



Faculty of Manufacturing Engineering

DEVELOPMENT OF PIPELINE CORROSION INSPECTION SYSTEM USING MACHINE VISION

Syahril Anuar Bin Idris

Doctor of Philosophy

2016

**DEVELOPMENT OF PIPELINE CORROSION INSPECTION SYSTEM USING
MACHINE VISION**

SYAHRIL ANUAR BIN IDRIS

A thesis submitted

in fulfillment of the requirements for the Doctor of Philosophy

Faculty of Manufacturing Engineering

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

2016

DECLARATION

I declare that this thesis entitled “Development of Pipeline Corrosion Inspection System Using Machine Vision” is the result of my own research except as cited in the references. The thesis has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

Signature : _____
Name : _____
Date : _____

APPROVAL

I hereby declare that I have read this thesis and in my opinion this thesis is sufficient in terms of scope and quality for the award of Doctor of Philosophy.

Signature : _____
Name : _____
Date : _____

DEDICATION

To my beloved father and mother,
who gave me the greatest gift anyone could give to another person:

They believed in me.

ABSTRACT

These days, utilization of camera as an inspection tool has been expanded. The flexible function of camera is adequate to obtain different kind of information. In Cawley (2001) review on NDT that was presented in 2001, Radiography, Ultrasonic, Eddy Current, Magnetic Particle, and Penetrant Testing were the top five techniques dominating the NDT market yet Visual Inspection is the most widely applied. Even though the popularity of visual inspection is higher compared to other NDT method, but due to the reliability issues it is often used together with other methods. This research work is focusing on developing a robust corrosion inspection system based on vision sensor that is able to accurately detect and classify corrosion based on the appearance features. By installing at an early stage, inspection system would be able to gather data and at the same time identify and analyse the collected data. Through the results, the analysed data is able to classify the corrosion type based on appearance. From the research work, the method of using image enhancement filters to improve accuracy of vision corrosion inspection system is identified. The detection of each macroscopic surface corrosion types; galvanic; crevice; erosion; pitting and exfoliation using vision inspection able to achieve 79% accuracy using the simulated dataset. The new method of corrosion inspection operation which able to generate prevention plan has qualified the Vision Corrosion Inspection System to be used during preliminary inspection. It is expected that the Vision Corrosion Inspection System can improve vision inspection as the pioneer in NDT method for corrosion inspection. In addition, framework of the developed Vision Corrosion Inspection system is applicable for other applications of vision inspection whereby it can be applied for other inspection process or extending its application to other problems.

ABSTRAK

Hari ini, penggunaan kamera sebagai alat pemeriksaan semakin meluas. Fleksibiliti fungsi kamera yang baik boleh mendapatkan pelbagai jenis maklumat. Dalam ulasan Cawley (2001) mengenai NDT, Radiography, Ultrasonic, Eddy Current, Magnetic Particle, dan Penetrant Testing adalah lima teknik yang mendominasi pasaran NDT, namun teknik Pemeriksaan Visual paling banyak digunakan. Walaupun populariti pemeriksaan visual lebih tinggi daripada kaedah NDT lain, disebabkan oleh isu kebolehpercayaan ia hanya digunakan sebagai alat bantuan untuk kaedah lain. Kerja penyelidikan ini tertumpu kepada pembangunan sistem pemeriksaan kakisan menggunakan sensor penglihatan yang mampu untuk mengesan dengan tepat dan mengelaskan kakisan berdasarkan ciri-ciri penampilan. Dengan memasang di peringkat awal, sistem pemeriksaan dapat mengumpul data dan pada masa yang sama menganalisis data yang dikumpul. Berdasarkan keputusan itu, data yang dianalisis dapat mengklasifikasikan jenis-jenis kakisan. Dari kerja penyelidikan ini kaedah menggunakan penapis bagi meningkatkan ketepatan sistem pemeriksaan kakisan dapat dikenalpasti. Pengesanan setiap jenis kakisan makroskopik menggunakan pemeriksaan penglihatan berjaya mencapai 79% ketepatan. Kaedah pemeriksaan karat yang baru ini mampu menjana rancangan pencegahan telah melayakkan Sistem Pemeriksaan kakisan menggunakan sensor penglihatan digunakan semasa pemeriksaan awal. Hasil penyelidikan ini akan menjadi satu kaedah baru pengesanan kakisan dan sebagai perintis dalam kaedah NDT untuk pemeriksaan kakisan. Tambahan lagi, rangka pembangunan Sistem Pemeriksaan kakisan menggunakan sensor penglihatan boleh digunakan untuk aplikasi menggunakan pemeriksaan penglihatan yang lain atau meluaskan pemakaiannya bagi masalah lain.

