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Recent Trends in Robotics and Computer Integrated Manufacturing: An Overview

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ABSTRACT:

The economy of a country is highly dependent on the manufacturing industry, which can make the country self- sufficient. Today, the capability of producing high quality products with shorter delivery times and the ability to produce according to the diverse customer requirements have become the characteristics expected of all manufacturing industries. The inclusion of robots in manufacturing has led to an exponential rise in the production capacity of any industry. Robotics and computer integrated manufacturing (CIM) technology is necessary to overcome the above issues and retain the revenue of a country in the highly competitive global market. This paper focuses on the recent advancements in robotics and computer integrated manufacturing.

Keywords: Robotics, Computer Integrated Manufacturing.

1. Introduction

From the 16th century, there has been a great revolution in the manufacturing industry. The quality, product design, innovation and delivery services are the primary expectations of the world .To achieve these requirements, manufacturing companies are compelled to seek advanced technologies. This led to the evolution of computer integrated manufacturing (CIM) in the early 1970s. The concept of CIM was initially coined by Dr. Joseph Harrington in 1973 in the book `Computer Integrated manufacturing'. CIM promotes a fundamental strategy of integrating manufacturing facilities and systems in an enterprise through computers and its peripherals. For the CIM to be successful, the integration of advanced manufacturing technologies (AMTs) should be achieved [10]. The development of fully autonomous systems appeared only in the second half of the 20th century. The first digitally operated and programmable robot, the Unimate, was installed in 1961 to lift hot pieces of metal from a die casting

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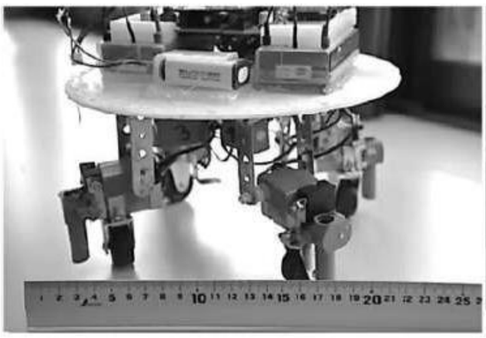
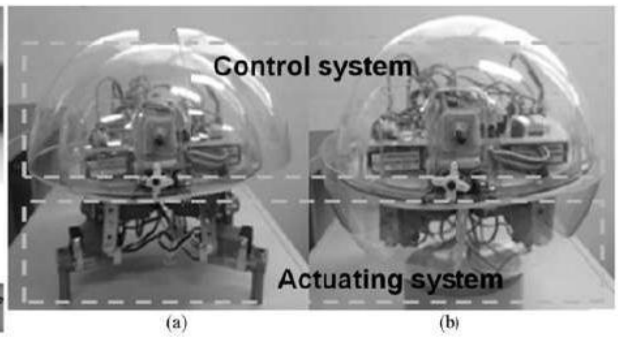
machine and stack them. Today, robots are used widely to perform jobs more cheaply, more accurately and more reliably, than humans. Robots are widely used in manufacturing, assembly, packing and packaging activities etc. In recent years much progress has been achieved in the field of robotics and computer integrated manufacturing, which are presented in this paper.

2. A roller-skating/walking mode-based amphibious robot.

An amphibious spherical robot capable of motion on both land and water was designed by Maoxun Li et al. to perform complicated underwater operations. The robot has three operating modes: water-jet propulsion mode, quadruped walking mode and roller skating mode as can be seen in Fig.1 and Fig.2 (Courtesy of Maoxun Li et al.). The robot moves on slopes or relatively smooth terrains with the help of passive wheels which provide the roller skating motion. The braking state is achieved with the help of a spring which is controlled by a servomotor on each leg (which compresses and releases the spring) which is represented in Fig.3 (Courtesy of Maoxun Li et al.). A closed loop control method by carrying a gyroscopic sensor to measure the yaw angle was implemented to improve the walking stability of the robot in the longitudinal direction. At low frequencies, the sliding velocity and walking velocity on the flat terrain were roughly equal. At a control frequency of 5.56 Hz, a maximum roller-skating velocity of 37.8cm/s was achieved and the robot was able to move down a slope with an incline of 10° with roller-skating gait. When moving down a slope, the roller skating gait is preferred than the modified walking for better mobile velocity and efficiency. The gait stability, velocity and directional control of the robots are studied on smooth terrains. [1]





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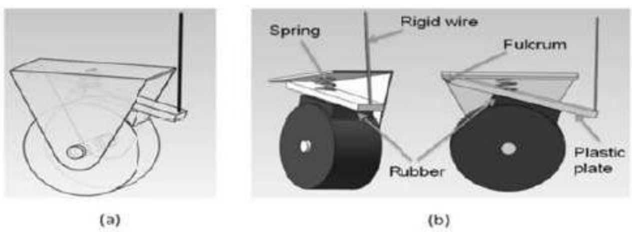

Fig.3 Breaking mechanism of the wheel.

