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Intelligent Automated Guided Vehicle using Visual Servoing

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I. INTRODUCTION

Automated guided vehicles (AGV) are playing an important role from the small-scale industry to the large-scale industry for handling of materials from one place to another inside the shop floor. In recent days, materials to be handled are more in numbers as the production and demand is increasing vigorously. The material transportation is desperately in need of a vehicle to circulate the materials inside the industry. Guided vehicles are generally installed with wires inside the ground at the space of 3cm and radio signals are transmitted through it to control the AGV. And it gradually decreased the work load of the human and increased the production efficiency. Thus, the need of an AGV has become more important to this technologically advanced robotic world. Normally, these systems are integrated into an overall production system, where there is a need to make direct changes in conception and planning of the shop floor to get the most out of them. But in the fast-changing production system and the adaptive shop floor, implementation of the AGV became very difficult, because it dependent on many systems such as wires, frequency, overall production, etc. Hence, a necessity arises to develop an independent AGV which can work of its own and make decision based on the changes in the surrounding environments. In this research, an intelligent AGV to navigate in desired path by Visual Servoing has been developed and tested.

II. LITERATURE SURVEY

Thefirst AGV was invented by Barrett Electronics in 1953. The Automatic guided vehicles have played a part in moving material andproduct for more than 50 years. Suman Kumar Das et al, proposed the recent technological developments in AGV's and described a formulation to control the traffic inside industrial workspace [1]. Suhlab Kumra et al, presented a navigation system for Omni-directional AGV's with Mecanum wheel and verified the accuracies to be 27.4944mm and 29.2521mm of the localization respectively [2]. Kwather Osman et al, developed a novel lane reference calculation approach in order to define a safe and optimal trajectory to be tracked by a road vehicle and validated the results through numerical simulation [3]. Rundong Yan et al, Investigated the reliability issues related to AGV's through fault tree analysis and mission reliability through petri net method, with the results the service capability and the potential profits of the AGV's are analysed [4]. Dimitrios Bechtsis et al, provided a critical taxonomy of key decisions for facilitating the adoption of AGV systems into SC design and planning and also Sustainable Supply Chain Cube (S2C2), a conceptual tool that integrates sustainable SC management with the proposed hierarchical decision-making framework for AGVs [5]. Shaoping Lu et al, proffered a radio frequency identification (RFID)-enabled positioning system in AGV for smart factory Based on the examinations, simulation studies and a testbed are carried out to evaluate the feasibility and practicality of the proposed approach, it is observed that large diameter antennas are used in driving zone and small diameter antennas are used in parking zone. This approach was compared with another method using passive RFID tags and it is superior to that method with greatly reduced tags' deployment [6]. Shahin Gelareh et al, contrived an AGV with the ability of pairing/unpairing enabling a pair of 1-TEU (20-foot Equivalent Unit) IAVs dynamically to join, transport containers of any size between 1-TEU and 1-FFE (40-foot Equivalent) and disjoin again [7]. Jeisung Lee et al, published a research on AGV's equipped with and efficient vehicle guiding method using a consumer grade web camera and fiduciary markers in which Four directional signals and 10 alphabet features are defined and used as markers, hence, a 98.87% recognition rate was achieved in the testing phase [8]. Angéla Rinkács et al, surveyed the formation possibilities of agent based structures in the simulation of an example material flow systems for AGV's, and also listed the models of making these adaptive, which makes them capable of continuously modify their features to the modelled physical system [9]. Mahdi Hamzheei et al, used the shortest path design problem (SPDP) on bidirectional path topology as one of the best-known types of network configurations for automated guided vehicles, also utilized an ant colony system (ACS) algorithm for better optimization [10]. JiLiang Luo et al, submitted an AGV system model as a control hardware PN (Petri-Net), and formulated a design using PN supervisor (the closed-loop PN) for collision prevention [11]. Zoran Miljkovic et al, presented a AGV with the main control algorithm consisting of two independent control loops: position-based control (PBC) for global navigation and image based visual servoing (IBVS) for fine motions needed for accurate steering towards loading/unloading point and the results provide the effectiveness of the proposed hybrid control approach [12]. Priyam Anil kumar Parikh et al, suggested an AGV using concepts of electric drives, Electro Pneumatics, machine vision, microcontroller (Arduino) and ZigBee wireless module, MATLAB GUI for human interface [13]. Philippe Lacomme et al, introduced a framework based on a disjunctive graph to model the joint scheduling problem and on a memetic algorithm for machines and AGVs scheduling to minimize time span [14]. Hamed Fazlollahtabar et al, discussed different methodologies related to optimizing AGV systems for the two significant problems of scheduling and routing at manufacturing, distribution, transhipment and transportation systems [15]. Shivani Godha, propounded an algorithm that detects all obstacles on road using a single onboard camera which is mounted on a travelled vehicle in real-time for driver assistance, and the given results are satisfactory [16]. Maminul Islam et al discussed the Accident Sensing, Indication and Safety with Alert system, and presented a system that can detect other life forms in the way, and can generate alarms in case of any calamities [17]. Surendra Pal Singh et al, reconstructed a 3D scene from video camera for virtual 3D modelling, to explore the potential of normal digital video camera for virtual 3D City modelling [18]. Nawaf Hazim Barnouti et al, improved the face recognition rate using different image processing techniques, thorugh which the system achieved the best recognition rate of 97.5% when tested using 9 training images and 1 testing image [19]. Justice Kwame Appati et al, studied the face feature extraction implementing Radon transform, and displayed that, the transformed face signatures are robust and invariant to the different pose [20].

