Development of an expert system for the repair and maintenance of bulldozer's work equipment failure

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Abstract

This work aimed to develop an expert fault diagnostic system for the repair and maintenance of bulldozer work equipment faults. An Expert System, ES is one of the many quick and efficient repairs and maintenance strategy that can be used on these machines. ES is a C# computer based programming software that can be adopted to extend the life span of equipments and reduce the cost of human expert for their repairs. In this work, an expert system was developed as a tool that will detect, analyse and proffer respective solutions to the bulldozer work equipment faults. A flowchart (logic chart) was also developed. The flowchart is a logical sequence for characterising and troubleshooting the causes of bulldozer's work equipment failure. In this report, the solutions to the detected faults: low or high hydraulic valve pressure, abnormal noise in the control valve was documented accordingly. The preferred solutions to the various faults observed were also included with snapshots from each interface of the developed program in the report. The ES developed can be adopted in the construction industries for carrying out repair and maintenance of equipment for optimum performance at a highly reduced cost. This can also be used as a teaching aid in the department of mechanical and mechatronics engineering and other fields of engineering institute. This study will enable automobile and maintenance workshops to proffer solutions to maintenance of bulldozer's work equipment failure and at the same time avoid costly damage and optimize the economic objective.

Keywords: bulldozer, expert system, artificial intelligence, construction equipment, maintenance, software, work equipment failure

1 INTRODUCTION

Over the years, the Expert System ES has become one of the most adopted and convenient resource models to solving immediate engineering problems [1]. An expert system is a computer program that simulates the judgement and behaviour of a human or an organization that has expert knowledge and experiences in a particular field [2]. In view of this, a great deal of research has been focused on the development of an Artificial Intelligence, AI which accepts inputs problems and output solutions from readily available knowledge based databases of different strategic and expert decision and solutions. Expert systems were one of the first applications that emerge from the initial research in AI, and the explanations for expert system reasoning were one of the first applications of natural language generation. This is because the need for explanations is required for the generation of a knowledge-based application (i.e. reasoning) [3].

Swartout et al., [4, 5] proposed the Explainable Expert System (EES) approach and Wick [6] proposed the Reconstructive Explainer (REx) approach. These two separate approaches were proposed to address the problems encountered in reasoning strategies employed by programs which do not form a good basis for understandable explanations. The EES concentrates on an abstract representation of strategic knowledge (i.e. how a particular action of a system is related to the overall goal) and on the representation of design rationale (i. e. why are actions reasonable in view of domain goals?). While the Reconstructive Explainer approach has a representation of domain knowledge and domain rule knowledge, which is completely separated from that used by the expert system itself. This knowledge is used to derive an "explanation path" through the domain knowledge representation [3].

In a general classification, the ES has a wide variety of methods that can be used to simulate its performance. For example, the process to simulate an ES could include:

1. The creation of a knowledge base which uses some knowledge representation structure to capture the knowledge of the Subject Matter Expert (SME).
2. A process of gathering that knowledge from the SME and codifying it accordingly to the structure, which is called knowledge engineering.
3. Once the system is developed, it is placed in the same real world problem solving situation as the human SME; typically as an aid to human workers or as supplement to some information system. Expert system may or not have learning components.

Artificial Intelligence (AI) technology provides proficiencies for the development of computer programs for executing a variety of tasks and at the same time modelling the intelligent way of problem solving by the operator, engineer, medical doctors, etc. Although the areas and methods of applications are different, AI technology provides a set of general philosophical theories to represent the problems and also the techniques for solving them. Based on this characteristic, it is rather very difficult to accurately define the term artificial intelligence [7, 8]. Newell et al., [7] describes the essential activities of AI as follows:

- To flexibly respond to situations
- To redefine ambiguous or contradictory messages
- To recognize the relative importance of different elements of a situation
- To find similarities between situations despite differences that may separate them.
- To draw distinctions between situations despite similarities that may link them.

