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Research paper



Open Architecture Control for CNC System – An Approach

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Abstract

The Open Architecture concept is gaining more attention because of growing demand from end users. Numerical Control systems are limited in terms of portability because they are dependent on vendor-specific environment, to overcome this limitation Open Architecture Control was introduced. Open Architecture improves portability, interoperability, scalability and ability to reconfigure of an existing CNC machine. Open control system increases the flexibility of CNC machine by allowing vendor-neutral environment. Open Architecture Controller allows the end user to modify the existing system by integrating components from different manufacturers which reduce cost as well as increase extendibility of the system. In this review paper, different initiatives and developments on Open Architecture Controller are presented. This paper also covers the approaches made by researchers in the field of simulation of table movement in CNC machine.

Keywords: *CNC; Open Architecture Control; MATLAB/SIMULINK.*

1. Introduction

The Computer Numerical Control (CNC) machine plays a very important role in the development of any manufacturing industry. Because of fast development in the assembling segment over the most recent two decades, the interest for adaptability in CNC framework was expanded. Since CNC system Architecture largely depends on computer technology, developers find difficulty in support of their previous solutions whenever there is the evolution of new technology in the computer field. This also creates problems to end users who want to modify their system using equipment from different manufacturers.

Open Architecture Control is a popular term in the field of machine control. The Openness of Architecture allows developers and end users to integrate parts from different manufacturers into the existing system to achieve their manufacturing needs [11]. This is the Aim of Open Architecture Controller to actualize and coordinate client particular controls with the assistance of open interfaces and arrangement strategies in a seller impartial condition [4].

The OAC framework have an unmistakable trait which permits association between two distinctive CNC structures [6, 11]. In Europe venture named OSACA (Open System Architecture for Control within Automation System) was started in the year 1992 to bring seller unbiased standard for the open control framework. In 1994 comparative task was conveyed in Japan named as an OSEC (Open System Environment for Manufacturing Consortium). In 1994 OMAC is framed as The Open Modular Architecture Controls client's gathering to give an association to organizations to cooperate and to give answers to issues in Open Modular Architecture innovations [11].

1.1. Open Architecture Control for CNC system

The IEEE characterized OAC as, "An open framework gives capacities that empower appropriately actualized applications to keep running on an assortment of stages from various sellers, interoperate with other framework applications and present a steady style of connection with the client" [11].

The Openness of system can be estimated by following criteria [11, 12]:

Portability- Is the ease with which an Application Module (AM) can be used on variety of systems without making alterations in it.

Extendibility- Any number of Application Module can run on a specific platform without any issues.

Interoperability- Application Module work together in a consistent manner to exchange and make use of information.

Scalability- It is the ability of a system to increase or to decrease according to the demand.

1.2. Control System Structure

OAC system controls are very sophisticated because of the need regarding their reliability and real-time data sharing. For controlling this complex system External and Internal Interfaces are used [11].

External Interfaces - External Interfaces connects control system to the user as well as to various units. They include programming and communication interfaces.

Internal Interfaces - They are used for exchanging data between various components which increases the capability of real-time tasks performed by the system.

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1.3. Hardware Structure of OAC

The hardware structure of open architecture CNC system consists of Human Machine interface Unit (HMU) and Machine control unit (MCU). They both have dedicated processors to carry out machine tool related tasks and other user related tasks separately [6].

MCU- MCU is an integral part of CNC system. It contains various empty slots in which control and few communication cards can be inserted. The slots containing various modules are interconnected by a bus. MCU also contains reserved slots to expand the function of a device. The functions of MCU includes converting coded instructions into machine tool movement, to generate axis motion commands.

HMU- It has a display panel along with machine tool panel. It provides the command input to control machine tool. It also provides a status display of machine tool.

1.4. Architecture of OAC

The Architecture contains various functional modules to do different functions. The motion controller module controls the movement of the respective axis by calculating interpolation data and PLC module does the function of controlling various ON/OFF switches [6].

The Architecture of OAC consists of functional modules and different layers to provide support for these modules [6].

Hardware Layer (HWL) – It is the fundamental component of system platform on which application software runs. It is located at bottom of architecture and contains modules for the network and Fieldbus interfaces.

Real-Time Operating System Layer (RTOSL) - It presents at bottom of software platform and it makes sure that specified operation completes at a specified time which increases predictability of the system.

Communication Management Layer (CML) - CML protects details of communication mechanism at the bottom level. It provides communication service by using standard interface.

Application Program Layer (APL) - APL transfers application programs into transfer modules like motion controller module, task controller module, etc.

1.5. Various Open CNC Initiatives

OSACA: The OSACA (Open System Architecture for Controls within Automation System) project was started in the year 1992, in Europe. The objective of this project was to develop a vendor-neutral environment and open control architecture for control systems. The essential approach of OSACA is to break down various levelled method for control usefulness into practical units by building up an application programming interface (API). The major problem with the OSACA is that there wasn't any advancement made in it since 1998.

OSEC: The Open System Environment for Controllers (OSEC) was a workgroup established by vendors in Japan to develop Japanese open controller. OSEC focused mainly on PC platform and Windows environment. The OSEC engineering was proposed to give end client, sellers, and so forth a standard stage for creating modern machines. The API in OSEC used to trade data between controller programming segments.