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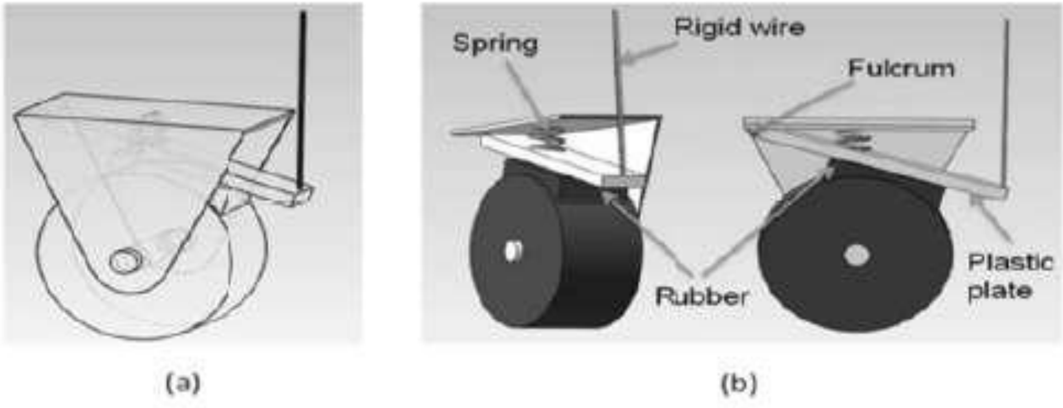

Fig.3 Breaking mechanism of the wheel.

3. A dynamic holding system for thin metal plate shearing machines.

A specific problem which occurs when cutting sheets with smaller thickness than 3 mm and length higher than 700 mm is the warpage in the latter cut sheet portion induced by the weight of the sheet already cut, which results in high bending stresses and poor quality of the product at the small area that is not yet cut. Analyzing the process, it was observed that some tools, when coupled to the equipment, should substantially increase the cutting process productivity and the final product quality. L.M.B. Araújo et al. developed a new tool shown in Fig.3 to avoid the lack of plate flatness after the plate was cut. Even though the existing solutions minimize the damage caused by the problem, the problem can be totally eliminated by the integration of a dynamic holder during the cutting process which is automatic.

The integration of the device does not need any changes in the machine and it is very easy to maintain. The holding platform was maintained at four positions: upper position, intermediate position, discharge position and rest position (for sheets having thickness more than 5mm). During the intermediate position, the holding platform is slightly lowered by bringing the cylinders holding the platform towards middle.

Three holding systems (conventional cylinders, servo-pneumatic cylinders and mixed versions) were tested at different inclination speeds by programming the control unit. The best solution was achieved using four servo-pneumatic cylinders, which allow a complete and coordinated movement of the holding system by adequate electronic control of the same. A central guiding system is provided below the holding platform. The position was adjusted using a control unit with the help of feedback-position signal. [2]

