Real Time Embedded Systems for Automatic Cruise Control in vehicles using Multi core processors

Anuj R Chadha

Electronics and Communication Engineering, Institute of Diploma Studies, Nirma University
Ahmedabad, Gujarat, India
anujc.88@gmail.com

***Abstract*— This paper is on the utilization of multi core processors in embedded systems for Automatic cruise control in vehicles for rapid, reliable and safe transport within specified area. Driverless vehicle designing and implementation is much complex task for which processor having single core cannot be relied upon. This paper also includes case study of an Automated Guided Vehicles (AGVs) with powerful multi-core processors. This paper discusses the software architecture for efficient risk estimation and decision making algorithms in AGVs, too. In this paper, I have adopted DSP TMS320DM642 as an image processor and ARM cortex A9 as controller. The embedded RTOS i.e. BIOS is transplanted on DSP to construct a software development platform for tasks management, which enhance reliability and real-time response of system.**

***Keywords*— Industrial computers; MIPS; Thumb instruction set; Ball grid array; VLIW; Pre-emptive scheduling**

I. Introduction

Automated guided vehicles (AGV) help in cost reduction and efficiency improvements in manufacturing plants. They have complex embedded systems inside to perform some specific tasks like Engine control system, fuel injection system, Obstruction alert, Vicinity alert, automatic navigation and digital read-outs. Processors having single core are not enough to perform such large number of tasks. In vehicle embedded system is a complex distributed system which is a cooperative work and requires compatibility and coordination between the products from different manufacturers. Automated guided vehicles are similar to automated line following mobile robots used to carry loads or for transportation in near by distance i.e. within a plant itself. For this task, AGV have to use sensors like Electro-magnetic, Optical or Vision sensors [4]. Compared to others, vision sensors using camera are the most reliable and accurate method of navigation [3]. Most of the existent AGVs were equipped with industrial computers (PLCs) as the main controllers having high costs. However, with the development of chip industry, more and more efficient microcontrollers and DSP can replace industrial computers, and help in reducing the cost of AGVs [4, 5]. Working algorithm for automatic navigation must be more efficient for real-time system. The I/O signals of DSP must be compatible to the I/O signals of micro-controller and vice versa. In recent years, the enhancement of embedded systems computation power, interrupt handling capability and high MIPS (million instructions per second) can meet system requirement. Two CCD cameras are fixed on vehicle to capture the scene of lane. One, on the front of vehicle, is used for prediction, the other, at the center of vehicle, is used for accurate positioning. An example of the in AGV embedded system using DSP TMS320DM64x and dual core ARM cortex A9 processor is demonstrated. TMS320DM64x family is powerful Digital Signal Processor (DSP) for audio/video or image processing and ARM cortex A9 is a microcontroller particularly suitable for industrial control which has dual core. Autonomous navigation requires many tasks like proper lane identification, self positioning, self balancing while changing direction and speed control of vehicles. Out of which, lane detection and self positioning are complex and many algorithms have been proposed for efficient implementation of above mentioned tasks.

II. Various issues in Automated Guided Vehicles and role of embedded systems

A. *Positioning and awareness about self location*

AGVs should be aware about their current position inside the specified area. It can be done by measuring its distance and angle of position from some specified remote controlling area. The knowledge of self location helps AGVs in the determination of starting point and to calculate the distance between starting point and destination.

B. *Self Balancing*

AGVs need to balance themselves while changing directions by keeping speed under control. For this proper feedback control algorithms should be implemented.

C. *Obstruction Monitoring*

Obstruction in the progressing path of AGVs can cause collisions. To protect our vehicles from such collisions, continuous obstruction monitoring should be done. For this, we can use Vision sensors, Infra-Red sensors or RFID mechanism. In this paper, I have proposed a model having two cameras having charged coupled devices, one on the front side and the other at the centre for proper positioning. If we use camera for image capturing, CPU have to perform image processing algorithms, which require digital signal processor. Obstruction monitoring is the most critical task, which involves cooperation and coordination between DSP and multi-core CPU.

D. Decision Making

The primary function of AGV is to make quick and real time decision based on the output of sensors. Decision making task require calculation of distance covered, for changing the direction, to acknowledge the people around it by siren or indicating Lamps. This task requires complex interrupt handling algorithms and interrupt latencies must be as small as possible.

E. Path Finding

Mostly, AGVs are line following vehicles, where more than one path from source to destination can be possible. In such cases, AGVs should be able to detect the smallest and/or collision free path [3].

F. Speed

The speed is an important concern for any vehicle. For flexible manufacturing system (FMS), AGV is one of the most essential parts. By using embedded systems having multi-core and powerful processors, we can increase the speed and hence design time or manufacturing time can be significantly reduced.