ACKNOWLEDGEMENTS

First and foremost, I would like to take this opportunity to express my sincere acknowledgement to my supervisor Dr. Fairul Azni bin Jafar, from Faculty of Manufacturing Engineering, Universiti Teknikal Malaysia Melaka (UTeM) for his essential supervision, support and encouragement towards the completion of this thesis.

I would also like to express my greatest gratitude to Associate Professor Dr. Zamberi bin Jamaluddin from Faculty of Manufacturing Engineering, Universiti Teknikal Malaysia Melaka (UTeM), co-supervisor of this project for his advice and suggestions.

My deepest gratitude to Dr. Ahmad Yusairi bin Bani Hashim and Mr Mahasan bin Mat Ali, also fellow lecturers and assistant engineer from Robotics and Automations Department, for their assistance and efforts in all the lab and analysis work. Not to forget my colleagues, for the advice and motivation in order for me to strive for success.

Special thanks to my father and mother, my siblings and my beloved wife for their financial and moral support in completing this doctorate. Lastly, thank you to everyone who had contributed to the crucial parts in realizing this project.

TABLE OF CONTENTS

	PAGE
ABSTRACT	i
ABSTRAK	ii
ACKNOWLEDGEMENTS	iii
TABLE OF CONTENTS	iv
LIST OF TABLES	vii
LIST OF FIGURES	viii
LIST OF APPENDICES	xi
LIST OF SYMBOLS, ABBREVIATIONS AND NOMENCLATURE	xii
LIST OF PUBLICATIONS	xiv
CHAPTER 1	1
INTRODUCTION	1
1.1 Background	1
1.2 Motivation	4
1.3 Problem Statement	5
1.4 Research Question & Hypothesis	7
1.5 Research Objective	8
1.6 Research Scope	8
1.7 Research Outline	10
CHAPTER 2	11
LITERATURE REVIEW	11
2.1 Introduction	11
2.2 Visual vs. Vision System	12
2.3 Measuring Visual Inspection Accuracy	17
2.4 Big 5 of Non-destructive Testing	22
2.5 Vision System in Corrosion Inspection	29
2.6 Artificial Intelligence for Vision Inspection	35
2.7 Expert Evaluations for Corrosion Inspection	40
2.8 Summary	45
CHAPTER 3	48
RESEARCH METHODOLOGY	48
3.1 Introduction	48
3.2 Research Design	49
3.2.1 Process Diagram	50
3.2.2 Experimental Setup	53

3.3	Instrumentation	55
	3.3.1 Tools	56
	3.3.2 Dataset	60
	3.3.3 Features	67
3.4	Validation	69
	3.4.1 Peak Signal to Noise-Ratio	70
	3.4.2 Cross Validation	72
3.5	Accuracy and Error Rate	74
3.6	Summary	76
 CHAPTER 4		78
SYSTEM DESIGN		78
4.1	Introduction	78
4.2	Inspection Framework Design	79
	4.2.1 Image Enhancement	83
	4.2.2 Corrosion Segmentation	86
	4.2.3 Corrosion Classification	88
4.3	Graphical User Interface Design	90
	4.3.1 Corrosion EYE v1.01	91
4.4	Experimental Design	94
	4.4.1 Experiment I – Filter Selection Based on PSNR Value	95
	4.4.2 Experiment II – Detection of Corrosion Image based on Red Channel Histogram	97
	4.4.3 Experiment III – Corrosion Classification based on Appearance Features	99
	4.4.4 Experiment IV – Validating Filter Image Enhancement Algorithm	101
	4.4.5 Experiment V – Validating Corrosion Classification using Cross Validation Method	103
4.5	Summary	105
 CHAPTER 5		107
RESULTS AND DISCUSSION		107
5.1	Introduction	107
5.2	Results	108
	5.2.1 Experiment I - Filter Selection based on PSNR value	108
	5.2.2 Experiment II - Detection of Corrosion Image based on Red Channel Histogram	117
	5.2.3 Experiment III - Corrosion Classification based on Appearance Features	122
	5.2.4 Experiment IV - Validating Filter Image Enhancement Algorithm	130
	5.2.5 Experiment V - Validating Corrosion Classification using Cross Validation	138

