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TRACKING AND MONITORING MODEL FOR PIPELINE PIGGING

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ABSTRACT

Mechanical method, Radioactive sources, magnetic transmission, and acoustics system have been used to detect the movement of pigs through pipelines over the years while, multiple proprietary and commercial software has been used to analyze various data format to assess the pipeline conditions. With varying degree of success these systems can be made to do the job for which they were created, however in terms of data collection and input the tracking of pigs still involved loads of manual data collection. This often led to inaccurate analysis. Considering the large amount of data and the critical timescales of pigging operations, it is suggested that data input take place automatically and integrated with the software analysis tool. Thus, tracking and monitoring model for pipeline pigging has been proposed to be implemented in petroleum and oil gas pipeline to enable the operator to track and monitor pigging operation and perform analysis on specific location based on the spatial information in the GIS database with minimum human intervention. Adapting a hybrid of vehicles and animal tracking system model, this thesis presents the Tracking and Monitoring Model for Pipeline Pigging to meet the requirements and constraints posed within the oil and gas pipeline environmental settings. This thesis also conduct feasibility study to address the constraint and requirements in developing this system through experimentations at Petronas Carigali Sdn Bhd Miri and propose and validates the data transmission design through simulation and analysis via Satellite Tool Kit (STK) and finally demonstrates how tracking will be visualized at the presentation layer by developing a system prototype using ArcGIS Tracking Analyst. This thesis also presents a sample analysis for pipeline model by using multiple data using a single application. Recommendation and findings from the experiments, STK simulation analysis and software development are intended to provide guidance in developing and implementing the system in real environment.

ملخص البحث

إن الطرق الميكانيكية، والأنظمة الإشعاعية، والنقل المغناطيسي، والطرق الصوتية قد تم إستخدامها في تحسس حركة جهاز التنظيف في خطوط الأنابيب لعدة سنين، بينما استخدمت طرق السوفت ويرالاقتصادية لتحليل المعلومات, ومعرفة حالة الأنابيب المثالية. مع اختلاف درجة النجاح فإنه من الممكن أن تؤدي هذه الأنظمة العمل الذي قامت من أجله, ومع ذلك فبالنسبة إلى جمع المعلومات وإدخالها إلى الأنظمة فإن تتبع جهاز التنظيف داخل الأنابيب اشتمل على جمع معلومات هائلة والتي يتم جمعها يدويا، وهذا غالباً يؤدي إلى عدم دقة التحليل بسبب الأخطاء الناتجة من العمليات اليدوية. لو أخذنا بنظر الإعتبار الكمية الهائلة من المعلومات وحدود الوقت الحرجة لعمليات التنظيف، فإنه من المقترح أن تكون عملية إدخال المعلومات في الوقت الفعلي, وإدخالها إلى الحاسوب سيؤدي إلى التغلّب على هذه الصعوبات. لهذا، فإن تتبع جهاز التنظيف في الوقت الفعلي, وتتبع نظام تنظيف الأنابيب قد تم إقتراح استعماله في صناعة النفط, والغاز لتمكن العامل المسؤول على الأنابيب في سهولة المتابعة والسيطرة على عملية التنظيف, وتأدية التحليل على مواقع معينة إعتمادا على المعلومات المتوفرة في بنك المعلومات التابع إلى نظام المعلومات الجغرافي (جي أس آي) مع أدنى تدخل من العاملين عليه. هذه الاطروحة تقدم الإطار المعماري للنظام ليفي بالغرض ويخدم الوضع المكلّف الموجود حالياً في صناعة النفط والغاز، بتبني موديل نظام تتبع المركبات والحيوانات. هذه الاطروحة تقوم بدراسة الجدوى لتحديد الحدود والمتطلبات لتطويرهذا النظام في مؤسسة بتروناس كاريكالي سنديريان بيرحاد ميري واقتراح وتثبيت تصميم نقل المعلومات باستعمال العدة الخاصة بالستلايت (أس تي كي) ومشا تها وتحليلها وفي النهاية برهنة كيفية إن التتبع بالوقت الفعلي سيقدم في النهاية تطوير نظام البروتوتايب باستخدام تحليل نظام تتبع (آرك جي آي أس). إن التوصيات والملاحظات من هذه التجارب بينت أن تحليل عملية التشابه, وتطوير السوفت وير سيوجه العامل المسؤول على الأنابيب بالطريقة التي سيتبعها لتطوير هذا النظام.

APPROVAL PAGE

I certify that I have supervised and read this study and that in my opinion, it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a dissertation for the degree of Master of Science in Computer and Information Engineering.

