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SERVICE ORIENTED ARCHITECTURE & REAL-TIME AGENT ACTIVATED MAINTENANCE FRAMEWORK FOR PORT EQUIPMENT MANAGEMENT

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Abstract

Real-time equipment management is keyword to many successful plants. Increasing competition has forced plants including port / terminal operators to seek new methods towards effective operation. Reducing maintenance budgets was gold standard in operational cost reduction, but in maintenance perspective it is a short-term strategy. Integrated monitoring system with effective predictive modeling element shall promote equipment reliability and availability. In Malaysia, major port operators spend substantial amount of money annually on maintenance. This paper outlines a proposal for integrating self-monitoring systems through use of emerging technologies. The proposed framework expected to ensure availability and reliability of equipments for port operation through real-time predictive data modeling.

Keywords
Reliability and maintenance engineering, predictive modeling, self-monitoring system, service oriented architecture, collaborative operational planning

1. Introduction
Expressions of port performance are commonly based on data recorded by port authorities who traditionally tend to focus on traffic or throughput recordings as parameters used in tariffing of port services. Port Authorities usually monitor berth occupancy and dwelling time of ships, characteristics of ship calls, and performance of ship-to-shore cargo handling and availability of the main pieces of handling equipment. Additional but often less reliable data may be available with regards to landward operations such as: dwelling time of cargo in ports' warehouses and storage areas, characteristics of customs and other administrative procedures and, rarely, performance of handling for pick-up and delivery of goods. Obtaining the equipment performance data and managing the efficiency of the equipment should play an important role in port performance measure and justification besides the operational, economical and administration factors.

1.1 Equipment Management
All equipment needs some kind of maintenance throughout its life-cycle to ensure operability of the equipment and maintenance of different approaches is critical for the level of reliability expected of the equipment. The history of maintenance activity started with the Breakdown Maintenance (BdM). The equipment is operated with only cleaning and/or lubrication done until it fails. Repair or replacement of component either minor or major is carried out only

when the equipment ceased to operate due to a breakdown. In early days the industry was not very highly mechanized and downtime did not matter much. The design of the equipment is generally simple and in most cases over-designed. This made the equipment easy to repair and reliable.

As the industry becomes more mechanized and equipment design gets more complex, productivity tends to rely heavily on the availability and reliability of the equipment. Equipment downtime comes under focus. This led to the idea that equipment failure could and should be prevented [1]. This brings about the concept of Preventive Maintenance (PM). PM is predetermined work performed to a schedule with the aim of preventing sudden failure of equipment component, to improve equipment reliability, decrease cost of replacement, protect the equipment and prolong the useful life of the equipment [2]. PM will not eliminate wear and tear but prolong them thus decrease cost of operation and extend useful life. At minimum PM shall include lubrication, cleaning, adjusting, minor component replacement and painting.

When a component has failed, expected to fail or ending its life-cycle, it needs to be repaired or replaced. The maintenance work which involves the repair or replacement of such components is defined as Corrective Maintenance (CM). CM can be planned (when the component is repaired/replaced as it is expected to fail or ending its life-cycle) or unplanned (when the component is repaired/replaced as it has failed). For the Planned CM the failure modes lend themselves to condition monitoring, which is the result of a regular inspection which identifies the failure in time for corrective maintenance to be planned and scheduled, then performed during a routine plant outage [3]. The Unplanned CM is associated with Breakdown Maintenance (BdM) as the repair/replacement is done after the component has failed [4].

While PM is able to improve reliability of equipment, it still has other drawbacks. PM is performed in fixed schedules regardless of the physical status of the equipment [4] thus includes performing unneeded maintenance activities which exposes equipments to possible damage. Human errors committed during the PM task and infant mortality of newly installed components eventually lead to breakdown of the equipment on which the PM was performed [5]. The requirement to reduce maintenance cost and to increase availability and reliability of the equipment has caused plants to look at other proactive maintenance strategies such as Condition Based Maintenance (CBM) or Predictive Maintenance (PdM). CBM/PdM can be defined as maintenance initiated based on the state of condition of an equipment. The information is collected through various condition monitoring techniques such as vibration analysis, fluid analysis, infrared thermography, voltage and current monitoring. The condition monitoring techniques of CBM are designed to actively monitor the equipment component.

1.2 Detection Sensor

Predictive maintenance programs regularly measure key indicators on critical equipment and track that information over time, helping technicians predict when repairs are necessary. The common measuring appliances are clamp meters, digital infrared thermometers, vibration sensors and insulation resistance testers. Other applications are thermography and power quality analyzers. These measurements are manually recorded or recorded through software systems and timely download by central processing system. In this paper we are moving towards smart sensors followed by data transmission through wireless protocols. The next challenge will be the uniqueness of the network topology and architecture design in accumulating the sensor output in terms of cost, efficiency, reliability and operational simplicity.