Simulation of the above planning activities with a computer is difficult. Some of the detailed activities could include planning, designing, diagnosis, classification, monitoring, etc of the sequence of activities in a logic manner. Hence, it is essential to understudy these engineering tasks in order to understand how they can be formally represented and used. Newell and Simon [8] proposed the physical symbol system hypothesis. This gave a fundamental understanding of the AI process. The authors stated that a physical symbol system consists of a set of entities called symbols, which are physical patterns that can occur as components of another type of entity called an expression (or symbol structure. For example a physical symbol system is a machine that produces through time an evolving collection of symbol structures.

Engineering is a collection of a set of intelligent tasks, consisting of different activities such as planning, analyzing, designing, constructing, managing and maintenance. The five different manifestations of intelligence enumerated by Newell et al., [7] can be adopted at different stages of engineering activities or any system in order to solve engineering problems intelligently. Decision making requires the processing of symbolic information in contrast to the conventional data processing. This entails the handling of facts and inferences using domain knowledge. Inference can be deduced through the knowledge base search using the established facts. The intensive research carried out in the area of AI in the last four decades resulted in the emergence of a number of useful techniques which can be used for solving many complex problems [9].

1.1 The Role of Expert Systems in Engineering

Engineering problem solving requires different computational tools. Inferences or deductions from a set of facts, which simulate intelligent decision making, plays a major role in many problem-solving activities [7]. For example, a highly creative decision-making activity is involved during the design stages of products. Creativity implies the ability to produce novel solutions which are better than the previous best alternative. In engineering design, computational tools are adapted to aid designers and present an array of creativity options. Just as creativity is linked to the intelligence and experience of the designer, the computational tools also have intelligence built into them that uses expert knowledge of the problem domain for decision making. Development of comprehensive software solutions in many engineering disciplines requires a seamless integration of different types of computational tools. AI and ES technology along with tools such Genetic Algorithms, GA and Artificial Neural Networks, ANN provide techniques for simulating intelligence in decision making and in the evolution and learning in computers. Also various activities in planning and management can be improved through the use of intelligent tools.

Simple techniques of knowledge-based systems technology such as problem decomposition, knowledge organization in different forms and at different levels and easy control of knowledge processing provide ideal techniques for the smooth integration of different tasks in an application. In addition, the adaptation of problem solving technique to varying environments and requirements can be easily achieved by using techniques provided by AI and ES systems. For example AI and ES technologies provide the much-needed software tools to integrate the various processes to build knowledge-based systems for computer aided engineering. These methodologies and associated tools are required to provide solutions for various tasks and to build integrated systems for computer aided engineering [10].

1.2 Repair Strategies in a Diagnostic Expert System

From the work of Clancey [11] it is recommended that test repair is a straightforward selection tool that can aid a successful diagnostic application in expert system. The author also state that the overview of Troubleshooting Expert System Tool, TEST in the repair strategies included overview of verification, alternative diagnostic and sequencing. Few other researchers agreed with the work of Clancey [11] and they differently concluded that the repair strategy of the Expert System is keyed to a successful and systematic diagnostic flow process and conclusion [12-17]. In a few cases, supplementary repair or treatment modules have been developed to provide customized or special case recommendations [18]. However, apart from the work of Hoffman [17], none of this work has attempted to formulate an approach which permits the degree of integration of diagnosis and repair tasks required to effectively troubleshoot faults in complex machines.

Pepper and Kahn, [19] proposed the Troubleshooting Expert System Tool, TEST, as a diagnostic tool that recognises a large class of integration issues and provides a representation more easily customized to differences in repair strategy, even within the same application domain. TEST is an application shell that provides a domain-independent diagnostic problem solver together with a library of schematic prototypes [18, 20]. Tedesco ([21] reported that the largest application of TEST since 1985 is that of Ford Motor Company's Service Bay Diagnostic System. Other applications include factory floor machine diagnosis, online monitoring of generator equipment, computer performance tuning, PLC controlled manufacturing equipment [22], etc. TEST strategy has also been implemented in Common Lisp using Knowledge Craft [19].