……..……...
Shihab Ahmad Hameed
Supervisor

I certify that I have read this study and that in my opinion, it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a dissertation for the degree of Master of Science in Computer and Information Engineering.

….……
Sheroz Khan
Internal Examiner

I certify that I have read this study and that, in my opinion, it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a dissertation for the degree of Master of Science in Computer and Information Engineering.

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Aziz Deraman
External Examiner

The dissertation was submitted to the Kulliyyah of Engineering and is accepted as a partial fulfilment of the requirements for the degree of Master of Science in Computer and Information Engineering

……
Ahmad Faris Ismail
Dean, Kulliyyah of Engineering

DECLARATION

I hereby declare that this thesis is the result of my own investigations, except where otherwise stated. I also declare that it has not been previously or concurrently submitted as a whole for any other degrees at IIUM or other institutions.

Rozaidah Saat

Signature..... Date. …….

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DECLARATION OF COPYRIGHT AND AFFIRMATION OF FAIR USE OF UNPUBLISHED RESEARCH

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Affirmed by Rozaidah Binti Saat.

…….. ……

Signature Date

Dedicated to my parents, family, and in loving memory of my niece Nur Syamira Fatin.

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LIST OF ABBREVIATIONS

ArcIMS	Arc Internet Map Server
ArcGIS	Arc Geographic Information System
BG	British Gas
C/N	Carrier to Noise Ratio
DEM	Digital Elevation Model
ESRI	Environmental Systems Research Institute
Eb/No	Energy per Bit per Noise Power Spectral Density
GCC	Gateway Control Center
GEO	Geosynchronous Earth Orbit
GES	Gateway Earth Station
GIS	Geographic Information System
GPS	Global Positioning System
GSM	Global System for Mobile Communications
ITU	International Telecommunication Union
LEO	Low Earth Orbit
MEO	Medium Earth Orbit
PCSB-SKO	Petronas Carigali Sdn Bhd. Sarawak Operation
PPTM	Pipeline Pigging Tracking and Monitoring
SDPSK	Symmetrical Differential Phase Shift Keying
STK	Satellite Tool Kit
TLEs	Two-Line Elements

CHAPTER ONE

INTRODUCTION

1.1 INTRODUCTION

Pig tracking and monitoring is important to detect and locate a stuck pig and it is also an essential tool for gathering data to update the status of the pipeline internal condition. In each of pigging operation, data will be recorded and analyzed and these tasks involve taking various data, review and combine them and require accurate analysis to ensure a correct decision is made for mitigation and contingency purposes.

Currently a mechanical, acoustics, radioactive sources and magnetic transmission methods have been used as means for pig detection and gathering the data while various data sources and application have been used throughout the pipeline organization to manage the integrity, maintenance and safety of their pipelines. With varying degrees of success, these systems can be made to do the job for which they were created. However in terms of data collection and input the tracking of pigs still involve loads of manual data collection making analysis of pipeline conditions subject to manual inspections. Manual data input necessitates the training of on-site workers as to how to interpret data, allow time for its input, and include error assumptions in final reports. This often leads to inaccurate analysis. Considering the large amount of data and the critical timescales of the pigging operations, it is ideal that data input take place electronically. An integrated pig tracking and monitoring system will ensure data availability, accuracy and quality which are needed for correct analysis.

Besides it will enable the pipeline operator to track the movement of pig at close intervals, obtained the data directly from the site so that the data can be analyzed consistently and at the same time the operation can be monitors and analyze without having to rely on multiple data sources and format.

1.2 RESEARCH PROBLEM STATEMENT

To address the issues of manual data input and interpretation, it is proposed that an integrated system that takes data and turns it into information in the context of managing a pipeline asset is developed by the pipeline operator. However, the challenge to build this system is that

i. No current tools or means that can directly send data to and from field to feed the data.
ii. There is no method for communicating when data is updated.
iii. The integrity and facility critical data exist in various forms throughout the organization which means these multi-format data whether in the form of paper records, digital (spreadsheets) or databases makes it difficult to perform analysis using a single application.

1.3 OBJECTIVES

The objectives of this research is to develop an integrated pig tracking and monitoring model that addresses these challenges and examine the technical feasibility of this model by taking Malaysia's pipeline setting into consideration. Implementation of this system requires cost and careful planning thus the development is divided into two phases. This research is dealing with the first phase of development which is:

i. Designing pig tracking and monitoring model that enable the field data to be sent from the pipeline to the end system which will also facilitate analysis using a single application.

ii. Perform feasibility studies for this model to obtain the details of the system design procedures and methodology so as to minimize risk of failure and provides suggestion for successful implementation of the system in real environment.

