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Internet of Things Based Cutting Tool Status Monitoring in a Computer Numerical Control Milling Machine

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***Abstract*— The Internet of Things (IoT) in the manufacturing industry shares machine data in real time. The majority of industrial data can be gathered and processed from machines and other remote IoT devices in a production system through data streaming. As sensors become smaller and more affordable, the Internet of things will attract more attention. It is possible to employ a wide range of sensors for monitoring, and with efficient open-source software, the status of the operation can be evaluated effectively. Our work aims at providing instructions for sending data (cutting tool status time) from Particle Photon devices connected to CNC milling machines to open-source software called ThingSpeak. This task is accomplished by integrating the Particle Photon device with the infrared sensor to the CNC milling machine. Three axis CNC vertical milling machine is used to manufacture the sample component. The status of the cutting tool, in this case the cutting time for each machining feature is monitored. Using infrared technology, the sensor detects whether the cutting tool is present. Particle photons measure machining time and communicate it to ThingSpeak. The ThingSpeak library will interpret the cloud information and displays it. With ThingSpeak software, we define the fields for various cutting tools and track every tool in real time. The time recorded using ThingSpeak software is found to be near to the time, which is monitored manually by the user. A major step in computer assisted process planning in manufacturing is monitoring the machining time for each cutting tool and it is successfully implemented in this research work.**

***Keywords*— Internet of Things; infrared sensors; particle photon; CNC155 mill machine; ThingSpeak; cutting tool status.**

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I. INTRODUCTION

Embedded devices are now increasingly connected to the Internet through the Internet of Things (IoT). The Internet of Things is a crucial aspect of cloud manufacturing and can be applied to a broad range of applications. An IoT surveillance system for monitoring cutting tools in a vertical CNC milling machine is the study's objective. IoT implementations in various manufacturing activities have been reviewed in recent literature.

A. Review of IoT in Manufacturing

Sensors can monitor robots and workers using temperature, force, and vibration sensors. Various production resources are detected by using IoT technology, and their status is documented [1]. Two methods of a reconfigurable manufacturing system based on IoT are employed to solve process planning in an article [2]. Research focuses on wireless communications and CAD/CAM technologies in CNC workshop production in a particular work. An IoT concept using temperature, accelerometers, and gyroscopes is implemented to monitor machining operations [5].

A previous study has analyzed fundamental consumer behavior changes and IoT architecture using broad data analytics [7]. This research is extremely practical and gives a theoretical reference to business decisions for its supply chain management in the IoT environment. In consideration of the important role of IoT in data collection and workshop surveillance, a dynamic IoT-based approach to logistics optimization is proposed. The Internet of things is used to monitor real-time factors, such as manufacturing details and materials requirements [8].

A new methodology has been proposed for the processing, network modeling, monitoring, and failure diagnosis of large-scale IoT machines. In the background of large-scale Industrial IoT, this modern approach reveals strong potential for optimum system design and maintenance [9]. Three industrial wireless tracking, and measurement instruments are developed and studied. The center of capacitive sensors is used to measure, understand motions, and measure the liquid level to satisfy industrial applications [10]. The perspectives and techniques have been used by previous study to convert existing manufacturing processes to cloud computing [11]. A decisional DNA-based knowledge representation system was proposed to represent and interpret data. According to the study, the author proposes a model which monitors in real-time, collects data and information at every step of the production process [12].

An intelligent development system based on six levels is proposed based on real-world manufacturing company requirements and the IoT's three-level architecture features. An information delivery process, large-scale data analysis, and a cloud infrastructure services network underpin the entire system [14]. A system for cloud-based process planning using agents has been proposed [15]. Data collection units can collect data from machines and data collection units that provide detailed information about the machine. These data are collected quickly and efficiently and sent through wireless sensors to a cloud gateway [17].

An assessment provides a two-step process for designing a process structure, and for each selection criterion, a case study of temperature monitoring is given as an example [19].In an IoT-enabled factory floor, many RFID data are analyzed using the Big Data Analytics method. The approach is validated through experimental studies [20]. SMILE is an innovative monitoring platform for the industrial sector. It provides automated services for the modern international monitoring of industry [21].

