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Bi-directional fault analysis of evaporator inspection system

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Abstract

In this paper, we have performed a safety analysis on an automotive evaporator inspection system. We performed the bi-directional analysis on the manufacturing line. Software Fault Tree Analysis (SFTA) as backward analysis and Software Failure Modes, Effects, & Criticality Analysis (SFMECA) as forward analysis are performed alternately to detect potential cause-to-effect relations. The analysis results indicate the possibility of searching and summarizing fault patterns for future reusability.

Key words : Automated Visual Inspection system (AVI), Software Fault Tree Analysis (SFTA), Software Failure Modes, Effects, & Criticality Analysis (SFMECA)

1. INTRODUCTION

For the Computer Integrated Manufacturing System (CIM) to be effective in productivity, related technologies such as manufacturing technology, inspection & control technology and network technology need to be combined in a harmonious way [1,2]. Automated visual inspection (AVI) system, as one of highly technical inspection & control technology, in modern manufacturing fields is complex in its infrastructure and is variable in the user's requirements. It is highly complex since it involves real-time computer vision, structured illumination, manufacturing line control and hardware/software system safety. Also, AVI system will be variable according to the product to manufacture and assembly environments. Manufacturing machines are divided into general-purpose machine and special-purpose machine. General-purpose machines are easily reused in multiple assembly lines, but special-purpose machines are hardly reusable.

Due to the nature of mechanical product assembly lines, safety requirements are needed as mentioned above, and need to be highly followed. Even the most automated mechanical product assembly lines involve human monitoring or intervention, and it is possible that accidents lead to human related loss. Also sometimes the product itself can be highly critical and defect of the product can lead to a catastrophic result.

In this paper, our goals are to analyze AVI system with cutting edge analysis techniques and to detect patterns to reuse from the analysis results. The contribution of the paper is straightforward from the goals. Until now, we are not aware of a bi-directional and commonality analysis application to AVI system product family. Furthermore, we don't find a research material on detecting patterns in safety analysis of AVI system product family. Considering the importance of safety analysis and inspection system in manufacturing industry, this paper can be helpful in the interdisciplinary fields.

In this paper, we have performed a safety analysis on an automotive evaporator inspection system. We performed the bi-directional analysis on each of the manufacturing lines. Software Fault Tree Analysis (SFTA) as backward analysis and Software Failure Modes, Effects, & Criticality Analysis (SFMECA) as forward analysis are performed alternately to detect potential cause-to-effect relations. From the analysis results, we plan to search and summarize patterns for reusability.

This paper is organized as follows. In section two, we will discuss relate works for this paper. It will include SFTA, SFMECA, commonality analysis and patterns. In section three, we will detail the approaches and the methods

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we have taken. In section four, we will discuss the analysis results and detected patterns. In section five, we will describe the conclusion with highlights/limitation of our project.

2. RELATED RESEARCH

A. Automated visual inspection (AVI)

Automated visual inspection is one application of machine vision area. We had implemented three automated visual inspection systems for Daewoo Automotive Component Co. [3] and two for Daewoo Automobile Co. [4]. In the five projects, we used Object Modeling Technique for design and development of AVI systems [5].

B. Fault tree analysis (FTA)

Fault tree analysis was originally developed in 1961 by H. A. Watson to evaluate the Minuteman Launch Control System [6]. Boolean logics are used to break down from the accident as a root node to basic events as leaf nodes. FTA is a top-down and backward search method. FTA was used for analyzing hardware system, but it is used to analyze software system nowadays. In case of SFTA, some quantitative features of FTA are not very useful.

C. Failure Modes and effects analysis (FMEA)

Failure modes and effects analysis was developed by reliability engineers to predict equipment reliability [6]. From the description of design as an input, level of granularity and failure modes are determined, and the effects of each failure mode are analyzed. FMEA is a bottom-up and forward search method. Failure modes, effects, and criticality analysis (FMECA) is FMEA with a more detailed analysis of the criticality of the failure. Software failure modes, effects, and criticality analysis (SFMECA) is a FMECA for software system.