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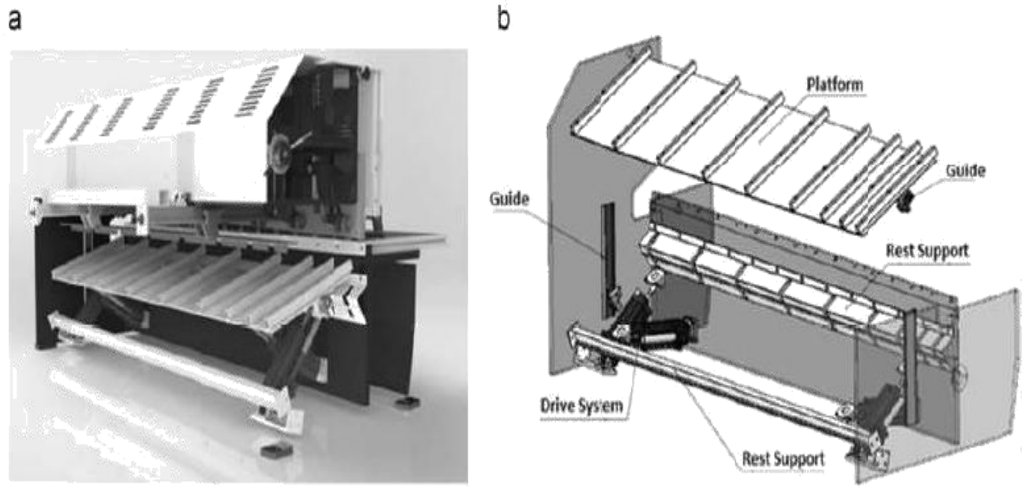

Fig.4 (a) Isometric view and (b) exploded view of preliminary holder version (Courtesy of L.M.B. Araújo et al.)

4. Multi-robot spot-welding cells for car-body assembly.

This technology uses coordinated robots to assemble metal panels with the help of spot welding. The implementation of the technology requires both cell design and motion planning. The cell design and motion planning are urrently managed by different and separate industrial functional units.

As this approach consumes a lot of time, a unified approach was developed by Stefania Pellegrinelli et al. which aimed at optimizing the holistic cell design and motion planning, reducing design time and errors. The approach was tested in both ad-hoc and industrial cases (provided by the Italian company COMAU S.p.

A.). Further,this method can be computerized, to accelerate the welding process and to reduce human efforts. The approach consists of four stages: Single robot off-line motion planning, off-line collision check of two robot paths, multi-robot cell design and off-line motion planning, and motion plan validation.

The proposed approach was implemented in a C++ software tool structured in 12 libraries. Some of them are: RAPID - decomposition of the environment in oriented bounding boxes (OBBs) and collision detection, OpenGL – graphical interface, ORL – trajectory planner for COMAU robots, Cplex – resolution of the mathematical model, BzzMath mathematical library. The motion plan is based on the Open Robot Realistic Library that catches the real robot behavior during trajectory generation.

OBB hierarchical decomposition was employed for collision checking. The welding methodology was provided as a solution for about 20 points only and is currently able to manage only one robot per cell. [3]

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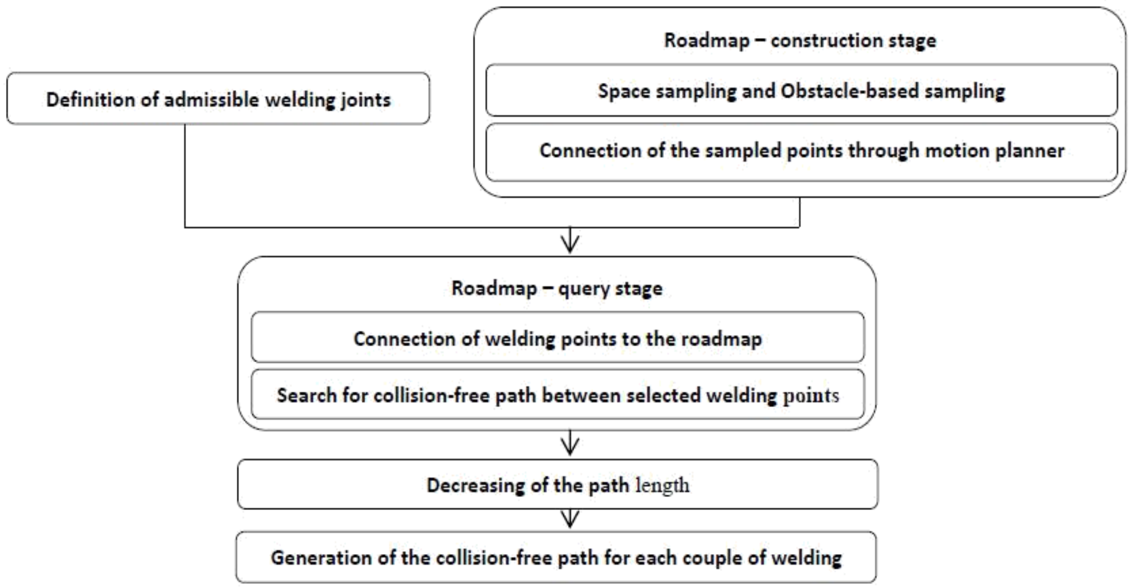

