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AN EXPLORATORY STUDY FOR CMM SOFTWARE INTEGRATED CONTROLLER – PART 1

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ABSTRACT
The CMM is a computer controlled robot for dimensional inspection, involving complex mathematical calculations and fast data transmissions both ways: computer (operator) – controller – actuators and reverse, probe – controller – computer. The delay between the operator command and the actual movement of the machine is significant, and other applications running on the computer increase this amount of time. Shortening the signal path by including the controllers in a software application will improve the transmission time and other features will be available. The portability of the programs developed in such application will be enhanced, the readings will be more accurate and finally a new type of hybrid CMM could be developed. Our purpose is to trace the major lines of this project and develop an application to control the movement and to acquire data from a positioning system with steppers.
Keywords: Coordinate Measuring Machine (CMM), Touch-probe, Main Controller, Encoder, Optical ruler, Software integrated control

1. INTRODUCTION
Coordinate Measuring Machines inspect manufactured parts to determine the geometrical errors and the shape deviations against the technical drawing or 3D model. The continuous improvement of the production processes and the increase of the customer demands lead to tighten tolerances and strict specifications. As a part of the production plan, the duration of an inspection is very important to meet the delivery time. Therefore in the last years the main CMM's producers focus their research to reduce the inspection lead time and to acquire more accurate data from the part inspected. Even if the computer uses a fast Ethernet card and the transmission is as fast as it can be, the delay between the computer and the controller and from the controller to actuators is significant, particularly when other applications are running on the computer. The CMM ensemble consists of three controllers (the main controller, probe-head controller and touch-probe controller), the computer and the machine itself (mechanics and actuators). A sketch of the CMM's components linked according to the signal flow is given in the figure 1.

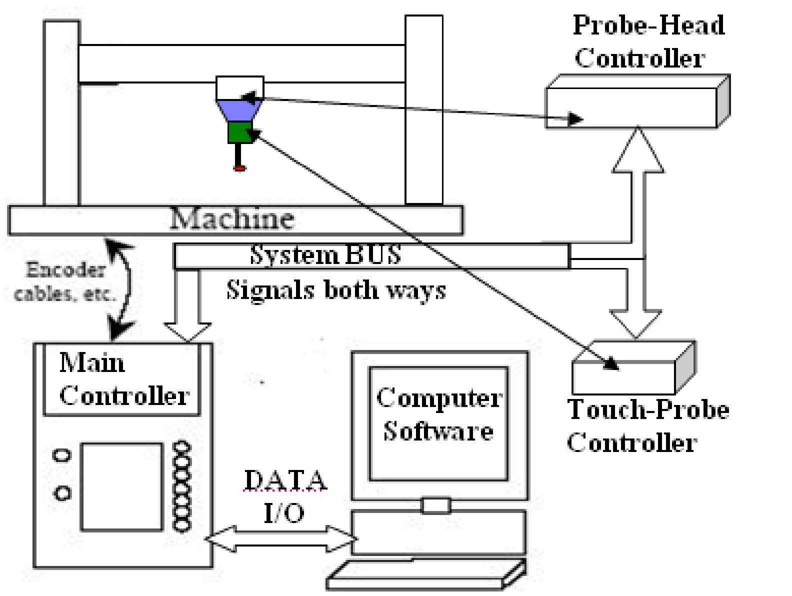

Figure 1. The CMM ensemble

Each controller has a precise task and the signals have a long path to cover. The signal transfer time must be added with the processing time in each controller, the conversion of the signals (A/D, D/A) and the response time to evaluate the total amount of one actuation cycle. The operator calls a function and set up the parameters for a measurement in the program; the software is no more then a friendly interface between human and machine, translating the operator intention into command signal. The signal is passed to the main controller where it is split between the actuators and the touch-probe controller. The motors put on move the ram; there are two speed phases: one for moving the probe near the inspected zone and one for touching the surface. Only when the machine is in measure stage (the pre-hit distance – safety distance between touch-probe and the inspected surface – is achieved) the signal from the main controller is passed to the touch-probe controller. After the deflection the probe is moved back to a prescribe distance (retract) and the arm rests. If the part geometry do not allowed to measure with the normal (A=0, B=0) angle, the operator might choose a different angle from a predefine list and the software pass another command to the probe-head controller. The feedback signals are gathered in the main controller, processed and converted in ASCI code for the computer. The reading signal is given by the touch-probe controller and the optical encoders read the position on the optical rulers and send the data to the main controller.

2. BLOCK-DIAGRAM AND THE SIGNAL FLOW

The current paper proposes a solution to shorten the path of the signal to and from the touch-probe elements of the machine. The main idea is to merge the software application with the controller's routines in a software integrated solution, shortening, in this way, the lead-time from the operator command and the display of the results on the screen.

Assuming that steppers are the actuators for this CMM, a software algorithm integrated in the main application can be apply to control directly the loop through incremental encoders[4], and moreover on the same BUS the computer controls the touch-probe, the probe-head and read the data from the optical rulers. The electrical characteristics and the invariable load on the motor shaft insure the utilization of this type of actuators. From the electrical point of view, stepping motor is incremental mechanism and the input is a digital processed signal in order to obtain specific angular displacement.[3] Each quantum of the input conducts to a certain portion of angular displacement, named step. A position is achieved after the rotor pass through all the intermediate transitions and the controller send out the entire drive sequence. The number of impulses prescribes the final location in the working volume of the CMM and the drive frequency is direct proportional with the moving velocity. The figure 2 presents the close loop driving system, with software control instead of a classic controller.