1.3 Wireless Sensor Network

The wireless sensor network (WSN) technology has been widely applied in military, industry, agriculture and many other areas [15, 16]. Long bundles of wires represent installation and long term maintenance cost, limiting the number of sensors that may be deployed, and therefore reducing the overall quality of the data reported. Wireless sensing network can eliminate number of limitations, such as installation logistics. An ideal network topology should be scalable, consumes very little power, smart and software programmable, capable of fast data acquisition, reliable and accurate over the long term, costs little to purchase and install, and requires no real maintenance. Selecting the optimum sensors and wireless communication link requires knowledge of the application and problem definition. Battery life, sensor refresh rates, and size are all major design considerations. Examples of low data rate sensors include temperature, humidity, and peak strain captured passively. Examples of high data rate sensors include strain, acceleration, and vibration. Recent advances have resulted in the ability to integrate sensors, radio communications, and digital electronics into a single integrated circuit (IC) package. This capability is enabling networks of very low cost sensors that are able to communicate with each other using low power wireless data routing protocols. A wireless sensor network (WSN) generally consists of a base-station (or "gateway") that can communicate with a number of wireless sensors via a radio link. Data is collected at the wireless sensor node, compressed, and transmitted to the gateway directly or, if required, uses other wireless sensor nodes to forward data to the gateway. The transmitted data is then presented to the system by the gateway connection. The use of wireless sensors allows for rapid installation of sensing equipment and allows access to locations that would not be practical if cables were attached. The use of wireless sensors in this application is enabling and allowing a measurement to be made in locations that was not practical for wired environment. The proposed wireless sensor network prototype is as in Figure 1.

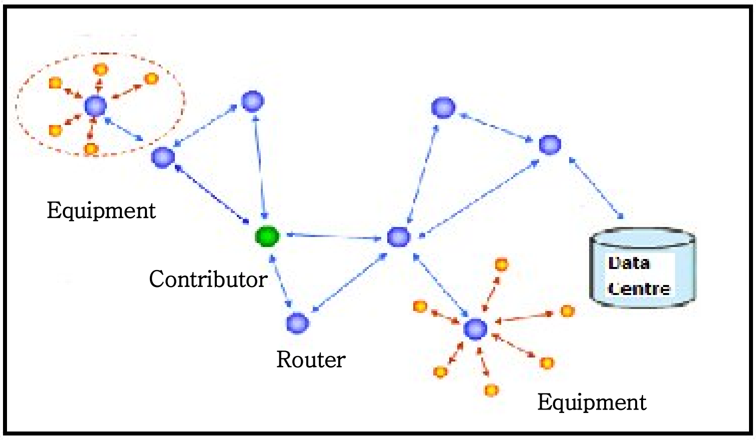

Figure 1: Proposed Wireless Sensor Network Prototype

1.4 Service Oriented Architecture

A service-oriented architecture (SOA) is essentially a collection of services. These services communicate with each other. The communication can involve either simple data passing or it could involve two or more services coordinating some activity. SOA is not just architecture of services seen from a technology perspective, but the policies, practices, and frameworks by which we ensure the right services are provided and consumed. So what we need is a framework for understanding what constitutes a good service. It is found to have varying levels of usefulness. We need some principles of service orientation that allow us to set policies, benchmarks and so on. The two most relevant aspects are: (1) interface related principles constitute of technology neutrality, standardization and consumability; (2) design principles which are more about achieving quality services, meeting real business needs, and making services easy to use, inherently adaptable, and easy to manage.