Fig.5 Approach Schema

5. Adaptive back stepping control for an n-degree of freedom robotic manipulator.

The adaptive back stepping control was designed by N. Nikdel et al. to improve the tracking performance and system stability of a robotic manipulator in the presence of non-linearity and parametric uncertainties. In contrast to the conventional adaptive certainty-equivalence design strategies, adaptive back stepping is a powerful approach to enhance the efficiency of the controlled system by decreasing the tracking error as well as control effort. To accomplish this, the system response overshoot and steady state error must be decreased and the tracking speed must be increased.

In this paper, the tracking error equations and dynamic equations for an n-DOF manipulator are formulated and response characteristics are improved by augmenting a new state to the system equations. The controller design steps and the stability are analyzed. The stability of the closed-loop system was achieved based on the Lyapunov theory via back stepping control approach. A variety of step, random and sinusoidal signals were considered as the desired reference commands and the controller succeeds in providing good tracking performance.

To solve the parametric uncertainties, an adaption law is proposed via adaptive back stepping mechanism. To study the effectiveness of the approach, experiments were carried out for a 2-DOF control and compared with the existing control methods. The state-augmented back stepping control method was found to be efficient in tracking the desired joint angles. This method was also simulated for a large industrial Scara manipulator. [4]

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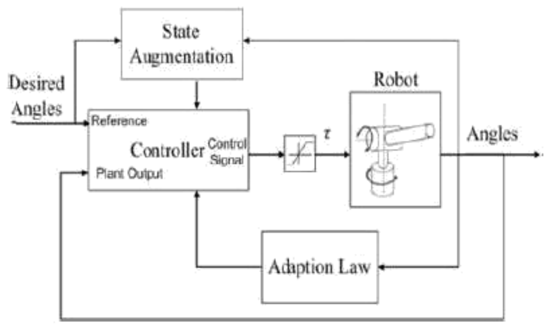

Fig.6 Block diagram of the state augmented adaptive back stepping controller (Courtesy of N. Nikdel et al.)

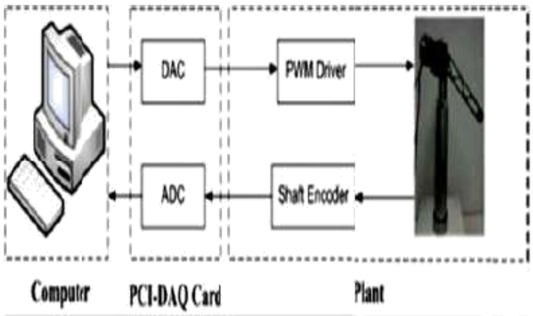

Fig.7 Schematic of the experimental setup (Courtesy of N. Nikdel et al.)

6. Control architectre of a Stacker crane based on an innovative wire-driven robot.

Automated Storage/Retrieval Systems (AS/RS) are computer controlled material handling systems which are usually based on Cartesian Storage/Retrieval Manipulators (SRM). A wire-driven SRM which was proposed by Bashir Salah et al. is intrinsically lightweight, thereby reducing energy consumption, allowing faster movements, and improving dynamic performance. In this paper, the design and simulation based evaluation of a stacker crane based on an innovative wire-driven SRM as seen in Fig.8 (Courtesy of Bashir Salah et al.) was performed which adopt flexible cables instead of rigid limbs. The control architecture was designed for handling mini-load operations. The incoming orders are sorted into four lists: dual command list, storage command list, retreival command list and expected command list. The equations that determine the single and dual command cycle times for the wire-driven SRM are developed in case of random and class-based storage policies. The suggested control architecture is validated for product, process and system design and configuration using a simulation software and is compared with an equivalent Cartesian SRM. Results show that the new wire-driven SRM design have less travel cycle times and more suitable for applications involving greater heights. [5]