1.4 SCOPE

The scopes of this research:

i. Focus in solving the problem in Malaysia and local pipeline environmental setting specifically in Petronas Carigali Miri. Thus the assumption, suggestion and implementation are based only on local pipeline environment.

ii. This research dealing with the first stage of the development, which is the feasibility study thus; system implementation in real pipeline environment is beyond the scope of this research.

1.5 RESEARCH METHODOLGY

In order to achieve the objective of this research, the following procedures are considered:

i. This research starts with the understanding of the problems and requirement analysis from Petronas Carigali Miri- Sarawak Operations.

ii. Development of an integrated pig tracking and monitoring model.

iii. Conduct experimentation for Magnetic module position determination to validate the data acquisition design.

iv. Conduct simulation analysis for Orbcomm satellite communication to validate the arrangement of transmission layer.

v. Development of interface and sample analysis to demonstrate the presentation layer.

1.6 THESIS OUTLINE

Chapter two discusses the current method for pig tracking, reviews current practice employed by pipeline operator and review different type of model for tracking and monitoring and concluded with the list of requirement in developing an integrated model for pig tracking and monitoring. Chapter three presents the proposed pig tracking and monitoring model which also describes the components, functionality and specification of each layer from data acquisition to the presentation layer. The feasibility study for data acquisition layer, transmission layer and presentation layer are presented in chapter four by experimentation, simulation and demonstration while the analysis of the results is discuss in chapter five. Finally the research findings, the outcomes, limitation and the future works are concluded in chapter six.

CHAPTER TWO

LITERATURE REVIEW

2.1 INTRODUCTION

This chapter is divided into three main sections. The initial part defined pig tracking system and reviews existing pig tracking method, the second part reviews existing tracking communication technology while the third section reviews available tracking application software. Comparison and preferred features of each tracking method, communication and application software are summarized in a comparison table and the design requirement are listed in the concluding section.

2.2 PIPELINE PIGGING

Pipelines, being the cheapest method of transporting fluids or gases, are specifically designed for continuous operation and optimum efficiency. Pigging operations are the solution in both obtaining and maintaining these two fundamentals (Tiratsoo, 1999). Pig or sometimes known as an acronym for Pipeline Internal Gauging (PIG) refers to special devices sent into a pipeline for cleaning the pipe interior or to inspect pipeline internal conditions. The use of pigs for pipeline operation is commonly referred to as pigging (Liu, 2003).

2.2.1 Purpose of Pigging

Pigging is needed in every stage of pipeline life. Cordell et al (2003) and Hiltscher et al (2003) listed 26 various reasons to pig a pipeline which mainly occurs during three

main instances; during pipeline construction, pipeline operation and pipeline decommissioning.

Pigging is conducted prior to the construction to remove the debris inside a pipeline. Once the pipeline is laid pig is inserted to verify whether the pipeline has been constructed as specified. After hydro testing and during pre-commissioning pig once again is run to remove the test water or mills scale, and once the pipeline is ready for operation, special pig is launched to coat pipeline interior with corrosion inhibitors (Cordell et al, 2003). During operations, pig is used in multi-product pipeline to separate different products. For crude oil and gas line which are prone to get layer of wax and liquid condensate on pipe wall, pigging operation needs to be performed regularly to improve pipeline flow. Meanwhile inspection pigging has to be conducted from time to time to monitor the pipeline condition, to examine the pipeline geometry and to detect corrosion, or leakage in the pipeline. Pigging operation is also carried out in repair work to coat the inside pipeline surface with inhibitors to avoid or reduce further corrosion (Tiratsoo, 1999).

Finally, even during pipeline decommissioning pig is launched to clear the product from line and to clean and dry the pipeline to avoid any hazard. Thus, a sequence of processes conducted during construction is carried out before putting the pipeline out of operation (Hiltscher et al, 2003).

2.2.2 Importance of Pig Tracking and Monitoring

In each stage of pipeline operations where pigs are utilized, there is always an uncertainty as to whether the pig will reach its receiving facility. Pig may get stuck or lost in the pipeline if it loses its seal, or if it encountered obstructions that it cannot negotiate (O'Donoghue, 2005). If this happen, stuck pig need to be located or else it

will block the pipeline. In some cases the pipeline need to be cut just to recover the stuck pig. This necessitates the operator to track the operation at close intervals because an obstruction can cause loss of man-hours and production down-time (PPSA, 1995).

2.3 PIG TRACKING

Pig tracking is used as a generic term to cover any requirement to monitor the movement or locate the position of pigs during the pigging operation, meanwhile pig tracking and monitoring system is a transmitter/receiver system installed on the pig or on the pipeline to enable the pipeline operator to track the pig's location either continuously or at a series of predetermined points (McAra, 2002).