5.3	Discussion	146
5.3.1	Accuracy	146
5.3.2	Inspection Framework	149
5.3.3	New Method of Inspection	154
CHAPTER 6		159
CONCLUSION		159
6.1	Introduction	159
6.2	Conclusion	160
6.3	Research Contribution	161
6.3.1	Body of knowledge	162
6.3.2	Industrial Sector	162
6.4	Future Works	163
REFERENCES		165
APPENDICES		180

LIST OF TABLES

TABLE	TITLE	PAGE
2.1	Selection Characteristic for Big 5 NDT Techniques	28
2.2	Comparison of Visual Inspection with Big 5 NDT Techniques	30
2.3	Corrosion Types Based on Image Profile	44
2.4	Filter Selection Parameters	45
2.5	Classifier Parameters Consideration	46
3.1	Specification for Boroscope Camera	57
3.2	Enhancement Filter Selection	58
3.3	The Summary of Hypothesis and Validation Analysis	70
4.1	Description for Each UI Function	92
5.1	Image Enhancement Using Wavelet De-Noising Filter	109
5.2	The Value of RMSE and PSNR on Each Filters Images	112
5.3	Result of Combination of Filter on Two Layer Filter	114
5.4	Result of Combination of Filter on Four Layer Filter	115
5.5	Corrosion Features Based on Appearance	123
5.6	Result for Simulation Dataset for Each Filters and PSNR Value	131
5.7	Result for Validation Dataset for Each Filter and PSNR Value	134
5.8	Corrosion Prevention Techniques (Davis, 2000)	155
5.9	Prevention Technique for Each Corrosion Class	156

LIST OF FIGURES

FIGURE	TITLE	PAGE
2.1	Machine Vision Application	15
2.2	NDT Qualification Requirement Based on ASNT	41
2.3	Corrosion Characterization Based on Appearance.	43
3.1	Image Inspection Process Cycle Fundamentals	49
3.2	Research Framework Design for Vision Corrosion Inspection System	50
3.3	Decision Tree Diagram	52
3.4	Experiment Setup for Vision Corrosion Inspection System	54
3.5	USB Boroscope Camera	56
3.6	Test Bed Design to Simulate Images of Corrosion	61
3.7	Experimental Setup for Galvanic Corrosion Simulation	62
3.8	Experimental Setup for Erosion Corrosion Simulation	64
3.9	Some of Sample Image Acquire for Simulation Dataset	65
3.10	Sample Images Acquire for Validation Dataset	66
3.11	Design Decision Tree Used to Classify Corrosion	68
3.12	Sample Program on Measuring PSNR Value.	72
3.13	Diagram of Cross Validation for 10-folds Method	73
3.14	Sample Program for Cross Validation	74
4.1	Diagram for the System Design	78
4.2	Image of Intelligent Pigging	79
4.3	System Flow of Pipeline Inspection Gauges	80
4.4	Vision Corrosion Inspection System Installed in Inspection System	82
4.5	Image Enhancement for Corrosion Detection	84

4.6	Corrosion Segmentation Process Flow Diagram.	86
4.7	Corrosion Classification Process Flow Diagram	88
4.8	GUIDE Layout Editor	90
4.9	Corrosion EYE v1.01 GUI	91
4.10	Process Diagram for Experiment I	95
4.11	Process Diagram for Experiment II	97
4.12	Process Diagram for Experiment III	99
4.13	Process Diagram for Experiment IV	101
4.14	Process Diagram for Experiment V	103
5.1	Raw Image Used for Experiment I	109
5.2	Result of Filtered Images for Each Filter	111
5.3	Result for Filtered Images on Multiple Layer Using Same Filter	113
5.4	Graph of PSNR Value for Each Filter on Multilayer	113
5.5	Corrosion Detection Using Histogram	117
5.6	Difference of Histogram Graph on Non-corroded and Corroded Image	118
5.7	Non corrode and Corroded Images Segmentation	119
5.8	Histogram Graph (Grayscale Subtract Red Channel)	120
5.9	Syntax for Features Classification	123
5.10	Training Data Parameter for Classification	124
5.11	Specification of Classification Tree	125
5.12	Rules Developed for Classification Tree	125
5.13	Diagram of Classification Tree	125
5.14	Testing Data Parameter for Classification	126
5.15	False Classification of Pitting Type	128
5.16	False Classification Due to Segmentation Problem	129
5.17	Sample Image Obtain from Testbed Use for Validation	130
5.18	Corrosion Segmentation for Unfiltered and Filtered Images (Simulation)	132
5.19	Sample Image Obtain from Validation Dataset Use for Validation	133
5.20	Corrosion Segmentation for Unfiltered and Filtered Images (Validation)	135
5.21	Classification Tree, Resubstitution Error and Cross Validation Loss	138
5.22	Finding Optimal Pruning Level by Minimizing CVLoss	139