III. VISUAL SERVOING AND IMAGE PROCESSING

Visual servoing has been studied in various forms for more than three decades starting from simple pick–and–place tasks to today's real-time, advanced manipulation of objects. In terms of manipulation, one of the main motivations for incorporating vision in the control loop was the demand for increased flexibility of robotic systems. Image based visual servo control utilizes image features derived from image plane and servo controls them to a desired goal configuration. Clearly the visual data is important input in this type of task. Hence, great deal of intelligence is required for the controller to use the data during navigation and collision avoidance. The purpose of the vision system is to direct the actions of the robot based on its visual input. Servoing consists primarily two techniques one involves using information from the image to directly control the degrees of freedom (DOF) of the robot, thus referred to as Image Based Visual Servoing (IBVS). While the other involves the geometric interpretation of the information extracted from the camera, such as estimating the pose of the target and parameters of the camera.

Image processing is fundamentally computer imaging where application involves a human being in the visual loop. In other words, the image is to be examined and an acted upon by people. The major topics within the field of image processing include:

Image restoration is the process of taking an image with some known or estimated degradation and restoring it to its original appearance. Image restoration is often employed in the field of photography or publishing. A camera is an optical instrument that records images that can be stored directly. These images may be still photographs or moving images such as videos or movies. In this research, the videos is captured and converted to bitmap format for ease of processing. The image obtained in the camera mainly depends on the surrounding light. Lighting includes both the use of artificial light sources like monochrome lamps and light fixtures, as well as natural illumination by capturing daylight.

Image enhancement involves taking an image and improving it visually. Enhancement methods tend to be problem specific. For example, a method that is used to enhance satellite images may not be suitable for enhancing medical images. Enhancement methods use knowledge of the human visual systems responses to improve an image visually.

Image compression involves reducing the massive amount of data needed to represent an image. This is achieved by eliminating data that are visually unnecessary and by taking advantage of the redundancy that is inherent in most images. All the image processing is done through the Matlab software. The sample image processed by the matlab is shown in the Fig 1.