JOP: Japanese Open Promotion Group (JOP) plans to give chances to different organizations to cooperate on institutionalization of open controller innovations. JOP likewise proposed to grow new innovation in view of open engineering controller with the goal that data procedure can be adjusted to another condition.

OMAC: The Open Modular Architecture Controllers user's group was formed by American car manufacturers in 1994. OMAC API used a component-based approach to obtain plug and play property. The OMAC objectives to 1) advance open design control improvement among control manufacturers; 2) acquire basic answers for both specialized and non-specialized issues in the improvement, execution and commercialization of open engineering control advances; and 3) work together with different Japanese and European client gatherings to frame normal worldwide API standard.

2. Literature Review

2.1. Open Architecture Control for CNC system

Ma Xiaong-bo et al [1] proposed a HIT-CNC system which was developed using off the shelf hardware to achieve portability and standardization of system. Hardware required in this system is an industrial personal computer (IPC) along with standard communication interface. The operating system is an essential part of machine control software. HIT-CNC system used Microsoft Windows NT with Venturecom's RTX as its real-time extension to get the real-time ability. In this HIT-CNC system, SERCOS is used as a communication interface. Rexorth's server system and motors are used in HIT-CNC. API is used to achieve adaptable control. OMAC is selected as the platform for a HIT-CNC system.

R Ramesh et al [2] proposed a scheme for building intelligent system into machine tools based on Open Architecture Controller Platform which can handle various tasks like decision making and it will act in accordance with Rapid-CAM system to convert the designed model into a machined component. Authors found the task of data sharing between servo loop and logic control as an intricate job. In this proposed system four level platform-based approach is used to differentiate various functionalities of CNC machine to add flexibility and openness to the system. A Rapid CAM system includes OAMC and Personal Computer. The software interface is used to generate the 3-D model in PRO-E and CAM package is used to generate a part program for the model which then transmitted to a controller. A 3-axis vertical machining centre is developed using open architecture controller which operates on EtherCAT.

Jorge Correa et al [3] proposed an Open Architecture for the control of CNC system based on open source electronics. The Architecture is a component-based approach aimed to achieve software and hardware modularity. This paper also includes a preliminary test of control to two-axis CNC stage and SIMULINK model for the rapid design of control loop parameters, Analysis and trajectory simulation of the machine tool. Software Architecture is based upon component-based approach and each component has independent FSM model. Proposed OAC consists of interpolation algorithm, servo control loop and emergency control. Interpolation algorithm has an independent microprocessor and it controls the motion of axis by generating pulses to servo controls via hardware interrupts. The hardware architecture is implemented on 3-axis CNC machine. The executive program communicates with PLC and HMI via a serial port of communication bus. PLC is directly connected to servo-control via I2C. The executive program runs on PC, PLC and Bus master program are combined into an Arduino mega 2560 board and servo controller runs in Arduino nano which is based on ATmega328 microprocessor.

Kamran Latif and YusriYusof [4] proposed an Open CNC system and used STEP-NC (Standard for The Exchange of Product data) or ISO 14649 data model instructions for operations. They proposed a technique to integrate hardware and software from different vendors into single PC based CNC system. For building up a model they utilized existing CNC machine and changed over into a more contemporary open framework at a decreased cost which is a case of a supportable assembling condition. The proposed archi-

tecture categorized in four tasks such as hardware configuration, software configuration, integration of hardware and software configuration and validating proposed system.

Beibei Li et al [5] proposed an Open Architecture based on two processor Architecture which controls different tasks separately. They introduced EtherCAT which is a Fieldbus technology having higher transmission speed which is beneficial for greater data transfer. The prototype also has been developed which was having five-axis machining centre and its performance was verified.

Jiewen Wu et al [6] proposed a hierarchical open CNC system along with its software design. The proposed architecture then implemented and its real-time performance is tested. The system used two OS one is for non-real-time activities and other is for real-time applications. Data is transferred between two OS by using shared memory. In this proposed system, the data flow in a stratified manner from the top to bottom layer.

2.2. Simulation Of CNC Feed Drive Using MATLAB/SIMULINK

Gabriel S. Racz et al [7] developed a simulation model for servo drive by using MATLAB/SIMULINK software. D.C servo motor is used to drive CNC table. The developed system uses tachometer and incremental rotational encoder. The accuracy of feed drive is tested by simulating the model using various parameters. The positional errors are tested for single axis movement. The results show that developed system is doing well at rejecting disturbances. The positional error remains constant for a broad range of input parameters.

XU Wei et al [8] proposed a multi-axis CNC drilling machine. The D.C servo motor was used to give feed to mechanism because of its dynamic response over a high-speed range. Simulink software is used to develop a simulation model which can simulate the operating conditions. The simulation values are then compared with actual experimented values of the system. After analyzing the results they found that developed system is quick and precise and also suggested that this system can be used for the automated production lines.