5.23	New Parameter for New Classification Tree	139
5.24	New Rules for New Classification Tree	140
5.25	New Classification Tree, Resubstitution Error and Cross Validation Loss	140
5.26	Test Data Parameter for New Tree	141
5.27	Validation Dataset Use for Flexibility Test	142
5.28	Test Data Parameter for Using Validation Dataset	142
5.29	Accuracy and Error Rate for Classification Tree	148
5.30	Visual Inspection Process Framework	150
5.31	New Vision Corrosion Inspection System Framework	151
5.32	Design Decision Tree Used to Classify Corrosion	153
5.33	GUI of Corrosion EYE v1.01	157

LIST OF APPENDICES

APPENDIX	TITLE	PAGE
A	Simulation Dataset (Training)	181
B	Simulation Dataset (Testing)	186
C	Validation Dataset	191
D	MATLAB ® Training Programming	192
E	MATLAB ® Corrosion EYE v1.01 GUI Programming	196

LIST OF SYMBOLS, ABBREVIATIONS AND NOMENCLATURE

MHz	-	Mega Hertz
KHz	-	Kilo Hertz
MB/s	-	Megabyte per second
°	-	Degree
s	-	Seconds
mm	-	millimetre
Cl ⁻	-	Chloride
H ⁺	-	Hydrogen
H ₂ O	-	Water
NaCl	-	Salt
Log ₁₀	-	Logarithm (base 10)
BWP	-	Bar Wrapped Pipe
EM	-	Electromagnetic
AFO	-	Acoustic Fibre Optic
PCCP	-	Pre-Stressed Concrete Cylinder Pipe
IQA	-	Image Quality Assessment
MOS	-	Mean Opinion Score
ECI	-	Element Condition Index
AI	-	Artificial Intelligence
TCP/IP	-	Transmission Control Protocol/Internet Protocol
ANN	-	Artificial Neural Network

SVM	-	Support Vector Machine
PSNR	-	Peak Signal to Noise Ratio
GUI	-	Graphical User Interface
NDT	-	Non-destructive Testing
MSE	-	Mean Square Error
PVC	-	Polyvinyl Chloride
PIGs	-	Pipeline Inspection Gauges
IP	-	Intelligent Pigs
ROI	-	Region of Interest
RGB	-	Additive Colour Model in Which Red, Green, and Blue
USB	-	Universal Serial Bus
ROV	-	Remotely Operated Vehicle
AUV	-	Automated Underwater Vehicle
NDE	-	Non-destructive Evaluation
CFA	-	Colour Filter Array
CASS	-	Cast Austenitic Stainless Steel
TOFD	-	Time-of-flight Diffraction
ET	-	Electromagnetic Testing
AC	-	Alternating Currents
GMR	-	Giant Magneto Resistive
PCB	-	Printed Circuit Boards
MFL	-	Magnetic Flux Leakage
ASNT	-	American Society for Non-destructive Testing
3D	-	Three Dimension
UI	-	User Interface

LIST OF PUBLICATIONS

Journal

Idris, S.A. and Jafar, F.A., 2014, January. Image Enhancement Based on Software Filter Optimization for Corrosion Inspection. In IEEE - International Journal of Simulation System, Science & Technology, Vol-15, No-3, pp. 345 - 350. (In conjunction to the 5th International Conference on Intelligent Systems, Modelling and Simulation. ISMS, 2014).

Idris, S.A., Jafar, F.A., Jamaludin, Z. and Blar, N., 2014. Improvement of Corrosion Detection Using Vision System for Pipeline Inspection, In Applied Mechanics & Materials, Vol. 761, pp. 125 - 131. (In conjunction to the International Conference on Design and Concurrent Engineering, iDECON 2014, 2014).