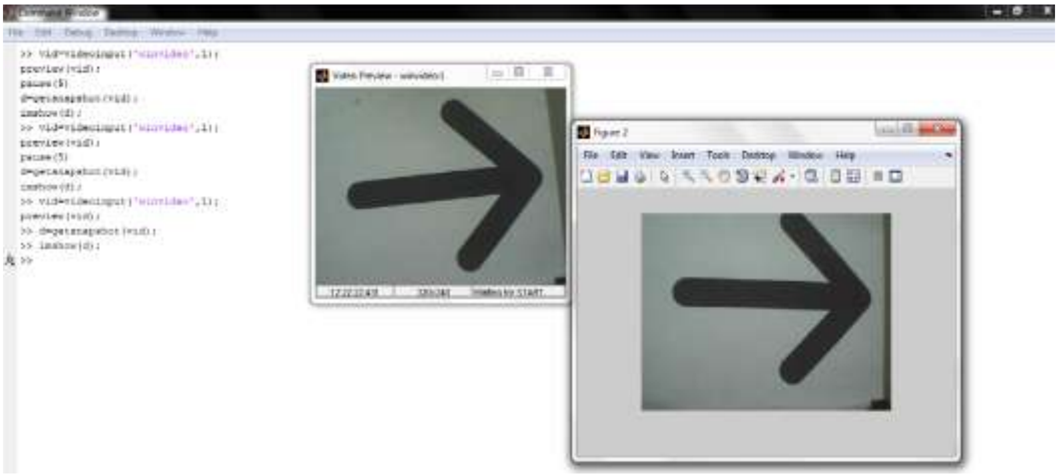

Figure 1. Image Capturing and Processing in Matlab

IV. INTELLIGENT AUTOMATED GUIDED VEHICLE

Generally, the AGV's are having four wheels but in this research, the concept of three wheelers has been applied, as four-wheelers are having more rolling resistance when comparison with three-wheeler. Steering response is 33% more responsive than a four-wheeler with respect to yaw axis. Tadpole configuration has more stability compared to a delta configuration. Unparalleled performance is offered by the three-wheeler compared to four-wheeler at an affordable cost. So, a tadpole type AGV had been designed and analyzed for the load carrying capacity in the FEA software. The stress distribution and the deflection obtained from the Solidworks workbench are shown in the Fig 2 and Fig 3.

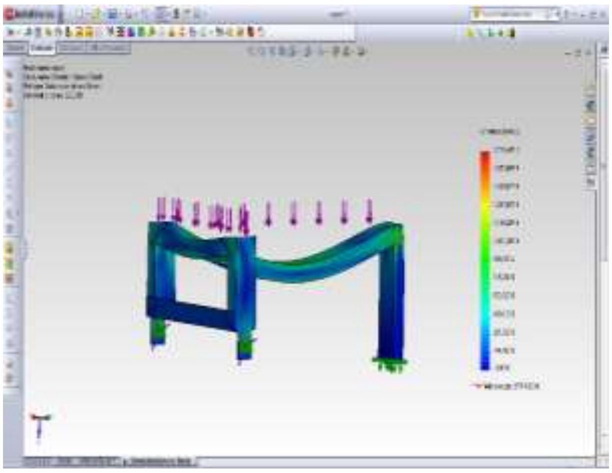

Figure 2: Stress Distribution

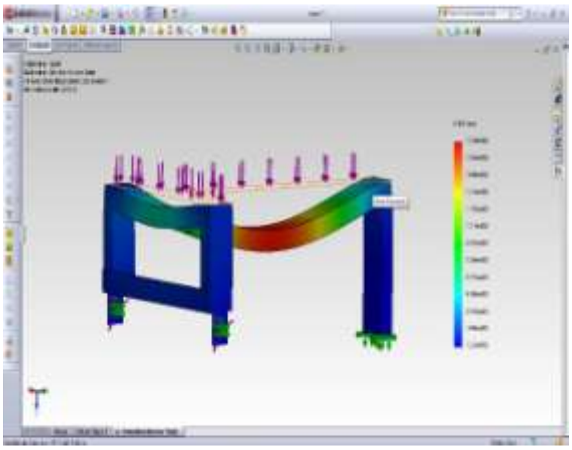

Figure 3: Displacement

In order to provide the intelligence to the AGV, a set of 500 images of the shop floor were stored in the database. Then the expert system has been developed for most of the situation in the shop floor and the solution methodology i.e. the decision for the movement of the AVG. The entire expert system module is developed based on the survey carried out in the machine shop floor where the batch type production was carried out. The expert system program is executed using Arduino microcontroller, intended to make the application of interactive objects or environments more accessible. The hardware consists of 32-bit Atmel ARM. As, Arduino's microcontroller is pre-programmed with a boot loader that simplifies uploading of programs to the on-chip flash memory, compared with other devices that typically need an external programmer. This helps in utilizing an Arduino more straightforward by allowing the use of an ordinary computer as the encoder.

The output from the controller is given to the motor controller, which stabilizes the voltage supplied to the motor. The high-power motor driver is a compact MOSFET motor driver. Ideal for use with heavy duty motors like wiper, power window motors and more. This analog switch works with a four-terminal simple MOSFET of either P or N type. The motor provided is High torque DC motors of 100 rpm and 25kg-cm torque carrying capacity.