Construction equipment range from the very heavy equipment to the portable and mobile lighter equipment, some of them with a precise description of their fuel functions. A crawler, which is very powerful and attached with a blade, is called a bulldozer. Even though any heavy engineering vehicle is known as bulldozer, it is actually a tractor with a dozer blade in this case. Diagnostic applications remain the most heavily explored area of expert systems technology, but little attention has been given to the selection, sequencing and interactive verification of repairs. These aspects of diagnostic behaviour, collectively referred to in this paper as repair strategy, are critical to the success of a real world machine diagnosis expert system. While it is easy to imagine a prototypical diagnostic system that identifies a single cause for observed symptoms, and recommends the corresponding, inevitably successful repair, this is an ideal but unlikely case. More often, technicians make repairs during the diagnostic process itself, and are prepared to:

(1) Select from among competing repair alternatives.
(2) Delay making certain repairs until deeper causes is identified.
(3) Continue with the diagnosis if the repair does not succeed [8].

1.3 Aim and Objectives

This project aimed to develop and provides principles, technical solutions and guidance for the development of an expert system that could enhance the repair and maintenance of bulldozer's work equipment failure. In order to achieve this, systematic frameworks for the sequential operation were carefully developed as follows:

a) Identify the cause of bulldozer's work equipment failure
b) Proffer solutions to the identified causes of failures in (a).
c) Develop a flow chart (logic chart) for trouble shooting the causes of failure
d) Develop a computer software (expert system) that will perform the role of an expert that will carry out the objectives (a and b)
e) Test and validate the expert system developed.

This is a method in which a computer system will be able to perform the role of experts in the repair and maintenance of bulldozer work equipment. It will also aid construction companies in human capacity management and improve the economic objectives of its operational output.

ISSN 2229-5518

2 RESEARCH METHODOLOGY

2.1 Failure mode algorithm

The bulldozer's work equipment like the hydraulic cylinder pressure, the control valve, the oil pump, safety valve etc. was studied with respect to the lack of sufficient power in work equipment. Each work equipment areas was carefully investigated in order to identify the causes of failure to their respective units and systematically develop an algorithm of solutions to deliver speedy help to the operator and reduce diagnostic time and cost for repairs.

In order to understand and diagnose the failure mode due to the lack of power of the bulldozer work equipment, questions were designed to systematically aid the development of the failure mode algorithm to analyze the failure characteristics and suggest solution parameters. In order to conserve space, a section of the failure mode algorithm is as shown in a flowchart of Figure 1.

