

Improved Automated Guided Vehicle System: The Benefit of Smart Diagnostic Tool Compared to Colored Petri Net Method

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Abstract

The objective of this paper is to demonstrate the importance of smart diagnostic tool (SDT) compared to colored petri net (CPN) method to improve automated guided vehicle (AGV) system for the material handling. In modern manufacturing system, the improvement of AGV system usually defines by maximizing the throughput and minimizing the cycle time of a production line without increasing the number of AGV. In this paper, safety and reliability of the AGV system are added factors to the improvement of AGV system. The CPN method works on the basis of a control algorithm, and the method could not diagnose the control algorithms in real operational time. The operation of autonomous vehicle needs robust control in real time operation. The SDT diagnoses the AGV system considering safety and reliability, and it helps to design and adjust various parameters to control the system in the dynamic environment to achieve the production goal continuously.

Keywords

Automated guided vehicle (AGV) system, Smart diagnostic tool (SDT), CPN method, Reliability

1. Introduction

The main goal of any manufacturing/production system is making money by producing non-defective products to meet the market demand. In recent time, it is really important to consider the safety factor in any manufacturing/production system besides money. In modern material handling system, automated guided vehicles (AGV) system is an essential technology to achieve the production goal. An AGV system includes one or more driverless vehicle which can be operated by programmable logic controller, especially for material handling operation in a production system. The programmable logic controller can be modeled using an intelligent method relevant with the production system. The colored petri net (CPN) is an intelligent method for modeling the AGV system. The smart diagnostic tool (SDT) diagnoses the AGV system considering safety and reliability factors in real time operation of a production system which is not possible by the CPN method. The SDT reduces cycle time of a production system by increasing system uptime in more effective way compared to the CPN method.

2. Improved Automated Guided Vehicle System

There are three important measurements in any production system to achieve the main goal, and those measurements are throughput, inventory, and operational expense. Variability, such as cycle time, is the most challenging word in real time production system. In regular basis, the improvement of AGV system defined by the improvement of measurements and variability of the production system. There are some design and control issues in an AGV system like guide-path layout, deadlocks, vehicle routing, etc. (Vis, 2006).

2.1 Comparison of Smart Diagnostic Tool and Colored Petri Net Method

The CPN method develops the model of AGV system considering the design and control issues which can be applied between workstations and AGV. Aized (2009) used advanced tools of CPN method in his research work for modeling and analyzing the real constraints of the AGV system. In his 2009 paper, the flexible guide-path layout helped to detect the redundant AGV, and the numbers of AGV of the system reduced by removing the redundant AGV. “The throughput, cycle time and AGV utilization have shown gradual improvements along with a decrease in the numbers of AGV resources due to the addition of guide-path flexibility” (Aized, 2009, p. 831). In his 2009

paper, the safety and reliability of the AGV system were not be considered to design and analyze the real constraints of the AGV system.

Bostelman and Shackelford (2010) stated that “intelligent systems might do anything from perceiving movement in their vicinity to meeting production goals to protecting nearby humans” (p. 1688). In 2010, Bostelman and Shackelford used safety sensors to confirm the safety purpose of the AGV system. Diagnostics gives diversified benefits such as operation and maintenance (O&M) cost reduction and enhanced reliability of the AGV system. Diagnostics follows some steps to achieve the goal, especially reliability of the AGV system. Initially, it is important to identify the current AGV health status. After that, diagnostics identifies the status of degradation of the AGV, especially the time to complete failure. Bostelman and Shackelford (2010) stated “NIST AGV uses diagnostics to monitor amplifier signal commands combined with wheel encoder signals and then calculate velocities and accelerations to support software gain adjustments and trapezoidal accelerations and decelerations” (p. 1688). The SDT used to diagnose the both control and maintenance of the AGV. Control diagnostics permits the AGV user to adjust the AGV control parameters and to know the vehicle faults. The maintenance diagnostics provides the maintenance schedule of AGV by giving the information of total service time and health status of AGV. Both control and maintenance diagnostics reduce the maintenance time, which minimize the downtime of AGV.