III. Embedded System Hardware in Automated Guided Vehicles

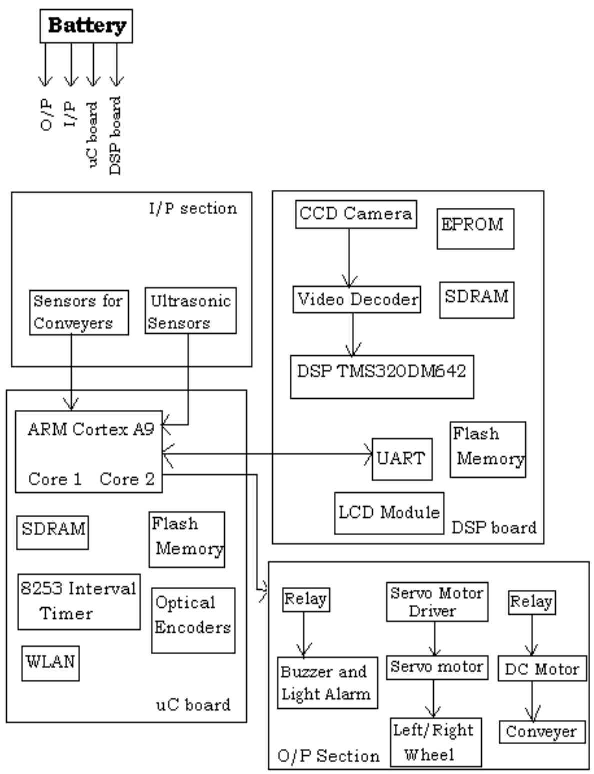

Fig.1 Embedded System Architecture of AGV

Embedded system in AGVs has modular architecture. A strong architecture along with robust construction and efficient algorithms are necessary for accurate AGVs [7]. Self control vehicles ranging from simple line following robots to highly complex vehicle with multiple vision sensors are characterised by their architecture which is shown in Figure 1. Battery supplies power to the Input, Output, Controller and DSP section via DC to DC converter for regulated supply.

1 The guideline on the ground 3 Two path errors
2 The PAL analog video signal 4 Speed diff of two wheels

Fig.2 The transmission process of visual guideline information

A. Input Section

I/P section consist of ultrasonic sensor and weight or touch sensor for conveyors whose output is fed to Controller section.

B. Micro-Processor Section

The applications where interrupt handling and continuous obstruction monitoring both are to be done simultaneously require complex and quick decision making process. For this, dual/multi core processors can give the best results. Multi-core processors enable parallel computing and offers very high throughput. ARM Cortex A9 having dual core, high performance and low power consumption processor is the most suitable controller for such applications. ARM Cortex A9 is 32-bit microcontroller for industrial control. It is based on TDMI 32 bit CPU with emulation and embedded trace support. Unlike other predecessor, ARM Cortex A9 has Harvard architecture. It has various on chip peripherals like timers, 8-channel 10 bit ADC, PWM channels and more than 9 external interrupt pins [10]. Controller section also consists of in-built wireless module for communication between vehicle and its remote control. This controller provides the use of Thumb instruction set by using which, we can increase the code density by 60 %. By using Thumb instruction set, 65 % memory is utilized for storage of the similar program by using normal 32-bit instructions. For the efficient usage of resources of CPU, Schedulers in today's operating systems have the primary goal of keeping all cores busy executing some run-able thread. [4]

C. DSP Section

DSP section consists of CCD camera unit for capturing the images of obstruction or of the external environment for self positioning. The images captured by CCD cameras are fed to video decoder and further they are given to DSP module. The TMS320DM642 DSP with 548-pin Ball Grid Array (BGA) package, developed by Texas Instruments (TI), is an excellent fixed-point DSP for image processing application [8]. The DSP is based on the second generation high-performance, advanced very-long instruction-word (VLIW) architecture. With performance of up to 5760 million instructions per second (MIPS) at a clock rate of 720 MHz, The DM642 DSP possesses the operational flexibility of high-speed controller and the numerical capability of array processor which is widely used for image processing algorithms [11]. Moreover, additional on-chip peripheral set may include configurable video ports, a management data input/output (MDIO) module, an inter-integrated circuit (I^2C) Bus module, 32-bit general-purpose timers, a user-configurable 16-bit or 32-bit host-port interface (HPI16/HPI32) and a 16-pin general-purpose input/output port (GPIO) with programmable interrupt/event generation modes. It also consists of UART which is Universal Asynchronous Receiver Transmitter for communication and cooperation with ARM processor. TFT (Thin Film Transistor) LCD module is also available at the DSP section. Flash memory is used for data storage. EPROM is used to store the program code. Flash memory is used to retain some images as reference.