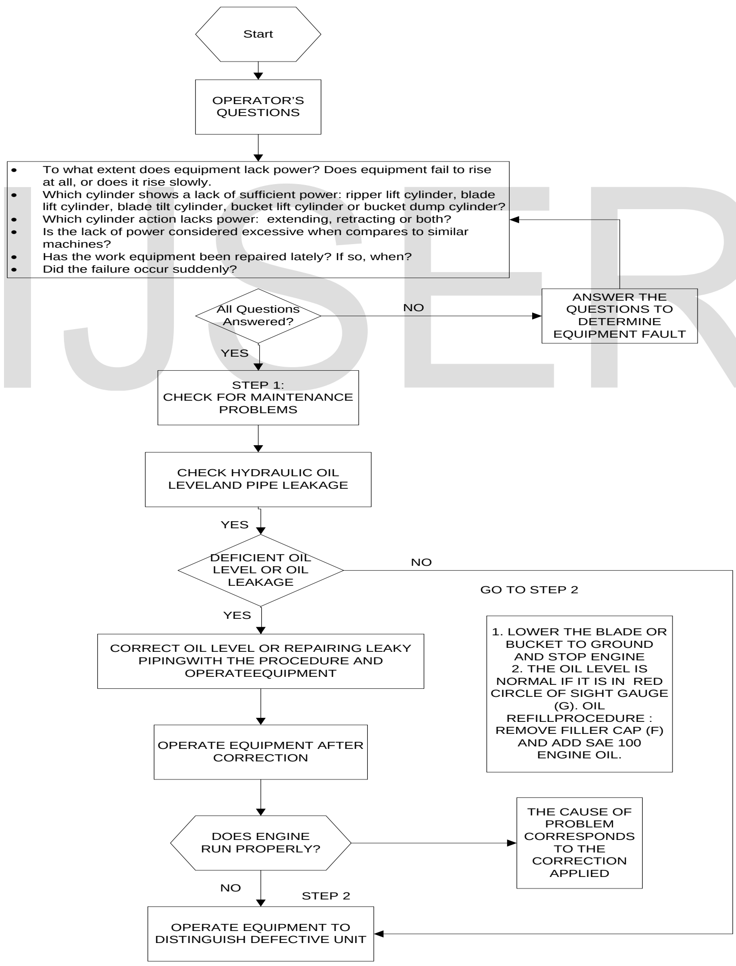

Figure 1: Failure mode algorithm flowchart

The cause of failure in the work equipment can be determined through the answers provided to the sampled questions above. Figure 2 shows the steps and procedures to resolve the problems associated with respect to the questions asked above. Each of these steps deals with each problem systematically, i.e. each step is detailed to solve the above proffered problems from simple maintenance to major repairs. It is advised that each of the outlined steps be carefully followed to avoid creation of more damage to the work equipment.

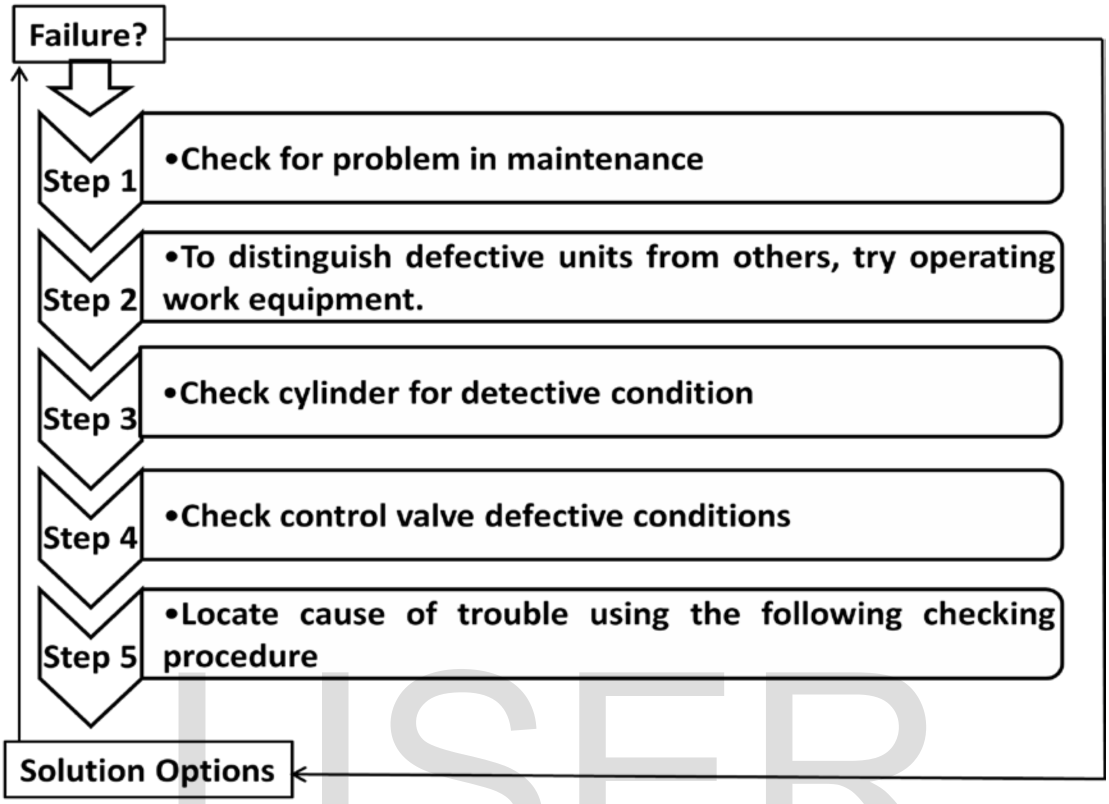

Figure 2: Solutions algorithm development steps

From Figure 2, a flow chart was developed. The flowchart shown in Figure 3 is a systematic ES approach used to diagnose and proffer solutions to the bulldozer work equipment.

