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Wireless Monitoring and Controlling of 3d Single Point Incremental Forming Process

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ABSTRACT

The wireless and internet of things technologies of the CNC machine has witnessed a noticed development recently, but the merge with the augmented Virtuality would enhance the industrial intelligence of that machine. This paper proposes a combination of the wireless sensors, 3-D CNC machine, and Virtual reality technologies for data controlling, processing, analyzing and monitoring.A 3D Single Point Incremental Forming (SPIF) system is taken to be the application of this method. The main objectives of this research is to verify the monitoring of the 3D (SPIF) machine environment in such a way that to fulfill the control and data analyzing remotely as well as reading several parameters that could avoid to miss the machine tools such as the temperature of the metal under processor for the tools of that process. Graphical User Interface (GUI) in MATLAB environment has been reported with a suitable algorithm based on mathematical modeling equations for the moving parts of the SPIF system. Several techniques investigated in terms of sensor types, sensorcompatible with this machine as well as data rate transmission that satisfies the real time monitoring and augmented reality process. The process starts from a digitized model of the appearance that the object should be reproduced, which may use prepared software to program the best strategy to follow the forming tool, the forming sheet metal shall be processed in a mobile platform applied layer by layer until the object has taken its final form. It is found that using two XBee Pro S1 capabilities as a wireless node with its built in microcontroller and suitable sensors can achieve the research objective with minimum power consumption and less cost for implementation.

INTRODUCTION

The single point incremental forming (SPIF) process consists in the deformation of a metal by means of a spherical tool. The spherical tool follows a tool-path which has been previously programmed in a special programming package, such as CAM system. The using of the new technologies has witnessed a noticed development recently. The merge of such CNC machine with the wireless sensor control and monitoring and consequently using the augmented Virtuality would enhance the industrial intelligence of that machine.

In the single point incremental forming process, strains on the metal or the sheet metal blank are localized in the contact area with the forming tool which deforms the sheet. The product geometry is achieved incrementally while the spherical forming tool follows the tool path. This is the main reason why the definition of the tool path should be considered as a critical operation when optimizing the accuracy of the final part.

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Remote control and remote access by wireless for many new CNC machines become a standard feature. Over any network or the internet is enabling to real-time remote and monitoring of unattended CNC machines.This capability is convincing to control and monitor machines from anywhere with several benefits that increased productivity and profitability through decreased machine downtime, service and training costs.The device is used by seamlessly integrates into common networks using a standard LAN and a wireless router. The CNC machines function via the Internet, so that the machine can be operated to manipulate the process, regardless of the distances to the actual machine. (Wang and Orban, 2004).

Wireless Data Control and monitoring:

In another concern, but based on the suitability of using the wireless sensor with this machine, there are several wireless sensor applications have been done in the field of positioning, localization of moved objects, or for tracking and monitoring. Therefore, different localization techniques have been implemented, developed and analyzed. Some researchers have addressed the concerned subject with different tools.

(Wang and Orban, 2004) present a kind of philosophy with open structural engineering for constant observing and remote control of organized CNC machines. It presents a method to bring traditional CNC machine tools on-line with combined monitoring and control capability. His application was through a milling machine case study. The paper (Monroy, Calderon and Miranda, 2005) demonstrates how a CNC machine lathe located 70 miles far from a particular place was instrumented and arranged with a three-segment piezoelectric dynamometer, piezoelectric accelerometers, and an impulse hammer so as to extradite force, acceleration, and stiffness measurements in real time, in this case a CNC program can be sent to the lathe and retrieve the current program loaded from it. Because of the distances, the system will use the Internet and wireless communications for the data exchange. In (SUNAR, 2013), the author focuses on controlling 3 axes controller to automat gripper controller throughout the machining process of CNC machine. The author here uses a remote desktop application for Windows 7 and Windows XP, which is quite common for a remote desktop application to be used to control a host computer that is far from the silent one, this required only internet connection. In the other trends, (Pezzullo, 2014) offers a solution for some of communication, productivity, and part quality problems by providing an applicationof a custom software which integrates an emerging interoperable data communication standard, with a particular data acquisition tools and custom sensors to monitor and communicate CNC machining data and process information, (Pezzullo, 2014) was designed to aid in the identification of chatter conditions to the machine operator and to other users to take action for chatter suppression and avoidance, which can reduce part quality and increase tool wear. Finally, in the application of wireless sensor networking,(Sh. Zhang, 2014) presents a flower watering control system to utilize remote wireless sensor network to gather the temperature and humidity, and lighting parameters of the flower agriculture environment. The XBee remote system has been used to control the procedures and manages the information.