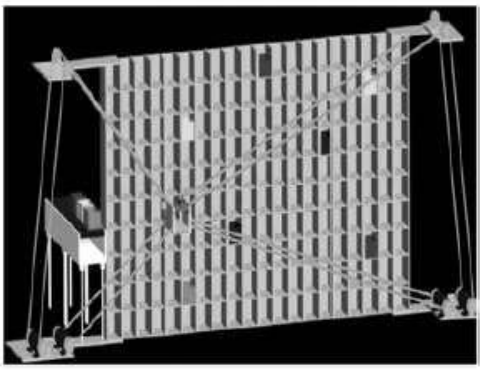

Fig.8 Basic design of a wire driven SRM

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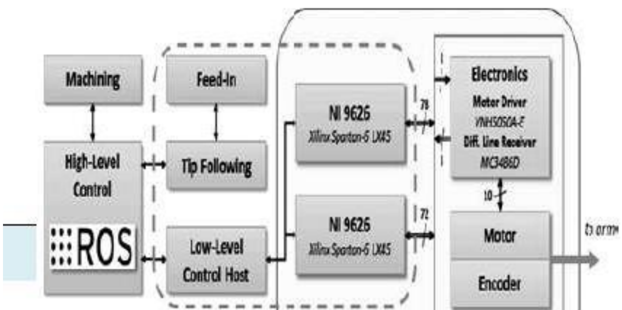
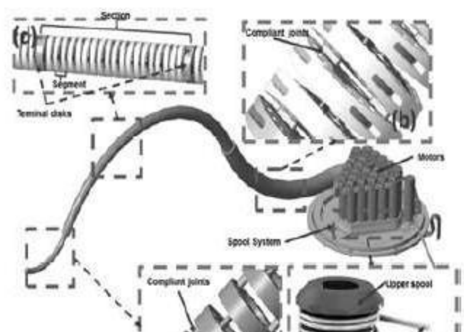
7. A slender continuum robotic system for on-wing inspection/repair of gas turbine engines.

The aerospace industry demands quick and cost effective maintenance works of aero-engines while they are still attached to the air frames by accessing from its front (i.e. fan section), thereby creating the need for navigation and multi-axial movements in a very constrained environment. This paper submitted by X. Dong et al. discusses the development of a highly flexible slender continuum robot of 25 degrees of freedom capable to uncoil from a drum to provide the feeding motion needed to navigate into crammed environments and then perform, with its last6 DOF, complex trajectories with a camera equipped machining end-effector for allowing in-situ interventions at a low pressure compressor of a gas turbine engine. As shown in Fig.10 (Courtesy of X. Dong et al.), this system has twin commanding cables to minimize the number of actuators and twin compliant joint to enable large bending angles (790o) arranged on a tapered structure (starting from 40 mm to13 mm at its end). Five control algorithms to enable the navigation and end-effector path generation have been implemented to achieve in-situ maintenance tasks. The low level control (LLC) of the continuum robot is based on two real time embedded targets (sbRIO9626) from National Instruments both running as slaves to a host operating on a computer connected over Ethernet (Fig.9). The boards each have a Field Programmable Gate Array (FPGA) Xilinx Spartan-6 LX45 capable of supporting the basic position control loops required to run each motor simultaneously.

The actuation pack consists of the following elements: base plate, motor pack assembly and cable guide, electrical and electronic command system, and an outer casing to assist in the coiling motion. The robot was tested against a specific target within a gas- turbine engine and it was concluded that the maximum deviations in navigation from the desired path (1000 mm length with bends between 45° and 90°) was 710mm and the maximum errors in positioning the end- effect or against a target situatedattheendofnavigationpathis1mm. This technology provides the aero engine manufacturers with a solution to perform complex tasks in an invasive manner. [6]





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8. An on-line shape-matching weld seam tracking system.

Automatic welding mainly includes the autonomous guidance of initial welding position, welding seam tracking, optimization of welding parameters during the welding process, and automatic localization of the finish point of the weld seam. A non-line laser-based machine vision system for seam tracking was presented by Yaoyu Ding et al. to reduce noise and achieve better tracking accuracy. The laser-based machine vision system includes three major modules: a laser-based vision sensor module, an image-processing module, and a multi-axis positioning module which are shown in Fig.11 (Courtesy of Yaoyu Ding et al.). The vision sensor was designed and calibrated based on the principle of laser triangulation. A shape-matching algorithm was implemented to achieve accurate seam tracking process to adapt to different groove-types and also automatically localize the starting and finishing point of the weld seam. Tests were performed on U-groove, tap-groove and free form groove to verify the algorithm's adaptability to different groove types and its ability to resist noise on the weld groove. A FIFO (first-in-first-out) principle based queue was defined and implemented to tackle the lag distance problem between the heat source and the vision sensor. The tracking algorithm, along with the FIFO queue was verified on a sine-shaped seam. A tracking accuracy of 70.5 mm was achieved in this test, which is acceptable in most of the arc welding applications. [7]