2.2 Software Development Tools

For this work, C# computer programming language was adopted. The C# is a multi-paradigm programming language encompassing strong typing, imperative, declarative, functional, generic, object-oriented (class-based), and component-oriented programming disciplines. It was developed by Microsoft within its. NET initiative and later approved as a standard by the European Computer Machinery Association, ECMA-334, [23] and ISO/IEC 23270 [24].

The GUI has the operator's interface at which the operator is expected to answer some questions (see Figure 1) as the diagnostic and failure detection and analysis procedure progresses. The operator is required to define the specific area of failure and especially where failure symptoms are suspected in order for the software (i.e. EI) to analyses the failure and then proffers an appropriate solution to the failure.

2.3 Assumptions for the Software Development

The following assumptions were made during the development of the failure-solution diagnostic algorithm:

1. The structure of the program is strictly derived from experts' knowledge
2. The operator must have a previous knowledge about bulldozer work equipment operations in order to be able to interpret proffered solutions and carry out the suggested repairs.
3. The operator must be computer operation proficient
4. The operator must be able to diagnose which area of the bulldozer work equipment has fault.

3 RESULTS AND DICSUSSION

Figure 3 displays immediately the operator launches the diagnose section of the program which in turn prompts the operator to select the corresponding suspected area(s) of failure(s) that needs to be corrected in the machine which is discussed into five sections. Each section will be addressed according to the necessary steps to be taken by the operator as well as the order in which the program has been designed.

Figure 3: Expert system welcome page

Figure 4 shows the maintenance section of the program which deals with the general maintenance of the work equipment. This page displays immediately the operator has been able to specify to the program the economy status of the equipment with respect to the maintenance section.

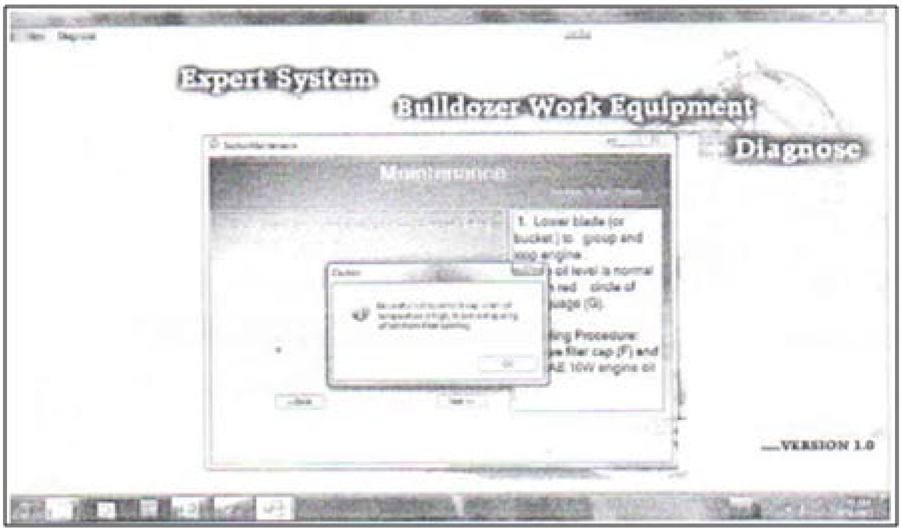

Figure 4: Maintenance section of the Expert System program

Figure 5 is the stage 2 of the program where the operator will be required to specify which of the units present in the work equipment lacks sufficient power. After which the program will take a decision based on the information provided as well as the knowledge database it contains to determine which area of the equipment lacks power and needs attention.