Idris, S.A., Jafar, F.A. and Abdullah, N., 2015. Study on Corrosion Features Analysis for Visual Inspection & Monitoring System: A NDT Technique. In Jurnal Teknologi Vol. 77, No. 21, pp. 111-112. (In conjunction to the Proceedings of Mechanical Engineering Research Day 2015: MERD'15, 2015).

Publication

Idris, S.A.; Jafar, F.A., Muhammad, M.N., Mat Ali, M., Overview of Underwater Image Inspection, In Proc. of The 4th International Conference on Underwater System Technology: Theory and Applications (USYS'12), Shah Alam, 4-6th December 2012.

Idris, S.A., Jafar, F.A., Blar, N. and Mat Ali, M., 2014. Analysis of Image Enhancement on Visual Corrosion Inspection using Multi Filter Network, In Proc. of The 24th Design Engineering Systems Division Annual Conference, Japan Society of Mechanical Engineers, University of Tokushima, Japan, 17th - 19th September 2014 (設計工学・システム部門講演会講演論文集, 24, 2014, 一般社団法人日本機械学会).

Idris, S.A., Jafar, F.A. and Blar, N., 2014. Optimization of Single Filter Network on Visual Corrosion Defect, In Proc. of The 11th IEEE International Conference on Ubiquitous Robots and Ambient Intelligence (URAI 2014), pp. 658-662 (SCOPUS).

Idris, S.A., Jafar, F.A. and Saffar, S., 2015. Improving visual corrosion inspection accuracy with image enhancement filters, In Proc. of The 12th IEEE International Conference on Ubiquitous Robots and Ambient Intelligence (URAI 2015) pp. 129-132 (SCOPUS).

Idris, S.A., and Jafar, F.A., 2015. Detection of Corrosion Image Based on Image Histogram, In Proc. of The 3rd IAPR Asian Conference on Pattern Recognition (ACPR 2015) - Doctoral Consortium, 2015.

Idris, S.A., Jafar, F.A., and Awang, N., 2016. On – Line Vision Corrosion Monitoring and Inspection System, In Proc. of The IEEE Image Processing, Image Analysis and Real-Time Imaging (IPIARTI) Symposium 2016, 2016.

Blar, N., Azni Jafar, F., Idris, S.A. and Mat Ali, M., 2014, June. A Review of Humanoid Robots Technical Characteristics in the Application for Robotic Teacher. In Applied Mechanics & Materials, Vol. 761, pp. 158-162. (In conjunction to the International Conference on Design and Concurrent Engineering, iDECON 2014, 2014).

Blar, N., Jafar, F.A., Idris, S.A. and Mat Ali, M., 2014, July. Robot and Human Teacher. In Proc. of IEEE - International Conference on Computer, Information and Telecommunication Systems (CITS), 2014. pp. 1-3, 2014.

Blar, N., Jafar, F.A., Idris, S.A. and Mat Ali, M., 2014. Work in progress: Experimental Design on Initial Investigation of Malaysian Technical Education Using Humanoid Robot Teacher and Human Teacher. In Proc. of The 11th IEEE International Conference on Ubiquitous Robots and Ambient Intelligence (URAI 2014), pp. 504-505. (SCOPUS).

Jafar, F.A., Ahmad, M.Z., Saffar, S., Mat Ali, M., Abdul Rahim, M.A. and Idris, S.A., 2014. 2305 Design and Development of Low Cost AGV for Educational Purposes. In Proc. of The 24th Design Engineering Systems Division Annual Conference, Japan Society of Mechanical Engineers, University of Tokushima, Japan, 17th - 19th September 2014 (設計工学・システム部門講演会講演論文集, 24, 2014, 一般社団法人日本機械学会).

Saffar, S., Jafar, F.A. and Idris, S.A., 2015. Navigation Method of PLC Based Mobile Robot, In Proc. of The 12th IEEE International Conference on Ubiquitous Robots and Ambient Intelligence (URAI 2015). pp 507-511. (SCOPUS).

Chapter in Books

Idris, S.A. and Jafar, F.A., 2014. Image Enhancement Filter Evaluation on Corrosion Visual Inspection. In Advanced Computer and Communication Engineering Technology, Springer International Publishing, pp. 651-660. (In conjunction to the 1st International Conference on Communication and Computer Engineering, ICOCOE 2014, 2014).