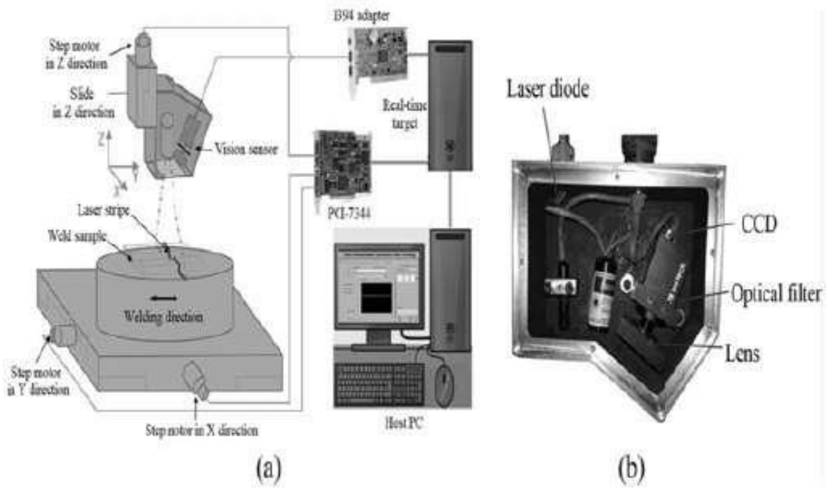

Fig.11 (a) Real-time laser-based machine vision system, (b) laser-based vision sensor

9. Development of a fiber optical occlusion based non-contact automatic tool setter for a micro milling machine.

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Micro-mechanical machining with miniature machine tool is an emerging technology, which offers many advantages such as significantly reduced cost, space, and energy consumption. Due to the small size of the tool used in the micro-machining operations, tool setting is one of the most challenging and time-consuming tasks. The accuracy of tool setting has a direct impact on the outcome of machining.

A low cost non-contact automated tool setter was devised by Xinyu Liu and Weihang Zhu to reduce the overall tool setup time for a micro milling machine. The automated tool setter was designed to address the tool setting in the Z-axis which accounted for majority of the total tool setting time. A fiber optic FSV30M sensor from Keyence that is equipped with a light emitting element and receiving sensor was used. The position of the micro-tool is detected by measuring the light intensity change as the tool crosses the emitted light beam. The analog measurement of the light intensity in voltage was gathered by the machine controller (DeltaTau Turbo PMAC2) through an A/D converter. The smallest detectable object is 5 mm, which is sufficient for micro-tool detection (5–500 mm). The optic cable was mounted on the workpiece palette with the help of a bracket. A detection algorithm was developed and implemented in the CNC machine controller. The influence of noise was minimized through averaging and by using a sample range based outlier discriminator. The system achieved 0.6 mm repeatability and 2 mm accuracy across different sizes of micro tools. The execution of each tool setting takes about 10 seconds, which is 80–90% reduction from the manual tool setting time. The performance of the system could be improved by using a band pass digital filter to clean up the noise in the signal. [8]

