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Modelling and Simulation of AGVs Using Petri Nets

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Introduction

It is a technologically anticipated development that robotics in our age will become widespread and find common application areas in almost all sectors such as defense, transportation, health, service and manufacturing. This process is still expanding and the role of robots in everyday life as well as in industrial applications is increasing. One of the important applications of robotic systems in manufacturing environments is automated guided vehicles (AGVs). AGVs are autonomous systems controlled by a central control unit, operate autonomously without the need for an operator, and are used for transporting materials from one point to another [1-3]. An AGV reduces the number of occupational accidents that occur due to human beings because it fulfills all kinds of transportation operations without human interference in departments such as production, logistics, warehouse and distribution. These systems, which are used to transport all kinds of goods in industrial environments, are one of the most suitable systems to reduce costs and increase productivity. The AGVs can see the obstacles in their way due to the highest level of security measures used and sensors, slow down and stay at a safe distance. So, they can work safely in the same environment with people. Because of all these features and modularity, AGVs are frequently used in modern and flexible manufacturing systems today.

AGVs carrying products/parts/materials between workstations are controlled by their own (embedded) computers/processors and they are connected to the central computer. The design and operation of AGVs, which are quite complex and expensive systems, are of great importance for achieving high performance in their use. AGVs, which are finding increasingly more application areas and capable of carrying tasks at different scales in various environments, are today's one of the major mobile robotic systems. For this reason, modeling and simulation of behavior of AGVs in working environments is of great importance and one of the most powerful tools for behavioral modeling of AGVs is Petri nets. Petri net is a bi-partite mathematical and graphical formalism consisting of place, transitions and arc as main constructs. Generally, places represent resources, transitions transformations and tokens holding of conditions, but any concept can be assigned to constructs depending upon modelling approach. Petri net can be used to model discrete event dynamical systems (DEDS) [4-8]. Petri net has the capability to model and analyze a discrete event dynamical system (DEDS) and an AGV embedded in a flexible manufacturing system is a good candidate to qualify for implementation of Petri net method. This paper summarizes two research studies for modelling, simulation and analysis of AGV behaviors using Petri nets. One of them is a Petri net model for the intended behavior of a demonstrative AGV for transferring packs between stations in a pre-defined manufacturing environment. The second is a Coloured Petri net model of a loop layout automated guided vehicle system embedded in an automated manufacturing system.

Petri Net Based Behavioural Simulation of a Pick Packing AGV

Petri net is used in our behavioural modelling and simulation study for a demonstrative pick packing AGV as an implementation of systematic behaviour-based design approach [9]. The AGV is considered as required to transfer some packs between four stations in a pre-defined environment. A Petri Net model for the intended behaviour with three pre-specified missions is developed based on rough conceptual structuring of the AGV. Model development and simulation has been done successfully using Artifex ™ modelling and simulation environment [10,11].

The general design requirement in the present case study is considered as the conceptualization of an AGV model to transfer some packs between finite number of stations and therefore, the required system is called as a "pick packing AGV". The operational behaviour of the pick packing AGV is based on a scenario and it is described as follows: The AGV will be able to travel in a predefined physical environment between a "Start Point" and four stations, and to transfer some packs between these stations. The AGV is expected to accomplish predefined missions without any external interference. A Petri Net model used to represent and simulate the intended behaviour of the pick packing AGV. The model is developed using ArtifexTM Graphical Modelling and Simulation Environment which a C-based development platform for discrete event simulation. Figure 1 shows the Top-Level Behavioural Model of the AGV in the ArtifexTM environment. The Top-Level Behavioural Model consists of six objects, namely units, which are Power Source and Processor Units, Right and Left Wheel Units, Robot Arm Unit and Gripper Unit. All units are connected to each other by interconnecting links that models the communication between these units. Petri Net structure of each unit is embedded in the top-level model.

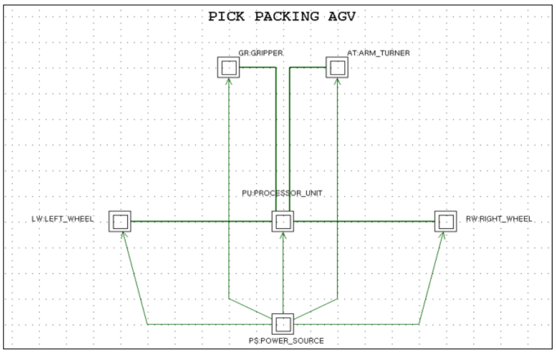

Figure 1: Top Level Behavioural Model in ArtifexTM Environment [10].

Modelling and Analysis of AGV for an Automated Manufacturing System using Coloured Petri Nets

A loop layout automated guided vehicle system embedded in an automated manufacturing system has been modelled and analyzed by applying colored Petri net method. This study focused at developing of automated guided vehicle system for serving a flexible manufacturing system comprising of six workstations arranged in a loop layout. AGVs are serving workstations moving sequentially in a loop layout. AGVS has been modelled and analyzed using Petri net method, specifically using color Petri net class implemented by CPN Tools. Modelling and analysis have been extended in this study by developing a lab scale prototype of an AGV which has been experimentally tested and verified in an automated manufacturing system. Simulation experiment results have been validated by developing and employing an AGV prototype inside an automated manufacturing system. The results show that an increase in number of AGVs in an automated manufacturing system increases system throughput whereas an increase in AGV speed, for a fixed number of AGVs in the system, is causing a decrease in throughput. The approach developed in this study can be employed to different system configurations to determine system performance.

Conclusion

As AGV systems find more application areas in industry, their modelling and simulation becomes more significant for industrial system design. Petri net tools are practical and highly useful tools to study and develop model design before expensive implementation. It is highly versatile at moderate sophistication and reasonably reliable output. A physical prototyping after modelling and simulation would be highly useful to foresee any probable problem location within the system before full scale testing. It is also a highly efficient approach for educational purposes at graduate levels.

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