V. ANALYSIS

The Von Mises yield criterion suggests that the yielding of materials begins when the second deviatoric stress invariant reaches a critical value. For this reason, it is sometimes called the plasticity or flow theory. The von Mises stress satisfies the property that two stress states with equal distortion energy have equal von Mises stress. The Von Mises stress for the IAGV is 1715387.3 N-m^2 and its yield strength is 27574200 N-m^2, which found to be under safe limit. The above analysis for the IAGV shows its displacement during its pay load. Deflection is the degree to which a structural element is displaced under a load. The maximum deflection is 1.739 *e^{-2}mm and the minimum deflection is 1.000*e^{-3} mm. Again, the deflection is under safe limit.

VI. EXPERIMENTAL IMPLEMENTATION

Initially the images of the shop floor and the control images are stored in the database. Some of the control images to control the AGV are given in the Fig 4.

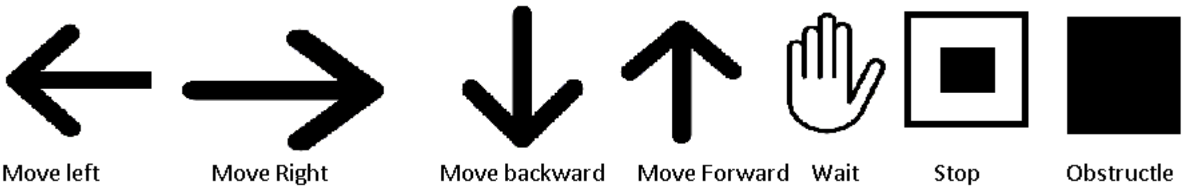

Figure 4: Sample Control images of AGV

Similarly, 100 images of the shop floor have been stored in the database. When the AGV starts for operation, the camera in the AGV captures the surrounding environment and the video is converted in to bitmap file format in the frequency of a image, per 5 seconds. The frequency can be varied based on AGV speed. Once the bitmap image is obtained, the header information is read for the processing. In bitmap file format, the actual image data starts from 54^{th} byte and the image is in inverted format. So, the image has been pre-processed. Further the image needs to be filtered for the noise and unwanted surrounding environment. The filtered image is converted to the monochrome image for fast computation. Because the entire processes have to be completed within 5 seconds, else the AGV will wait for further user decision for movement. Thus, the converted monochrome image has further compressed in size without any data loss to the size of 21x9 for easy computation. The processed image having only the details of the control commends. And the information obtained by interpreting the image is given to the controller.

The inputs to the controller are then interpreted to control command, IR sensor signal, ultrasonic sensor signal and the radio frequency remote signal from the user remote control. The output from the controller are the buzzer, left side motor (LSM), right side motor (RSM) and to the display. For example, if the control command is left direction sign, then the controller sends the high signal to the RSM and low signal to LSM for 3 secs continuously, then high signal for both LSM and RSM for 2 secs continuously, then low signal for both LSM and RSM. In mean time the controller checks for the input signal for further movement. The movement and the decision taken by the expert system are displayed for operator understanding. The AGV having 16 IR sensors to detect the nearby obstacles and human beings. Also 8 ultrasonic sensors used to identify the distance of the next object. Thus, the AGV can move in any environment based on the control signals. The control signals can often be changed if the layout modified and the same AGV can manipulated as such for any type of shop floor without any pre-request arrangements.

VII. CONCLUSION

In this research work, IAGV has been designed and fabricated which uses the concept of machine vision. These AGV can detect the direction signs present in the path and changes it direction accordingly. The AGV needs no further guidance systems to be installed, so any change to the layout can be accommodated. The developed AGV uses the image processing technique and the structure that has been analysed for load carrying capacity depicts satisfactory results. The wheels are designed as a tripod arrangement for faster turning and to minimize frictional energy loss. The obstacle avoidance system makes the AGV safer in the work environment. By the robot is also furnished with a module to sense the charge level of the battery and if it goes down to the certain level, the robot itself, the robot itself should self-navigate to charging station and charges by itself. Consequently, the developed IAGV can be the best alternative for material handling in the industrial environments.

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