Augmented Reality:

Most industrial machines have witnessed developed to become advanced tools where the control and automation with feedback is made possible through a dedicated control by computers. The computer lets us to fully or partially automate different or complex procedures with more secure and precise. Real-time data processing is obtainable and many parameters can be controlled through the computer interface. The automation can also allow the operator to monitor multiple machines remotely and simultaneously, therefore, reducing the number of required operators.

In (Olwal, Gustafsson and Lindfors, 2008), the authors show how Augmented Reality (AR) can be utilized to make close combine of procedure information with the workspace of a modern computer numerical control (CNC) machine. AR permits us to merge intelligent computer design with genuine items in a physical environment. They offer what is called ‘ASTOR’ which is an autostereoscopic optical transparent spatial AR framework, to give real-time 3D visual input without the requirement for user-worn hardware. The design is geometrically enlisted with the workspace and give an intuitive representation of the procedure, such projects would increase the client's understanding and simplifying the operation of the machine.

(Zhang, Ong and Nee, 2010) This paper expands on past works of incorporating the AR innovation with a CNC machining environment utilizing following and enrollment techniques, with a tighten on in situ simulation. Particularly arranged for a 3-axes CNC machine, a multi-regional calculation plan is proposed to render a cutting simulation between a real cutter and a virtual workpiece, which can be directed in situ to furnish the mechanic with a natural and thorough environment. A cross breed following technique and a NC code-versatile cutter enrollment strategy are proposed and approved with test results. The analyses led demonstrate that this in situ simulation framework can reinforce the user's understanding and monitor of the machining process as the simulations are performed on genuine machines, while (Soori, Arezoo and Habibi, 2014) display a virtual machining framework with a specific end goal to uphold dimensional, geometric and device avoidance mistakes in three-axes processing operations. The framework gets 21 dimensional and geometrical mistakes of a machine device and machining codes of a particular part as information. In the other hand, (Acuña, Chancusi and Navarrete, 2015) show the configuration and development of a 3D printer that can deliver physical models in three-axes from a virtual model planned in CAD programming for the Laboratory CNC of the University of the Armed Forces ESPE. The procedure begins from a digitized model of the object which prepared before by utilizing free software, it is modified a system for tracking the injector for printing prototype, the material projectile plastic that states the mobile platform applied layer by layer until the model has taken its last shape. The machine comprises of four instruments or axes: X, Y, Z frame a mobile platform progressively the extruder component, which has the capacity of expelling a plastic fiber through a smelter. Control is through PC with free software and hardware, it will change a 3D model programming language G code.

The wireless radio class that is industrially hardened and proven to be reliable in the harshest environments is commonly deployed in mission-critical industrial applications. These radio devices such as XBeemay offer the most effective, economical solution when compared to other options. When compared with fiber, for example, wireless systems are easy to install. If a buried cable is damaged and requires repair or replacement, the costs can be high. Wireless systems are relatively maintenance-free, and, if maintenance becomes necessary, they are easily maintained. Once installed, top class wireless systems rarely need servicing. If maintenance is required, the best systems provide information regarding a pending maintenance concern, and the location or type of maintenance required can be remotely detected. Operators, therefore, only need for the service if and when necessary, saving time and money. If correctly engineered and installed, wireless systems will last maintenance-free for years. At least one of the top class wireless manufacturers provides backwards compatible solutions throughout its product lines-saving on maintenance as well as stocking and replacement costs.

This research proposes a wireless data processing, monitoring and management for 3D Single Point Incremental Forming (SPIF) system that fulfils the objectives, firstly, to use appropriate wireless data communication system and sufficient wireless sensors with compatible communication technique. Secondly, to investigate the obstacles that hamper the accuracy of the data transmission and the localization of the real time position of the moving tool in (SPIF).

MATERIAL AND METHODS

Different sampling frequency of the three analogue signals of 3-D prototype structure has been investigated in this research. Only two nodes of Xbee S1 Pro RF module have been utilized to build the wireless data processing and management of this proposed system in order to optimize the 3-D localization accuracy of the Point Incremental Forming system and to reduce the components as well as the computational cost during the signal processing. The orientation, dimensions and distance of the moving parts of the 3-D machine during the forming process is calculated from the data transmission parameter values. We also investigated the software algorithm for the energy management to maintain the energy saving of the machine power dissipation based on energy parameter node sensors.

The measurement accuracy indicated by the root mean square error (rms error) and a standard deviation that should be less than a specified value in the range of the distances within the movement space.

We started with following flowchart which shown in Fig. 1, it represents our steps, that we followed to achieve the research objectives.