Bi-directional analysis (BDA) is a systematic assessment technique based on inductive (e.g. FMECA) and deductive (e.g. FTA) methodology. BDA has synergy in that it is an adaptation and integration of two successful methodologies, and there’s a research to use the technique for certification of safety critical systems [7].

D. Commonality analysis

Commonality analysis is a process to describe common and variable characteristics of a product family. Directory of terms, commonalities, variabilities and parameters of variability are analyzed from the process. With the result of commonality analysis, an application engineering environment is developed to produce family members as quickly and cheaply as possible [8].

There has been a research on safety analysis of requirements for product family. Checklists and BDA are used for the safety analysis [9]. Another research is to use patterns for reusing variabilities in commonality analysis [8]. Recently, a new kind of top-down, tree-based analysis technique, Fault Contribution Tree Analysis (FCTA), was developed to use SFTA for product family [10].

E. Patterns

In object-oriented fields, patterns are example models that occur frequently in design or analysis. In design, patterns help people understand problem in common ways who don’t have an experience of the project [11]. Design patterns are usually collected by experts who find repeating themes in design. The experts take each theme and describe it so that others can read the pattern and see how to apply it. Similarly, analysis patterns are researched and collected [12]. Therefore, the acquired patterns can be reused in components of design and analysis. Adapter and option design patterns are used in reusing variabilities in commonality analysis [8]. In this report, we followed Ardis’ techniques [8] for AVI system.

3. PROPOSED APPROACH

A. AVI system overview

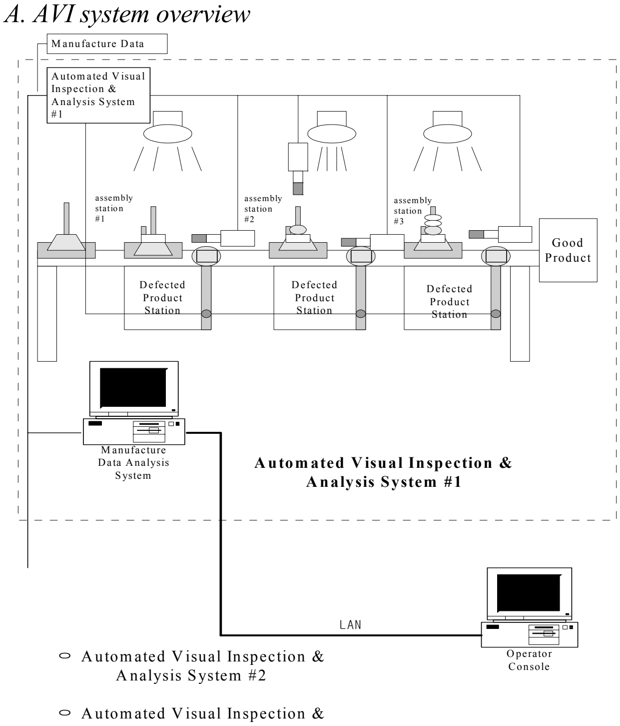
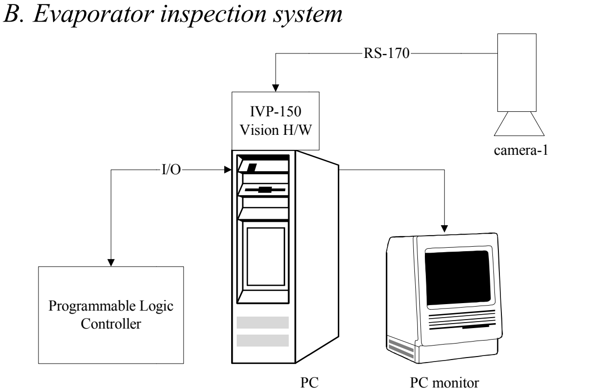