In new research, authors propose an IoT system that tracks waste in real-time, evaluates waste and manages waste capacity in shops. This paper illustrates how waste can be tracked and benchmarked with the microfluidic machine line [22]. For data acquisition and an automated fatigue crack detection system, IoT techniques and cloud storage infrastructure have been developed. A real-time application software, which allows users to view the identification results, can be viewed at their offices upon request [24].

In a new study, an architecture has been proposed based on a three-layer structure [25]. The effects of natural disasters and the harm caused can be greatly reduced by saving an alert and tracking in real-time during a catastrophe. As the transmission line changes temperature, the sensors read it in real-time. To analyze the energy efficiency of die casting systems, the Internet of things is recommended. Case study results revealed several energy-saving possibilities [27].

B. Review of IoT in other fields

In a study, deep learning technologies are explored for the management of privacy. This project used machine learning-based methods to protect IoT privacy by encouraging coworkers to discuss how to use data resources [3]. A new solution has been proposed for managing soldiers' health remotely inside unfavorable environments [4]. A new study attempted to increase performance and improve safety in electric vehicle behavior management by using Internet of things technologies [6].

New research examines and addresses tracking items, collection, and positioning of monitoring points in the smart power surveillance system. The machine feature debugging of data mining in an IoT environment develops an experimental forum[13]. In work, a monitoring service is discussed that provides information on the status and availability of the machine tool in real-time [16].

A study suggests one can plant and water crops from anywhere online through farmbot applications, which are computer or mobile-controlled[18]. Several security challenges are addressed in a study within IoT architecture due to its openness to threats at all levels. The threat detection system is designed to be fully intelligent [23]. The MongoDB database system is designed to solve the challenges associated with relational databases. There is speculation that NoSQL can be used as an efficient and speedy database system and that relational database should be linked into a standardized and accurate database framework [26].

An Internet-enabled monitoring, and controlling system is used for crop management in agriculture. IoT grows with Arduino microcontrollers or Raspberry Pi microcomputers in greenhouses. In addition, Bluetooth, ZigBee, and Wi-Fi are used [28]. For IoT Smart City applications, this paper proposes to apply deep learning techniques to identify botnets. Two layers of architecture are used to handle broad information in real-time [29]. According to a study, the IoT remote health surveillance framework consists of three functional sections, the AIM Smart-Edge, the intermediate cloud, and the physician's visualization framework [30].

The manufacturing industry is working to produce new goods and services to obtain competitive advantages on the worldwide market. Consequently, sophisticated sensor technologies are frequently employed in production systems to enhance information and system control visibility. Industry 4.0 seeks to raise the production system to a new generation of smart manufacturing systems in recent times.

Previous researchers monitored the temperature, pressure, and vibrations of the CNC machine. Monitoring machining time using IoT devices in CNC is the first of its kind. This machining center uses sensors and software to monitor cutting tool machining times; this monitoring is vital in process planning. In this research, particle photon and infrared sensors are used to monitor the cutting time in CNC milling machines, and the results are interpreted by a cloud-based system called ThingSpeak.

II. Materials and Methods

The primary focus of this work is to track the state of the cutting tools, how long it takes to perform an operation with a specific cutting tool, and to monitor the amount of time spent with each cutting tool.

A. Instruments Used

Hardware Requirement for the project:

- Particle photon device
- Wireless network connection
- Infrared obstacle sensors
- Jumper wires
- LED
- Small resistor (100 Ω – 1 kΩ)
- USB cable

Software requirement for the project:

- Solid works software for modeling and numerical code generation
- Particle build web IDE
- ThingSpeak software for visualizing data

B. 3D modeling of sample component using Solidworks software

As shown in Figure1, a sample milling component is modeled using Solidworks software. Automatic feature recognition is a key module that makes it possible to analyze, identify, and extract features from a model for downstream machining. The product details in Solidworks are generated using DimXpert. With Solidworks DimXpert, dimensions can be automated, datum selections are made, and tolerance and measurements added.

Data, surface finish, and various tolerance characteristics are extracted, and they are used as inputs in the process-planning step. Artificial intelligence is then used to generate process planning [31] and Numerical control codes, with the component being subsequently machined using a three-axis vertical milling machine. The sample component consists of features such as face, chamfer, hole, pocket and slot. To manufacture the above-mentioned features seven different types cutting tools are used.