CHAPTER 1

INTRODUCTION

1.1 Background

An inspection is an organized detailed examination or evaluation exercise. An inspection activity involves the measurements, tests, and gauges applied to certain characteristics in regard to an object or activity (Chaturvedi, 2008). The results are compared to specified requirements or standards for determining whether the item or activity is in line with these targets. Corrosion inspection and monitoring are key activities in ensuring asset integrity and control of corrosion. Field information and the outcomes of research laboratory evaluations should be slanted to obtain up-to-date corrosion information. Corrosion inspection and monitoring includes assessment of (Davis, 2000):

- In-line systems cover installation of devices directly into the process.
- On-line monitoring includes deployment of corrosion monitoring directly
- Off-line monitoring is achieved through the use of NDT techniques

The costs of corrosion vary considerably from industry to industry. One of the industries that is highly impacted by corrosion is oil and gas industry. This is because, steel pipeline use to transfer medium oil and gas between places. However, steel pipe can corrode in service and may suffer degradation from defects. Therefore, the first step in any corrosion prevention program is to identify and quantify the present of corrosion (Davis, 2000).

In May 2013, in the City of Calgary, a deteriorated Bar Wrapped Pipe (BWP) due to corrosion was detected by Pure Technology during scheduled inspection (Pure Technology, 2013). Due to the pipe useful life is nearing the end, the pipe section was replaced. However, by replacing BWP earlier than its end life, the cost compared to the usage has increased. This can be avoided by using an adequate inspection system that is able to detect earlier and suggest the prevention method to prolong the pipe useful life. Another case of early detection occurrence is in 2012 when Tucson Water (2012) went into emergency mode when several wire breaks occurred in a short period of time on one of its 96-inch PCCP water transmission mains which indicates there was a high risk of failure. Tucson Water was able to react quickly to the wire breaks by reducing the pressure in the pipe and diverting the water from another main to serve its customers, subsequently preventing a failure. This is the second time it happens, with the first occurrence in 1999. After the first occurrence, Tucson Water has developed a pipeline management program inclusive of electromagnetic (EM) assessment (Groisman, 2009) and Acoustic Fibre Optic (AFO) monitoring (Maalej et al., 2004). Even if a catastrophe is avoided, should the system be able to detect and at the same time suggest a solution, an emergency situation can be avoided.

There is a lot of different experiments and analysis methods used to identify corrosion damage for inspection and monitoring purposes. One of the methods is mechanical measurements by calculating weight loss, chemical analysis, and visual inspections. Corrosion occurs in several widely differing forms. Classification is usually based on one of three factors (Liang et al., 2010):

- Nature of corrode- Corrosion can be classified as “wet” or “dry”.
- Mechanism of corrosion- Involves electrochemical or direct chemical reactions.
- Appearance of the corroded metal- Either uniform (metal corrodes at the same rate over the entire surface, or localized which only small areas are affected).

Through using visual as corrosion inspections, the corrosion level identification requires an expert who can clearly determine the corrosion based on experience as well as types of corrosion, with red rust as a common experience. Usually, the corrosion process produces rough surfaces, and image analysis based on textural features can be used for quantification and discrimination of corrosion extent and type (Livens et al., 1996), (Pidaparti et al., 2013). Additional to textural features, colour progressions of metallic surfaces are also used for the detection of corrosion because of different metal oxides and other corrosion products (Medeiros et al., 2010).

With the abilities to classify corrosion based on the appearance of the corroded metal, this research work proposes a new approach on corrosion detection by using vision system as corrosion is either uniform and the metal corrodes at the same rate over the entire surface, or localized, in which case only small areas are affected. The detection of the corrosion “areas” is detected by means of visual sensor, using camera or video that is able to determine and analyse the sensed areas.

The proposed visual inspection system is to be implemented in a monitoring stage. During the monitoring, the visual inspection system would be able to gather data and at the same time process and analyse the collected data. With the results, the analysed data are able to be used to classify the corrosion type and also determine the actions to be taken.

Corrosion detection method using vision for a pipeline inspection system is able to improve current corrosion detection and reduce overall time for inspection. By using the images as the inspection data, the analogue signal loss due to the communication interference can be eliminated, as the image data are able to recover required features based on other features. Furthermore, the system is able to adapt to the unrefined environment, thus, making the proposed system robust and useful for other detection applications.