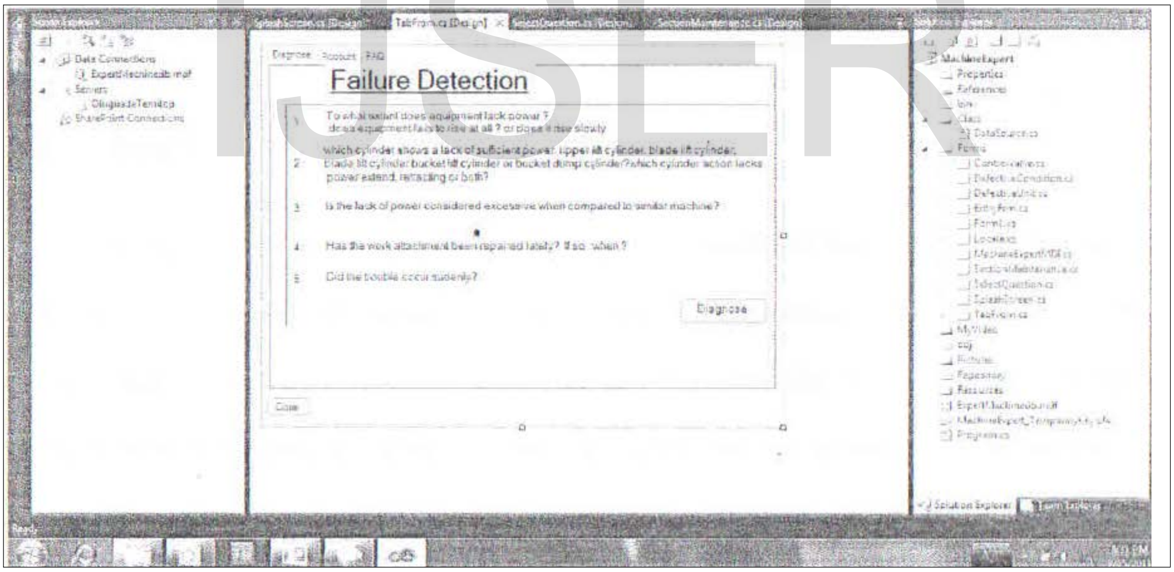

Figure 5: Failure detection page of the Expert System program

Figure 6 shows the page of the defective condition on the work equipment, it gives the details of the each defeat that can found in each cylinder, symptoms and the necessary procedures for repair or replacements. This page pops up in step 3 of the repair procedures.

ISSN 2229-5518

Figure 6: Defective unit section of the Expert system program

This section reveals where problems concerning the several failures in control valves are attended to. The necessary procedures for repair are also highlighted for noise detection, spurting of oil in the hydraulic cylinder. It is required of the operator to follow the highlighted procedures to instruction so as to prevent further damage to the work equipment.

The last section of the programme is shown in Figure 7. This section deals in depth with the location of failures caused by pressure in the hydraulic cylinder. It contains the types of failure in hydraulic cylinders of the work equipment's as well as the corresponding procedures for correction for the equipment. It deals with the status of the work equipment on low hydraulic pressure as well as high hydraulic pressure showing in full details a table that contains the standards of pressure gauges, methods of measuring the hydraulic pressure in the cylinder together with the international standards for pressure in bulldozer work equipment's.