3. Fuzzy System

Fuzzy system deals with linguistic knowledge and imprecise entities of a model in a computer environment. The structure of nonlinear mapping can be provided by fuzzy logic and fuzzy set theory. Fuzzy system (FS) is able to handle uncertainty rather than pure numerical reasoning, and it gives flexibility to the designers. A fuzzy logic system maps crisp inputs (i.e. measurement deltas) to crisp outputs (i.e. damage and damage locations) by using four components, and the components are rules, fuzzifier, inference engine, defuzzifier. The fuzzifier is used for mapping crisp inputs into fuzzy sets. The inference engine determines the procedure to combine fuzzy sets. In order to use the crisp numbers as an output of fuzzy logic system in some applications, defuzzifier is needed to calculate crisp values from fuzzy values.

3.1 Fuzzy Sets

Fuzzy set can be defined on a universe of discourse. It is denoted as function, membership function which can take only two values, zero and unity.

3.2 Linguistic Variables

Linguistic variable characterizes the numerical value which is an element of universe of discourse.

3.3 Membership Functions

Membership functions define fuzzy sets because they are normalized to one so they can take values between 0 and 1. The shapes for membership functions are triangular, trapezoidal, piecewise linear, Gaussian, and these shapes are commonly used by designers. In fuzzy system, membership function can overlap.

3.4 Inference Engine

Inference engine uses fuzzy rules to implement a mapping from the fuzzy sets in the input space to the fuzzy sets in the output space. So, the fuzzy inference engine is decision making logic.

3.5 Knowledge Base

In fuzzy rule based system, the knowledge base is contained of two components named data base, rule base. Data base contains the explanations of the scaling factors and the membership functions of the fuzzy sets by specifying the linguistic variables. A rule base is composed by the collection of fuzzy rules.

3.6 Deficiency in Fuzzy System

There are some deficiencies in fuzzy system like unable to generate best fuzzy rules and to select appropriate number of fuzzy sets.

4. Development of Genetic Fuzzy System

Genetic algorithm works as a learning procedure either for generating best fuzzy rules or for selecting the best set of inputs. The optimization of membership functions and scaling functions can be done by genetic algorithms. Hence, the hybridization between fuzzy system and genetic algorithm leads to genetic fuzzy system.