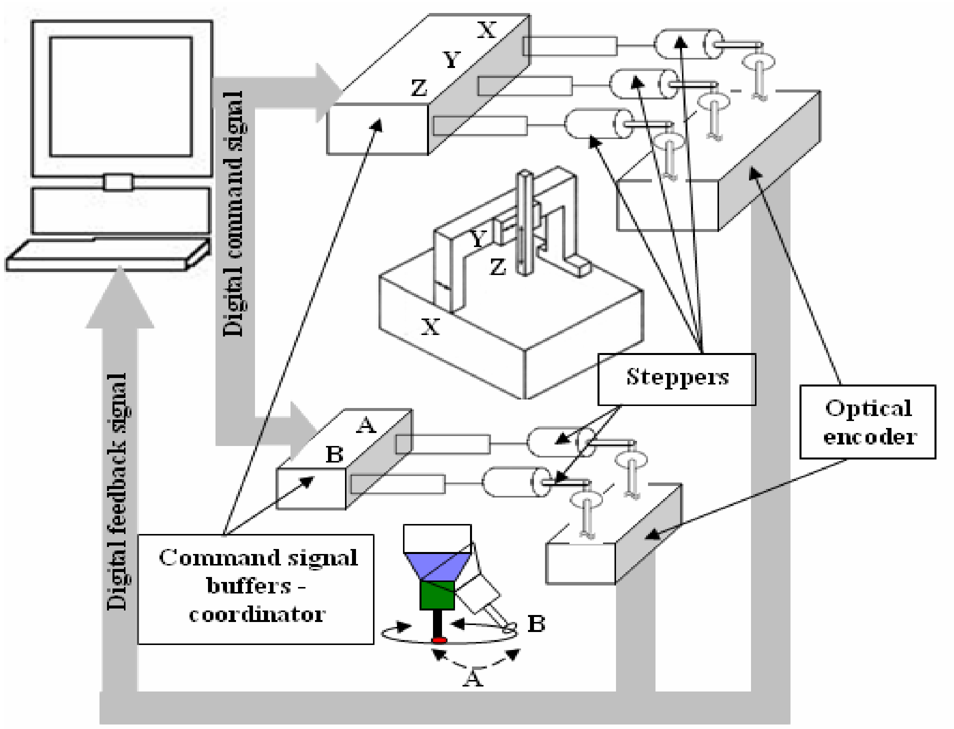

Figure 2. Software integrated closed loop controller

The only computer external element that helps to form the command signal is a coordinator before the steppers that acts as a buffer to store the input signal if the driving frequency is higher then the step rate and as a signal splitter for each stepper.[2] Another reason for this element is to limit overcharged currents from the electrical circuit in order to protect the computer ports. In the figure 2 the two blocks (coordinator for sliding on the axes – translation and coordinator for probe head – angular displacement of the touch probe) are pictured separately only for explanatory considerations, in praxis being necessary only one.

3. DIGITAL CONTROL SYSTEM

To understand the way this control system is working, further details regarding the CMM structure must be brought into discussion and clarified.

The purpose of the feedback-loop of the actuators is to maintain a uniform movement (acceleration and deceleration from the initial to the prescribed position), to sustain a constant torque and to avoid faults in synchronization of the motors while pass on the machine axes.[1] The optical encoder's signals are not accurate enough to establish the Cartesian coordinates of the touch probe during movement and therefore are neither used to identify the position nor to acquire readings for metrological inspection. Each axis has embedded a precise, glass ruler with interpretable scale lines by a reading sensor. For every translation the computer counts the number of the scale lines passed and at each 10 mm there is a check point on the scale to compare the stored sum with this 10 mm indicator. The optical scales have a null-point, often called reference point and the direction to the end of the scale is the positive direction. If the checksum does not match the 10 mm indicator an error message is displayed and the movement stops. If the movement is successful the current position of the touch probe is stored. The position sensors from the optical scales output a digital signal, easy to be processed by the computer.

The probe-head has one motor for each rotation axes (A in vertical plane, B in horizontal plane) and can achieve only discrete positions. Most common probe-heads have a 7.5º step for both axes with a range from 0 to 90º (in some cases 105º) for A-axis and from -180º to +180º for B-axis. The first advantage of using hybrid step-motors is due to its own discrete movement characteristic and depending on the number of poles even smaller steps can be achieved. The second benefit comes from the permanent magnets that can hold the position even if the phases are not energized. But the most important gain is that all signals are digital therefore no conversion is necessary and command can be passed directly from the computer acquisition card.

4. CONCLUSION

The most important benefit of the proposed CMM architecture is that the path of the signal is shortening due to the removal of the controllers. The system process only digital signals any conversion being useless and the controller is replaced by a software data processing making any update faster and easier via a patch released by the producer. The delays and the tact difference between the computer and the controller are eliminated, conducting to a substantial time saving. If the software is build on an open sourcing architecture any fault can be faster corrected. In the second part of the paper the control algorithm is presented and the advantages and the disadvantages are discussed.

The economical consideration on medium and long term can be estimated, but only the hardware price for the controllers can cover a big portion of the research investment. Adding to this integrated software solution benefits from fuzzy path planning algorithm and image recognition for identification of the position and the geometry of the inspected parts the sketch of a new generation of CMMs is drawn.

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