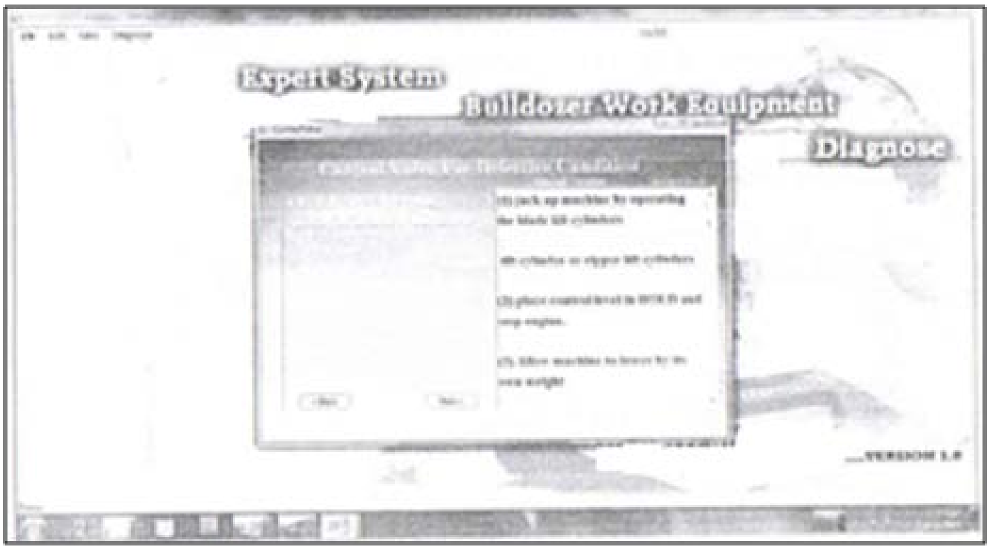

Figure 7: Depth with the location of failures

Typically, expert systems function can be optimized with specification activities or problems and a discrete database of digitized facts, rules, cases and models. As a software program, the expert system integrates a searching and sorting program from the available knowledge database. The specific searching and sorting program for an expert system is known as the interference engine which in turn provides the user/operator with the knowledge based analysis as well as the necessary solution to the specific problem. The systematic processing rules and logic associated with the problem or task at hand are contained in the interference engine. The expert system also has a second component called the knowledge database. The knowledge database stores the necessary factual, procedural and experiential/solution information required for knowledge transfer between the operator and the expert system. For this reason, expert systems are often referred to as knowledge-based information systems.

In order to create the expert databases, it is important to extract information from human expert. This information could be extracted through interviews, observation, and case study and self-reporting choices. As well as using programmatic and physical integration of logic, data and choice expert systems integrate the examination and interpretation of data input with specific rules of behaviour and facts to arrive at a recommended outcome. By widely distributing human expertise through expert systems, business can realize benefits in consistency, accuracy and reliability in problem solving activities.

4 CONCLUSIONS AND RECOMMENDATIONS

Expert systems can reduce production downtime and as a result, increase output and quality. In specific situations, ongoing use of an experts system may be cheaper and more consistent than the services of a human expert. The costs of expert system vary considerably and often include post development costs such as training and maintenance. Prices for the software development itself range from the few thousands of dollars for a very simple system to millions for a major undertaking. For large companies and complex activities, sufficiently powerful computer hardware must be available and frequently programming must be done to integrate the new expert system with existing information systems and process controls.

Expert systems are very useful and highly effective means of solving problems that surface in our everyday life activities. During the use of machines, error and breakdown can be experienced especially because of internal or external failures in the working system of the machine. The failures are time and location dependent of the equipment or machine as at breakdown time (i.e. if the breakdown occurs especially where an expert attention will be required, the machine will be rendered useless and will delay the progress of the expected completion time of the required assignment to be carried out).

The overall data collection and the program development proved difficult but rewarding; these would have been insignificant if available information has been adequate enough to practically solve all the problems concerning the lack of sufficient power in the work equipment and other repair and maintenance (either corrective or preventive) measures. The data collection is particularly important in the analysis of the failure modes. The information concerning abrupt failure during operations are collated from the database in order to determine the rate of failure and predict the expected working life of this equipment.

The method for failure detection in bulldozer's work equipment with different corrective measures can be summarized with following steps:

- Diagnosis of the failure area in the work equipment
- Detecting the specific part(s) that is/are affected
- Analysis of the cause of failure
- Proffered solution(s) to correct the failure
- Application of the solution
- Test running of the work equipment for proper working condition

Obviously knowing the cause of failure of the work equipment enables quick and easy application of the best corrective measure. The effectiveness of the work equipment deteriorates certainly with time, although the time span varies. Although the adoption of the expert system for diagnostics analysis of failure is recommended, however for a more reliable and acceptable system performance, preventive measures should be undertaken rather than corrective measures.

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