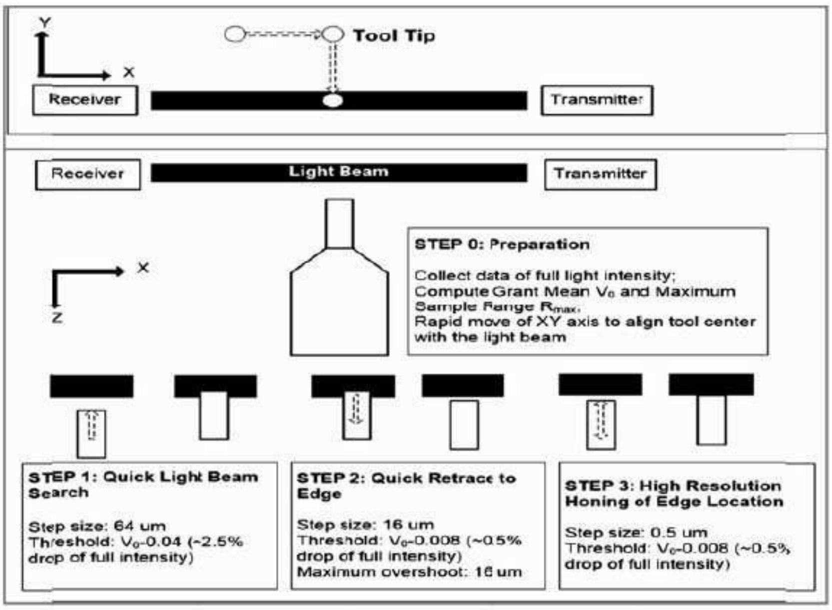

Fig.12 Flow chart of the edge search/detection algorithm (Courtesy ofXinyu Liu and Weihang Zhu)

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10. Development of metrology.

A novel cloud-based multi-tenant model creation service for automatic virtual Virtual metrology allows the production quality of a workpiece to be known just after processing of the workpiece is completed, without physically measuring them. AVM (Automatic Virtual Metrology) is the highest-level technology for VM (Virtual Metrology) applications from the perspective of automation. In this paper, the problem of how to systematically and effectively overcome MC-related limitations of the existing AVM system is tackled so that it can robustly support multiple users across factories to create their VM models simultaneously in distributed manufacturing settings. A private cloud was built by Min-Hsiung Hung et al. in the e-Manufacturing Research Center of the National Cheng Kung University, Taiwan, using VM ware software and then deployed in all servers of the cloud-based AVM system. The architecture of the private cloud-based AVM system is described in Fig.13 (Courtesy of Min-Hsiung Hung et al.). This technology was developed using many cloud computing and IT technologies such as such as virtualization software, XML, Web Service, Multi-tenancy technique, and HTML 5.An active-push mechanism based on WCF (Windows Communication Foundation) Call back technology is developed to serve as the communication mechanism among components of the CMMCS for allowing the server to timely and actively push results to the client. The new AVM technology was tested by creating VM models using the CMMCS (Cloud-based Multi-tenant Model Creation System) for CNC machine tools in machining wheel rims of automobiles in a factory in Taiwan which demonstrated that the CMMCS can allow multiple users from different tenants to simultaneously create their VM models, while enabling the MC cloud services to be more robust for processing MC requests, having higher CPU-usage rates in the underlying virtual machines, and achieving better cross platform usage, compared to the original MC functionality.[9]

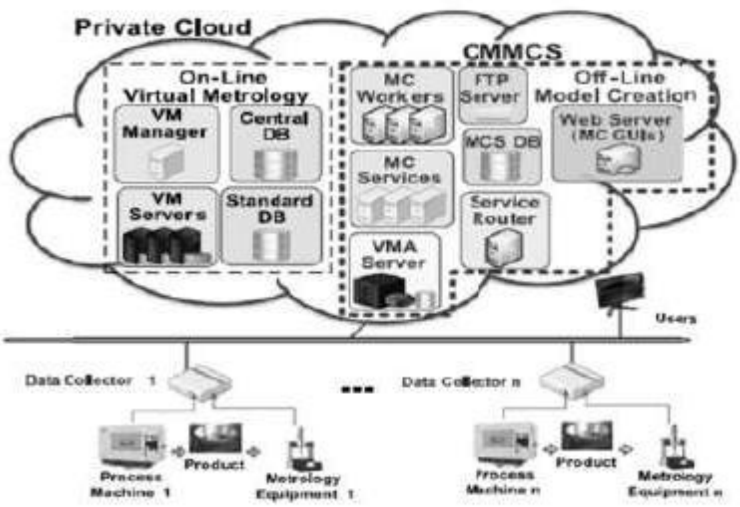

Fig.13 Architecture of the private cloud-based AVM system.

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11. Conclusion

The increasing needs of the world in terms of both quantity and quality can be meted out only by employing robots and computer integrated manufacturing. Over these years, much development has been achieved in the field of robotics and automation systems, which has also caused an equivalent growth in the manufacturing industry sector. In addition, much progress needs to be done to minimize errors and to handle complex maintenance operations.

The manufacturing sector which is heavily relied upon by many developing nations needs to be further developed to satisfy the ambitions of the industrialists and to promote the interests of the governments.

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