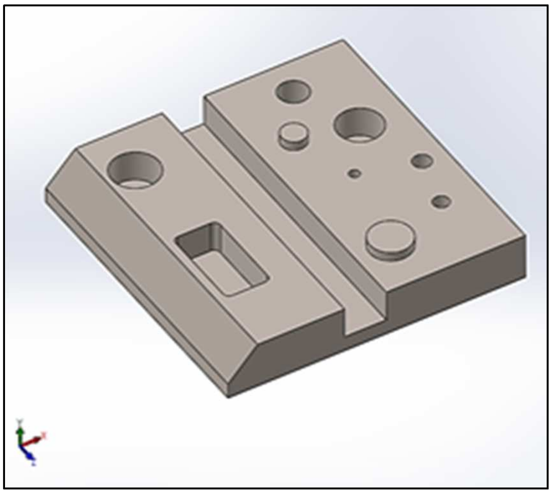

Fig. 1 Screenshot of 3D modeling of sample component using Solidworks

C. Infrared sensors interfacing with Particle Photons

Light-emitting diodes (LEDs) from active IR sensors emit IR rays, and their receivers detect the reflected rays. Infrared light is reflected on the cutting tool and detected by the receiver whenever it approaches the sensor. IR sensors have this property that allows them to be used as proximity sensors. The IR sensor measures the position of the tool when the tool is moved to the operating position with IR refraction. Seven cutting tool operations are being monitored and seven IR sensors are placed on each cutting tool.

In Figure2, it is shown how the infrared sensors are interconnected with particle photons. In particle photons, IR locations are continually checked, and their data are continuously transmitted. An integrated IR receiver and IR transmitter is used in the infrared obstruction sensor module, which sends IR energy and aims to detect any obstacle to reflected IR energy in front of the sensor modules. The module features an integrated potentiometer that allows the user to alter the range of detection. The sensor has an excellent and steady response either in the ambient light or darkness.

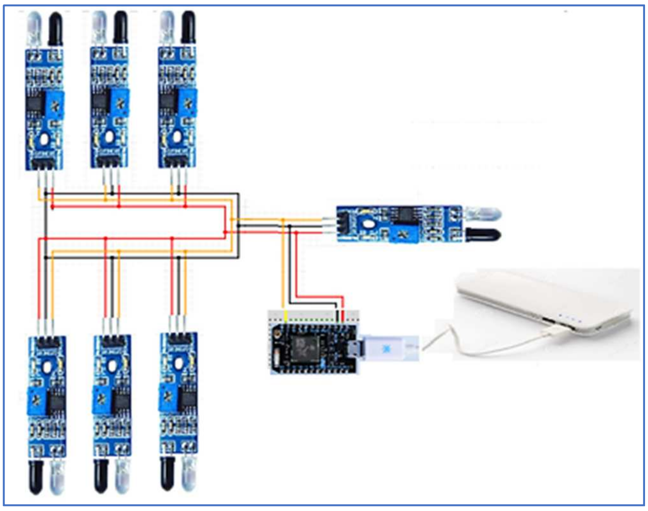

Fig. 2 Interfacing Infrared sensor with Particle photon

D. Particle Web IDE code

For Internet of Things applications, an important component on the platform is the Particle framework. It facilitates the building, connecting, and managing of connected systems. It is a Wi-Fi kit and features the status of the current board mode. Status LED has multiple blinker settings. Once connected to the Internet, the board breathe cyan and flashes green if it tries to connect to Wi-Fi. Blink blue means that the board is in a hearing mode.

```
void loop() {
for (inti=0;i<480;++i)//
    {
tool1_Face=digitalWrite(D0)
tool3_Boss=digitalWrite(D1);
tool9_Drill=digitalWrite(D2);
tool4_drillsmall=digitalWrite(D3);
tool2_pocket=digitalWrite(D4);
tool5_slot=digitalWrite(D5);
tool6_chamfer=digitalWrite(D6);
ThingSpeak.setField(1,tool3_Face);
ThingSpeak.setField(2,tool3_Boss);
ThingSpeak.setField(6,tool9_Drill);
ThingSpeak.setField(5,tool4_drillsmall);
ThingSpeak.setField(3,tool2_pocket);
ThingSpeak.setField(4,tool5_slot);
ThingSpeak.setField(7,tool8_chamfer);
ThingSpeak.writeFields(myChannelNumber,
myWriteAPIKey);
delay (1000)
 }
```