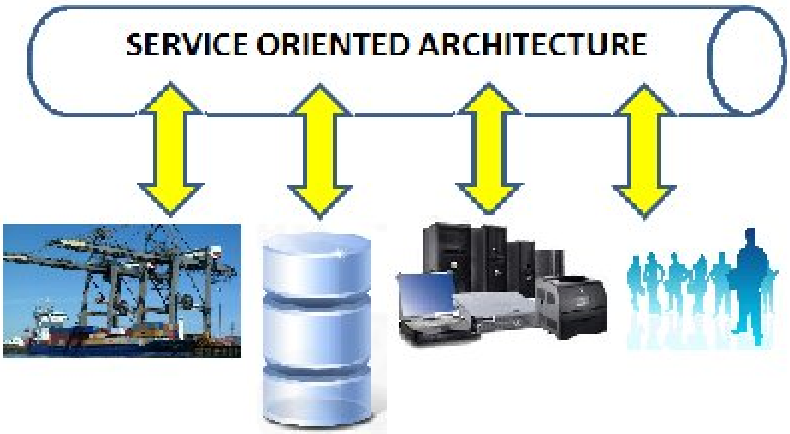

Figure 2: SOA Based Port Equipment Maintenance Management Prototype

Figure 2 reflecting the basic concept of SOA application in port equipment maintenance prototype. The nature of SOA classifies it as a loose coupling architecture. Loose coupling means that the client of a service is essentially independent of the service. The way a client (which can be another service) communicates with the service doesn't depend on the implementation of the service. Significantly, this means that the client doesn't have to know very much about the service to use it. For instance, the client doesn't need to know what language the service is coded in or what platform the service runs on. The client communicates with the service according to a specified, well-defined interface, and then leaves it up to the service implementation to perform the necessary processing. Loose coupling enables services to be document-oriented (or document-centric). A document-oriented service accepts a document as input, as opposed to something more granular like a numeric value or Java object. The client does not know or care what business function in the service will process the document. It's up to the service to determine what business function (or functions) to apply based on the content of the document. The strong five reasons for adopting SOA as preferred architecture in this design are: (a) reusability; (b) scalability; (c) interoperability; (d) flexibility; (e) cost efficiency.

1.5 Condition Monitoring

Engineering growth has necessitated various strategies for equipment maintenance management. Yi Zeng et al. [6] proposed a fuzzy adaptive particle swarm optimization algorithm that is scientific and efficient, and adapts to predictive maintenance management for any complicated equipment. Kim and May [7] employed evidential reasoning to identify malfunctions of semiconductor manufacturing equipment by combining evidence originating from equipment maintenance history, on-line sensor data, and in-line post-process measurements. Bohez and Thieravarut [8] used a hybrid reasoning approach between a deep model and a shallow model for the diagnosis of computer numerically controlled machines. Chevalier et al. [9], integrated casual reasoning and fuzzy logic reasoning for manufacturing line supervision and maintenance. To some extent, these maintenance strategies have successfully been used and have solved some practical problems. Currently data collected from the various condition monitoring techniques is manually done and analyzed and Condition Based Maintenance (CBM) is executed. Condition monitoring techniques of CBM are model-based and rely on the concept of analytical redundancy [10, 11]. As Figure 3 illustrates, a mathematical model of the monitored system runs in parallel to the physical system.

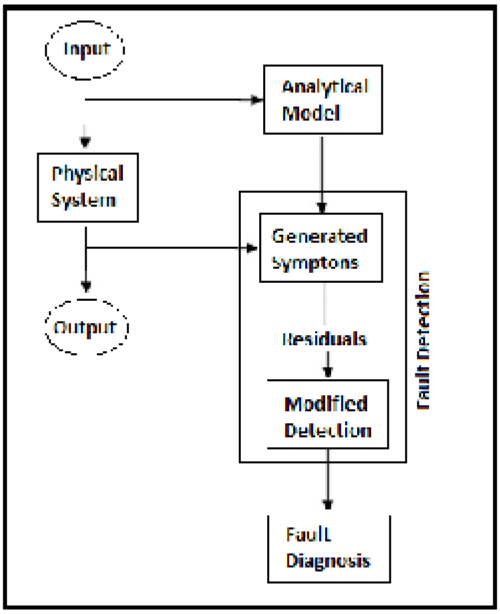

Figure 3: Physical Equipment Maintenance System and Parallel Monitoring System

Symptoms are generated by taking the difference (residual) between features of the model and features of the real system [12]. If the physical system is healthy, the residuals will be close to zero. However, if the system is degrading, due to wear or ageing, one or more of the residuals will drift away from zero. Typically, the decision about whether a fault has or has not occurred is made based on either statistical testing [1] or a single-valued number called a threshold. If a fault is detected, this triggers the diagnosis process, which uses the signature of the residuals to determine the cause of the fault. There are three significant problems with the current methods. 1) The residuals are calculated only at the current point of operation. 2) The decision is made on the assumption that a statistically certain difference between the model and real system is worth calling to the operator's attention (causing false alarms). 3) The intelligent systems used in condition based maintenance is an automatic process that determines when a fault is going to occur in a system, and subsequently diagnoses the cause of the fault. The symptoms are not intuitively understandable to nominally-trained maintenance personnel. In order to enhance the reliability, safety, and maintainability of components and reduce the cost of their overall maintenance, we are proposing a novel method: Real-time Agent Activated Maintenance (RAAM). RAAM will be accomplished by real-time sensors deployed to monitor the health of the equipment. When an impending problem is detected, the condition serves as a trigger for the responsible technician to perform a specific maintenance task on the equipment. The analysis of the above problems has shown effective and efficient pre-determinations of when, where, what, how, and who shall maintain equipment systems are very important for cost-effective maintenance. A proper maintenance plan should be prepared at an early stage, well before the equipment problems become critical and eventually cause fatal breakdowns.