Fig. 1 Architectural diagram of general AVI system

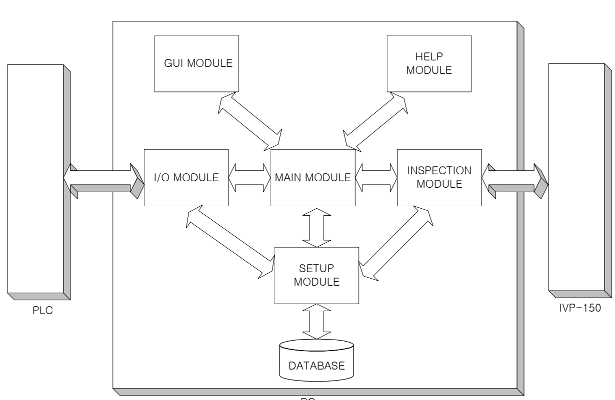
Fig 1 shows the overall architectural diagram of general AVI system. At each station that needs visual inspection, machine vision system with cameras and structured lights is installed. Data analysis system acquires data from each station for quality control of defect rate.

B. Evaporator inspection system



(a) Evaporator inspection system diagram

(b) Evaporator image



(c) Evaporator architectural diagram

Fig. 2 Evaporator inspection system

Fig 2 is about Evaporator inspection system with stacker. Fig 2a shows assembly environment, Fig 2b shows an architectural diagram, and Fig 3c shows a digitized image captured by vision system's camera.

C. Bi-Directional Analysis (BDA)

For bi-directional analysis, we first performed backward analysis and forward analysis. The reason is that we do not gather requirements in the requirement analysis stage. Instead we already implemented systems and try to analyze the system to find reusable patterns.

The analysis steps are shown in fig 3. From given failure list, backward search is performed to find basic events that need to be corrected. Relative inputs for the events are summarized. And the relative inputs are analyzed by forward search technique to find possible cause-failure relations. This process is repeated until there are no observed failures left.

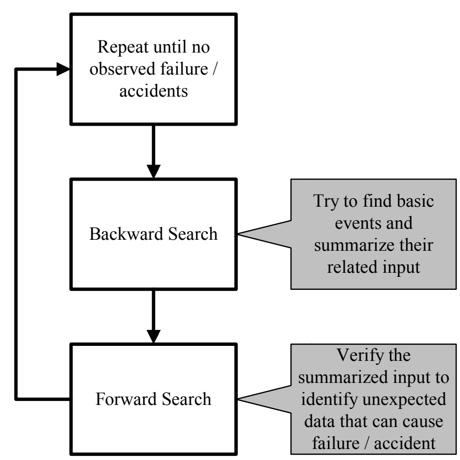


Fig. 3 Bi-Directional Analysis

4. RESULTS

We started from seed accidents. We performed backward search to find input that cause the failure. From the range verification of input, we analyze forward search to find a possible cause-failure relations. Since stacking evaporator is performed by human, some accidents are catastrophic.

The first three seed accidents are positive false by wrong template matching, negative false inspection by electric noise, and pressure of human finger. Positive false is a moderate level of error, negative false is critical level, and human finger pressure is catastrophic level. We built SFTA from the accidents. From the basic events, we summarized the inputs that affect the basic events. Then, we perform SFMECA for the inputs. At first run of SFMECA, we found two new possible failures, which were stacker overloaded and missing evaporator foils.

5. CONCLUSION

The contributions of this research to academia and industry are as follows:

A. Software safety analysis in AVI system

We applied BDA and commonality analysis to AVI system product family. This research improves overall AVI system safety by applying software system safety methodology, and therefore beneficial to automotive manufacturing industry, including CIM environment.

B. Reusable patterns in the software safety analysis

We have tried reusable patterns to model variabilities in AVI System. We have found out the patterns are also useful for AVI product family.

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