D. Output Section

Output section consists of the relays for buzzer or light alarms. Servo motors are utilized to rotate both right/left wheels. DC motors are used to control the motion of conveyor belt [9]. Separate servo motors are preferable for left and right wheels.

III. Software Development In Automated Guided Vehicles

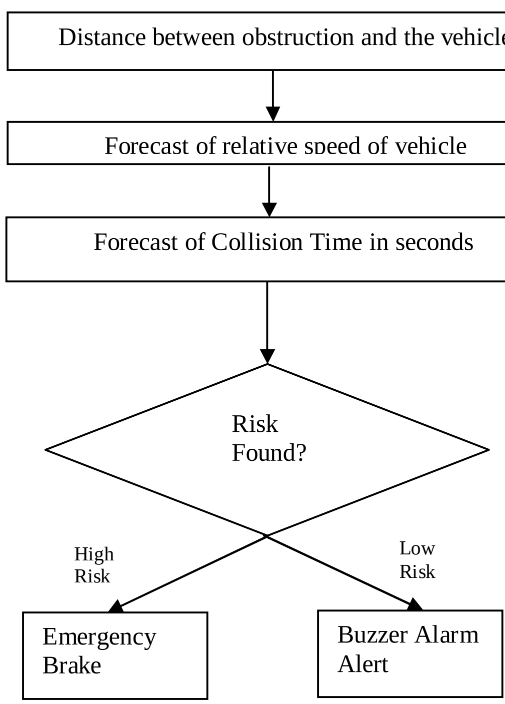

Fig.2 Flow chart of functioning of AGV

The RTOS for such AGVs must be preemptive. Low priority tasks should release the resources for high priority tasks. Continuous monitoring by the vision sensors keep checking of the obstructions and distance between vehicle and obstruction. The software should also be designed to forecast the time of collision and relative speed of vehicle. If any risk is found while moving AGV, the corrective action is taken according to the gravity of risk. If risk is high i.e. sudden obstruction, emergency brakes are used to stop the vehicle. If risk is low, then some form of buzzer alarm or light indication alarms are used as indicators for immediate corrective action. DSP/BIOS is a scalable real-time kernel. It is designed for applications that require real-time scheduling and synchronization, host-to-target communication, or real time instrumentation. Moreover, DSP/BIOS provides preemptive multi-threading, hardware abstraction, real time analysis, and configuration tools [6]. DSP/BIOS provide several types of program threads with different priorities. Each thread type has different execution and preemption characteristics. The thread types (from highest to lowest priority) are: Hardware interrupts (HWI), that are triggered in response to external asynchronous hardware events in order to perform a critical task that is subject to a hard deadline; Software interrupts (SWI), that triggered by calling SWI functions from the program; Tasks (TSK), that can be suspended during execution until necessary resources are available; Background thread (IDL), that executes the idle loop (IDL) at the lowest priority. DSP/BIOS modules have completed their initialization procedures; the main routine is called, by which hardware interrupts are initialized. After that BIOS_start is called after the return from main routine, which is responsible for enabling the DSP/BIOS modules and invoking the MOD_startup macro for each DSP/BIOS. At last, the task scheduler runs TSK_idle which calls IDL_loop. High performance algorithms are designed to accurately detect the artificial guide line. Image captured by camera I is processed using median filters that particularly effective in the presence of impulse noise. Segmenting, edge detecting algorithms and the method of least square can be used to calculate equation of path line. Then the vision system is used to calculate relative distance and slope of guide line [7]. Image captured by camera II can be used to predict lane information of the future moment. Especially when AGV running speed exceed 1.5m/s. horizontal and vertical direction Hough transform is used to predict straight and turning way. The algorithms should be effective and robust when illumination condition changes.

IV. Conclusion and Future Developments

In vehicle embedded systems have to be hard real time and the interrupt latency time should be very low i.e. in the range of µsec. The movement of AGV in the predefined area should be reliable and care should be taken to prevent it from accidents which may cause damage to industrial environment. Automatic ranging system of vehicles with risk estimation and decision making can be used for various vehicles. This model is limited for the use in a small, pre-defined area and in many cases pre-defined routes, too. By adding some more sensors and using complex algorithms, we can design vehicles which do not need drivers when driving conditions are better and driver can easily take over the control when driving conditions become adverse. By using multi-core CPUs, Automated guided vehicles can be developed for the use in the area where environment is not suitable for human beings i.e. the land rovers for vehicles to study the atmosphere of other planets. AGVs can also be used at the war-fronts. Automated guided vehicles designed and manufactured by using multi-core processors will significantly reduce the time of transportation of raw materials inside the manufacturing unit and reduce the and it's a better option as compared to conveyer belt.

V. REFERENCES

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