Referring to Fig. 1, the control system that governs the machine is based on a computer system through a master software transforms the object in MATLAB codes, this information is sent to a second system address corresponding to a controller card,and one interface card with their drivers to control actuators and receives feedback granted by the sensors. The software packages should allow conversion MATLAB file for wireless serial data code,, as control variables to tune, one time, the values of the three axis positions at each step or sampling time and simultaneously received the feedback of that three location,on the other hand, a measure ofthe tool temperature of the machine tool has been checked over the operation time as a warning signal to avoidtool damage or the failure in the forming process.

The second step is the selection of wireless technology (XBee S1 Pro) that adopted to satisfy the wireless communication of the data between the host (the operator remote computer) and the client (the 3-D SPIF) machine.

To access and configure the data, USB interface card connected to the Host PC which considered as a coordinator node, while the other node has been connected with 3D SPIF machine to read the measured analogue data of the three axis as well as the tool temperature.

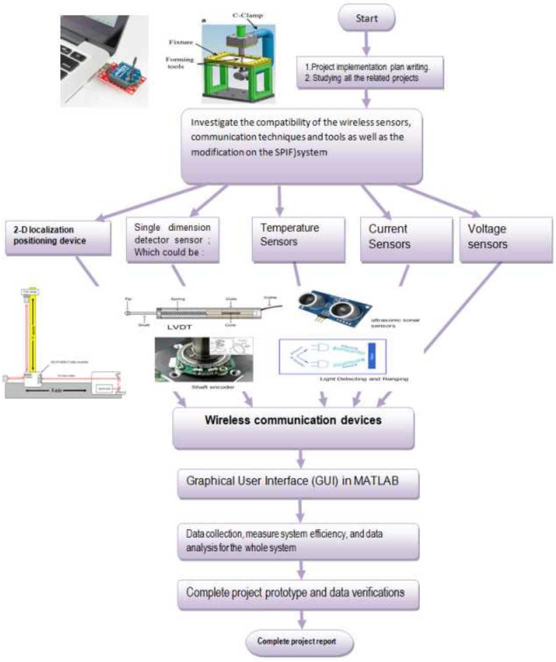

Fig. 1: Research Flowchart.

Then, we've designed the prototype structure for implementing the proposed method as shown in Fig. 2.

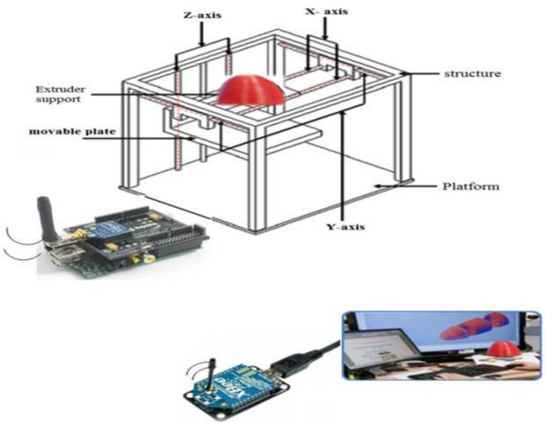

Fig. 2: Proposed Wireless Communication System.

Software design:

The software X-CTU, which be used to program the two XBees to configure the parameters directly by connecting the module after installation USB serial port (COM). The host coordinator Xbee is connected to a PC and driven by MATLAB software. Whereas, the other one configured to read the measured values from the sensors that described in Fig.1. MATLAB program is used as a software to analysis the data with used appropriate faction to access the attained information about the machine tool orientation and the temperature data without any extra environment software.

Figure 3, shows the preliminary experimental measurements of six channels, three of them have been used to collect the data of the 3 axis position of the machine tool, while one more used to read the temperature, the other extra two channels prepared for future optioning signals.

RESULTS AND DISCUSSION

The design starts with a prototype card to test the performance in terms of the data transmission rate and the accuracy of the received data to analyze as well as the analytical estimation of the machine tool 3-D positioning without following the conventional design which utilizes, in most cases, extra microcontroller card such as Arduino. We used linear potentiometers and multi-turn one to connect its output to the port of Xbee (client or machine) XBee. To test the accuracy of the received data, we used an oscilloscope to compare readings for the 3-D locations and the temperature that are all expressed in terms of voltage. Therefore, the received signal compared with the wired oscilloscope one.

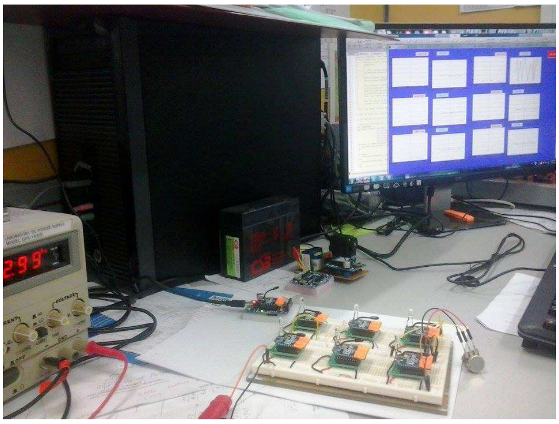

Fig. 3: Preliminary experimental measurements of six analogue channels.

