partial fulfillment of the requirements for the degree of Bachelor of Science in Electronics and Communications Engineering with Contribution No. CEIT 2018-19-2-023. Prepared under the supervision of Engr. Nemilyn A. Fadchar.

INTRODUCTION

Plants play a vital role in the ecosystem. It gives life to animals and people by being the source of food and nutrients for the body. Without plants, we may not be able to breath because there will be no means of carbon dioxide absorption. Consequently, it is important for us to prioritize the primary needs of a plant since well-fed plants result into a healthier, more fruitful, and more good-looking state. According to (LaLiberte, 2018), the basic needs of a plant are carbon, hydrogen and oxygen. Other essential nutrient elements, which can be found from soil, are grouped into macronutrients and micronutrients. Loch (n.d.) stated that nitrogen (N), phosphorus (P), and potassium (K) are the basic macronutrients. Among this nutrients, N is a great indicator of soil fertility. N is one of the essential elements measured in agricultural soils in order to regulate the amount of fertilizer to be applied in regard to the requirement of the crops. This is to avoid the excessive application of N which can result to the percolating of nitrate in groundwater reservoirs. When a plant