M. Ebrahimi et al [9] presented a mathematical model of CNC feed drive for calculation of various parameters such as table displacement, backlash error, stiffness and friction. The developed model consists of a ball screw mechanism and motor to drive the screw for the movement of the table. Simulation helps to determine and optimize above parameters to increase effectiveness of the model.

3. Result and Discussion

In present industrial scenario, CNC machines are in demand due to their flexibility, efficiency, repeatability etc. But still, CNC machines are required to be made advanced due to variation in customer and manufacturers demand, support for different original equipment manufacturers (OEM's) and also to reduce the cost of modification. Open Architecture Control can help the manufacturer to solve this problem. Open Architecture Control concept can be used on existing as well as on new CNC system. After implementation of OAC, the system can be easily customized by using parts from different OEM's also it enables cross-platform capability of the system.
After studying literature, we found that there are still some problems faced by researchers who want to develop CNC system on open architecture control. The main problem researchers are facing of making the open system more responsive to different software and hardware platforms. After going through all above research papers we felt that we can improve existing system by improving its real-time data sharing capability. The current system struggles at the real-time data sharing and processing and it sometimes gives previous values to the system rather than current value which makes data inconsistent. In future, we can make CNC system more intelligent, reliable which can take decisions by its own and improves its process.

3.1. Proposed SIMULINK Model for Open Architecture Control CNC System

We are developing 3-axis CNC machine system based on Open Architecture Control. We will be using a servo motor to give feed to ball screw mechanism which will move CNC table to require position. Our objective for using ball screw mechanism along with servo motor is that to improve accuracy and to reduce error in the final position of the table. We developed a Simulation model in MATLAB/SIMULINK software for proposed Open CNC system which is used to simulate the physical conditions and analyze the performance parameters. This will help to optimize the process by comparing the simulation results with actual output values from developed open architecture control CNC system.

Input parameters required for simulation of MATLAB/SIMULINK Model are described in Table 1.

Table 1: Input Parameters

Sr. No.	Parameters	Values
1	Lead Screw Pitch	5 mm
2	Motor Inertia	0.000515 kg/m^2
3	Input Signal	2 rad/sec

The simulation is done for 30 sec with input signal of 2 radians per sec.

The output is in the form of angular displacement as per the pitch of lead screw; through this, distance travel can be evaluated (Table 2).

Table 2: Output Parameters

Sr. No.	Parameters	Values
1	Angular Displacement in 30 sec	290 degree
2	Angular Displacement	0.16 rad/sec
3	Speed	1.60 Rpm
4	Linear Velocity	0.0172 m/sec

Thus, distance travel in 30 sec is 0.516 m with radius of 10.75 mm.

Effects of changing pitch on Output Parameters is shown in Figure 1 and Figure 2.

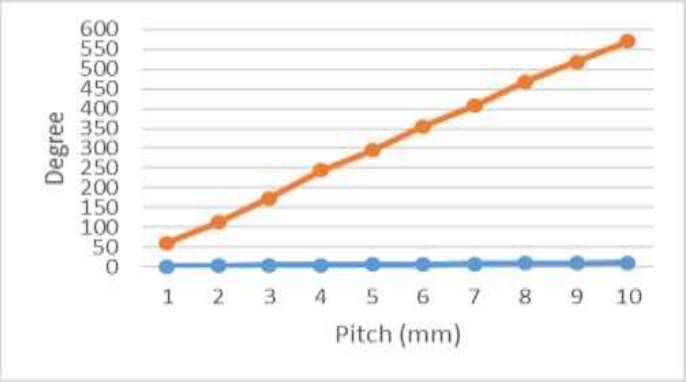


Fig. 1: Pitch vs. Degree

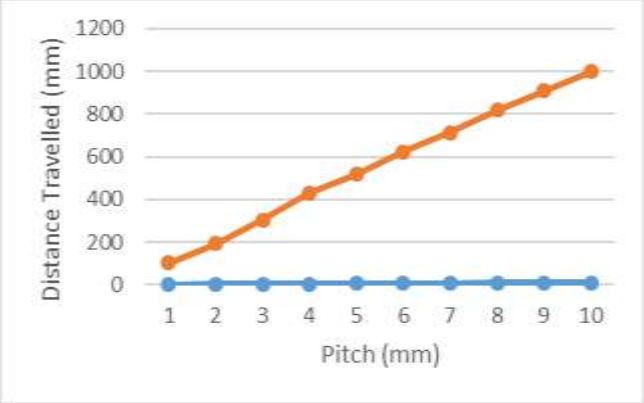


Fig. 2: Pitch vs. Distance Travelled

4. Conclusion

The purpose of this review is to view trends in composition study made in the area of Open Architecture Control for CNC as well as to highlight research made in the simulation of the feed mechanism for table movement or tool movement in CNC machines. Reviewed papers proposed various theories on CNC system based on Open Architecture along with experimentations made on proposed models or prototypes. Going through review articles it is clear that Open Architecture promotes vendor neutrality which helps in keeping the cost of the system upgradation or expansion minimum. The current study suggests difficulties in parallel data sharing, real-time data processing and commercial implementation of Open Architecture System. Further studies can be done to make Open Architecture more Open, Modular and Intelligent.

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