The input or the transmitter of the system varies. It can be in the form of mechanical movements, magnetic flux, acoustic, and even radioactive sources. Meanwhile the output of the system is the pig location whether in the form of XY coordinate, or a code of a predetermine location. Some system also giving out the speed of the pig and the time it passes the predetermined location. This output is usually received by a detector which is in a form of hand-held gadget or receiver which has to be carried in a vehicle along the pipeline.

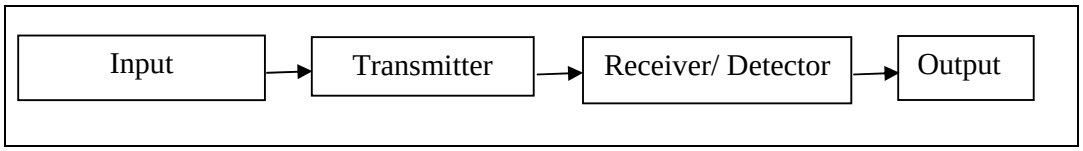

Figure 2.1: Block Diagram of a Pig Tracking System

2.4 EXISTING METHODS IN PIG TRACKING AND MONITORING

The four basic methods which have been used in tracking a pipeline pig are mechanical, radioactive sources, magnetism, and acoustics (Farqué, 1996). Each method involves specialized equipment which must be incorporated into the pig or piping system before the pig is launched, except for an acoustic method which relies on a traditional ways of placing an ear against the pipeline to listen for the pig to strike the weld joints. Sometimes lengths of chain were attached to the pigs to enhance the operator's ability to hear a pig pass. However, this method can only work if the listener has direct contact with the pipeline and it usually results in the chain got lost in the pipelines which added to be an item that pig is supposed to remove from the line. Simple electronic amplification devices that aid the listener by amplifying the sounds of a pipeline also have been developed. Although these were efficient in tracking a moving pig, major problems arise when a pig gets stuck as it produces very little sound (Tiratsoo, 1999). Realising that acoustic listening device does not allow for locating stationary pigs, variety of systems that transmit a signal from a device attached to a pig is developed by commercial pigging companies (Farqué, 1996). These systems allow greater flexibility, and produce better precision for location. These systems can be divided into passive and active tracking system. Mechanical and radioactive tracking are categorize into passive tracking while ultrasonic and magnetic transmission system are classified under active tracking system.

2.4.1 Passive Tracking Methods

In mechanical pig tracking, devices are normally welded to the pipeline with levers protruding into the pipeline to get struck by the passing pig. Thus, it signals the passage by a visual representation. Sophisticated mechanical transmitters with

capability to output passage indication electronically also have been developed in which the mechanical devices flip up a flag when the pig actuates a pressure or mechanical sensors.

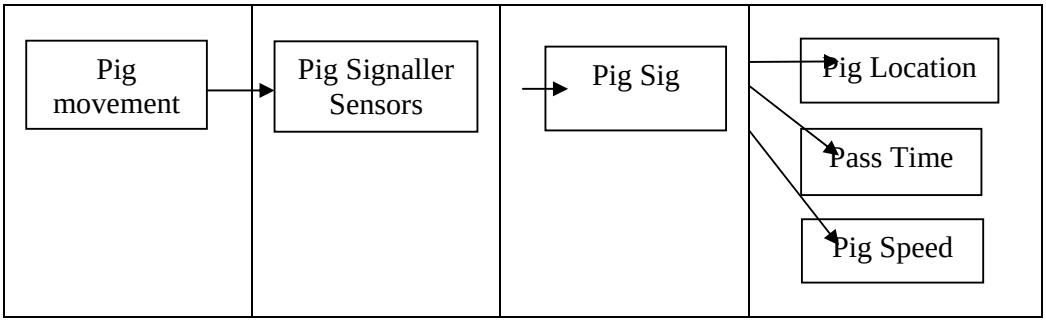

Figure 2.2: Block Diagram of a Mechanical Pig Tracking System

However, this method requires semi or permanent installation and intrusion into the pipeline. This is not ideal since intrusion creates potential corrosion and increase the possibility for the leakage trouble spots (McAra, 2002). Another drawback is that, when a pig gets stuck inside the pipeline, there are no means to assist the operator to find the exact location. In addition, as mechanical indicators are one-shot signallers, with the operator responsible for manually resetting the device after every passage, the risk of having inaccurate data increases if the operator arrives at the unit after the pig has passed or totally forgets to reset the signallers.

The second passive tracking method involves fitting selected radioactive source (alpha, beta or gamma) to the pig, and to relocate it by means of a Geiger counter. The detectors are places along the pipe prior to launching the pig.