2. Literature Review

For many decades, condition monitoring has been well established 'best practices' for the Information Technology (IT) operations. However, most recent independent surveys still suggest that these capabilities are virtually non-existent, or not an enterprise-wide capability, in equipment operations outside the realm of IT services, such as transportation, logistics, healthcare, utilities, communications, and other sectors. In [17], the authors firstly identify the main rationale of needs in plant asset management. The authors found that the need in this domain where not just deterministic reactive behavior is required, but where computational intelligence can be used profitably to aggregate information about complex situations for human deciders and to optimize available reaction options. Consequently, one possible implementation paradigm for plant asset management systems is intelligent software agents [18]. In [19] asset optimization seeks improved operating practices through the use of process analysis and diagnostic monitoring to notify operations and maintenance systems of quality deviations and to permit further improvements. Asset optimization involves the manipulation of real time process and equipment status to improve performance, equipment availability and overall process effectiveness.

The strategies behind predictive maintenance and asset optimization have been around for more than a decade. The major drawbacks have been traditional management of the information collected and the limits of the typical plant organization. Usually, independent functions and islands of automation have precluded their implementation. In [20], the author validated the use of neural network approach for the condition monitoring system in an off-line proof of concept procedure. It has been shown that classification of machine system parameters, on the basis of motion current signature, using a neural network approach is possible. After reviewing the current maintenance management practices, we find that condition-based fault diagnosis and the prediction of the equipment deterioration trend are vital in maintenance management approaches. Condition monitoring, intelligent condition-based fault diagnosis and the prediction of the trend of equipment deterioration need to be integrated to provide a comprehensive decision support for maintenance management. All these encourage us to develop a new framework for a Real-time Agent Activated Maintenance (RAAM), including the prediction of the trend of equipment deterioration, for condition-based maintenance.

3. Methodology

Findings from the literature review conducted help the researcher to see the current trend in the industrial equipment management. The usage of condition monitoring begin to rose after realization of the importance of condition monitoring by the industry professionals as well as the leaders in order to achieve better in the competitive market compared to the previous years. Added with more recent trend of WSN and SOA in equipment management approach has further advanced the equipment management professionals. Every single person in this industry acknowledged that the complexity of equipment maintenance systems must be understand well before proceeds to "knowledge managementization", especially from the party that have suffered from the failures of the condition monitoring efforts. As we all know, we learn best from the mistake, hence as we know in advanced about the root, the cause, the factors affecting it, we can plan the precaution steps.

The problem statement of this research obtained within the port operation system in Malaysia. We can say that the implementation of condition monitoring is not widely dispersed to every stakeholder within Malaysian port industry. From the literature review, we came to know that the successful of implementation depends heavily on several factors; 1) the importance of good and reliable equipment knowledge 2) understanding the importance of differences in operational culture and process 3) the importance of communications, flexibility and accountability 4) the human resource which means having good education and user training 5) community of practice 6) the reliability and integrity of operational information and knowledge 7) the technology availability. But we must keep in our mind one very important issue about technology. IT is a tool, not a goal. Success should not be measured by the number of equipments with computerized monitoring systems. Success is when MTBF outcomes improved. Success is when everyone can learn which methods and diagnosis works, and which do not, in days instead of decades. The objectives of this research firstly to identify most critical breakdown parameters in port operation. This question can be answered by doing the static data modeling using their breakdown historical data.

The second objective is to look at the systematic approach to identify the suitable detection sensors to place in equipment for the performance monitoring. The next objective will be designing the predictive agent by incorporating the real-time operation data. WSN and SOA architecture design and the integration challenges will be our next objective to address in this proposal. Implementing the integration process of heterogeneous port equipment maintenance system that resides in an outdoor environment of a port will be a great challenge. The approach to obtain answer for this challenge is to analyze the data collected from the first objectives and compare it with the successful factors of implementing the proposed integration. The mapping process can help to see the process and knowledge flow clearer for further actions. Next, from the data analysis, we are intended to able to understand the strength and the weaknesses of the current process and then suggest the necessary way of solutions.

This research scope of study will be bounded within one operational port which are currently in the testing phase of the Real-time Predictive Agent base Monitoring. The important issues here, it to obtain the trust from the port operations so that the level of sincerity in answering the question will be highly contribute to the accurateness of the suggested approach.

4. Conclusion

Overall, this research would really have a huge impact in the industry if the research is given the best effort, the best assistance, and co-operation from the port equipment maintenance professionals.

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