The ADC of the XBee microcontroller is 10 bit resolution conversion. This means that the ADC assumes 3.3V is 1023 and anything less than 3.3V will be a ratio between 3.3V and 1023.

$$\frac{Resolution\ of\ the\ ADC}{System\ Voltage} = \frac{ADC\ Reading}{Analog\ Voltage\ Measured}$$

Analogue to digital conversions are dependent on the system voltage. Because we predominantly use the 10-bit ADC of the XBee on a 3.3V system, we can simplify this equation slightly:

$$\frac{1023}{3.3} = \frac{ADC\ Reading}{Analog\ Voltage\ Measured}$$

Fig. 4 and 5 show the results of testing the data transmission that was measured by using an oscilloscope, one time, for comparison purposes and through the Xbee RF on another time. In order to increase the accuracy, the output data signal has been sampled based-on two different mediums as shown in the graphs which are obtained from calibrated oscilloscope and MATLAB. As a result, both figures show the similarities at the output. The accuracy of the proposed wireless data acquisition circuit, which utilizes the Xbee RF Module, has been approved in this experiment. In addition, the results obtained from wireless connection are more accurate and smoother as compared with the wired one (data from oscilloscope).

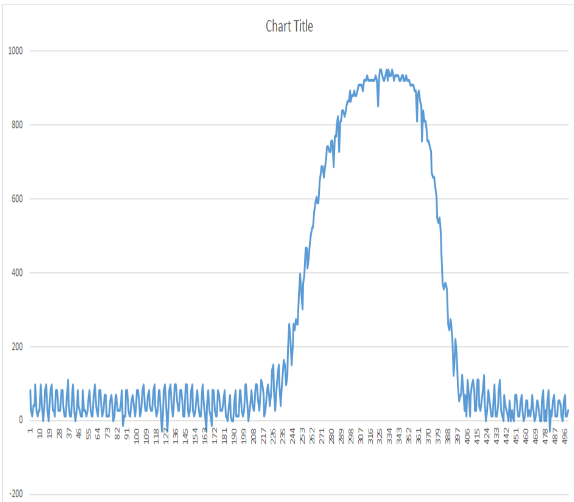

Fig. 4: Test signal from oscilloscope.

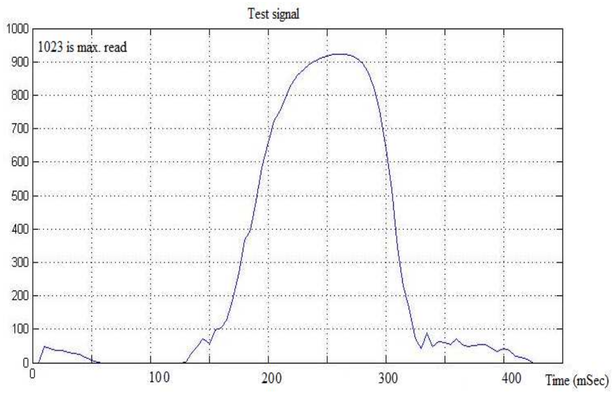

Fig. 5: Test signal from Wireless Communication.

Table 1: comparison results between the proposed and the traditional node in terms of consuming power.

Specifications of microcontroller	traditional use Arduino Uno	Proposed use XBee Pro
Data Process Power (mW)	400	64
Transmit Power (mW)	1.9	1.3
Operating Voltage (V)	5	3.3

Conclusion:

Zigbee, Xbee, A standards-based wireless solution, Zigbee offers a self-healing and a mesh network. It has also a direct sequence protocol that is susceptible to interference, especially when compared with proprietary protocol systems. The range is extremely short compared to others, and, as users add repeaters to lengthen the range, the throughput quickly degrades. At 230 kilobits per second (Kbps), the throughput without repeaters is acceptable in many applications as in SPIF. To extend the range and improve the data transfer, however, repeaters are required.

In this paper, we designed the mechanical structure to utilize it in the experimental measurements of the proposed system and to collect the localization data of the SPIF machine tool as well as the tool temperature to use the data for monitoring and control. The proposed system allows end-users real-time access of up to six analogue signal with relatively accurate results as compared with wired based measures signals. The remote host operator also can easilycontrol the machine behavior while monitoring the tool orientation. In addition, this proposed work can be more efficient with a machine that operates in hard environments. There are more improvements and developments occurred currently to complete the system with all its objectives towards integrated wireless augmented Virtuality applied on the SPIF machine with minimum power consumption and efficient low cost components.

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