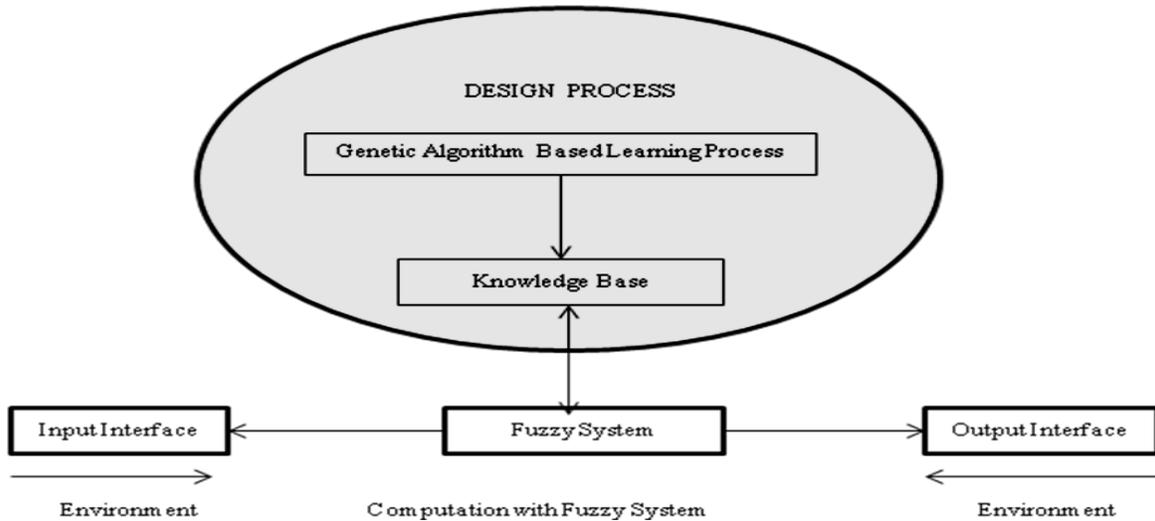


Figure 1: Genetic fuzzy rule-based system

The experiment had been done on health state classification of composite helicopter rotor blades. The possibility of damage in composite rotor blades was either uniform along the whole blade due to the vibrating environment of helicopter or localised due to sudden impact of foreign object or due to irregular loading conditions. The global genetic fuzzy system had been used to detect matrix cracking and debonding/delamination along the whole blade. The local genetic fuzzy system had been used to detect matrix cracking and debonding/delamination in the various parts of blade.

4.1 Global Damage Detection

The global genetic fuzzy system had been used to predict the damage along the whole blade.

Input and Output

The measurement deltas on displacement, force and moment are the inputs of global genetic fuzzy system to detect damage along the whole blade. The damage levels in the matrix cracking and debonding/delamination are the outputs of global genetic fuzzy system. The output had been classified in 12 categories.

Fuzzification

The crisp numbers in this fuzzy system were matrix crack densities for matrix cracking and the effective strain ratios (ESR) for debonding/delamination. These two damage types had been divided into linguistic variables. Displacement measurement deltas were considered for defining the rules, and the force and moment measurement deltas were considered for damage prediction. The measurement deltas were considered as fuzzy variables. These input variables were defined by the fuzzy sets with Gaussian membership functions. The noise model can be expressed as

$$x = m + u\alpha$$

Here, x is noisy measurement delta (normalized), m is midpoint (normalized), u is linguistic variable, and α denotes as a noise level parameter which defines the maximum variance between the computed value of m and simulated measured value of x .

Rules Generation

An aeroelastic analysis of the composite helicopter blade in forward flight had provided numerical values, and the fuzzy system rules had been obtained by fuzzification of these numerical values. The degree of membership in

the fuzzy set had been calculated for each measurement delta to a given damage level. The damage level with the highest degree of membership had been considered as most expected damage level.

Tuning of the Rules

The fuzzy system had been tuned with noisy measurement deltas due to vibrating environment of helicopter. The success rate can be expressed as the ratio of total number of classifications to the number of correct classifications.

The genetic algorithm had been used to calculate standard deviation of the Gaussian membership functions for optimization of success rate.

4.2 Local Damage Detection

The local genetic fuzzy system had been used to predict the damage in various parts of the blade.

Input and Output

The measurement deltas on strain at five locations of blade are the inputs of local genetic fuzzy system to detect damage. The damage levels and locations are the outputs of local genetic fuzzy system. The output had been classified in 8 categories.

Fuzzification

The crisp numbers in this fuzzy system were matrix crack densities and the effective strain ratios (ESR) at a given location. The five locations were tip, outboard, center, inboard, and root. Tip ranges from 0% to 20% of the blade from the free end, outboard from 20% to 40%, center from 40% to 60%, inboard from 60% to 80%, root from 80% to 100%.

There were several level of damages at each damage location and spilt into linguistic variables. The fuzzy logic rules were defined on the shear strains which had been obtained for a few main matrix crack densities and effective strain ratios. Strain based measurement deltas were considered as input fuzzy variables which defined by the fuzzy sets with Gaussian membership functions.

Rules Generation

The total number of thirty six fuzzy rules had been used to represent the complete matrix crack and debonding/delamination detection system. It had been done by representing one “undamaged” level of damage by one rule and seven damage levels at five locations by five rules each.

5. Conclusion and Future Research

The SDT reduces cycle time of a production system by increasing AGV system up-time. The SDT also provides the safety of the AGV user, and it is an important factor for any industry. The CPN method is useful for improving throughput and reducing cycle time when all the vehicles are in action. It is really important to diagnose the AGV system to know the reliability or probability of failure of the system, and CPN method is unable to diagnose the system.

The future research on human-machine interface in the AGV system is really important because human can make error in modeling of any system which leads to the failure of the AGV system.

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