Fig. 3 Web IDE Particle photon sample code

Particle Web IDE provides the ability to program the particle devices by providing the platform to write code in the browser without installing any development tool. Particle provides a different platform to program the device, but Web IDE is the easiest way to perform the task. It has a user-friendly interface with different options to make the job easier and less time-consuming. As shown in Figure 3, the particle app generates a cutting tool status code. A Particle account is created, solid Wi-Fi connectivity is provided to get started, and the code is flashed.

E. Creating Cutting Tool Fields with ThingSpeak software

Through ThingSpeak, the data is automatically charted so we can monitor CNC units remotely. It allows to see how data is collected from any web browser or mobile device, and devices are monitored in real-time. Channels store all the data that a ThingSpeak application collects. Each channel contains fields that can be used to store any type of data. ThingSpeak is used to analyze and visualize data collected in a channel. In ThingSpeak, the API key is created, which facilitates communication between particle photon and ThingSpeak. Figure 4 shows the ThingSpeak channels created for the different cutting tools.

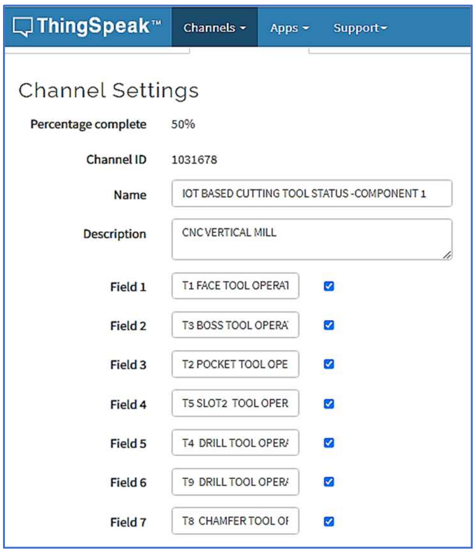

Fig. 4 Screenshot of ThingSpeak Channels

The particle cloud and ThingSpeak are used for logging the time the cutting tool is in operation. This cloud detects all tools in the project, and the user can see when each tool is in operation by logging the operation time. In this study, there are seven fields created for the cutting tools in ThingSpeak. Different fields use different cutting tools based on the machining operation. Field1 monitors the face cutting tool operation, likewise different other fields monitor different cutting tools.

F. Machining Sample Component in 3axis Vertical MILLING machine

CNC is a programmed instruction that provides guidance on correct machine movements. A CNC machine uses cutting tools to transform raw material into a finished model. For the experimental work, as illustrated in Figure 5, the CNC Emco Mill155 machine is utilized. It operates according to the 3axis concept. CNC Mill155 has a computer, keyboard, and mouse connections. Many tools are linked to the tool holders. The tool holder is equipped with milling and drilling cutting tools on the tool drum.

The tool is manually or automatically adjusted during the CNC program. The tool drum includes logic in order to choose the quickest method to turn the drum. This minimizes the time to modify the tool. The machine has a toolbox with ten cutting tools. The Solidworks program is initially used to simulate the NC code produced for this component. These codes are then entered in order to produce the component.

Fig. 5 Machining of sample component using CNC 3axis vertical milling machine monitored by IoT device

III. Results and Discussion

The machining time is monitored in CNC Vertical milling machine. This is accomplished by attaching a particle photon interfaced with an infrared sensor to the CNC machine to detect the tool availability and to monitor the time taken by each cutting tool using the ThingSpeak software. To monitor the status of the cutting tool using the cloud API, code is run on the device using the particle function. Information is sent to the ThingSpeak channel, which is created by flashing the particle photon. ThingSpeak displays the state of the cutting tool for every tool and operation. Device code can run according to the cloud API's demands using the particle option.

Table 1 gives details on CNC machine monitoring.It shows seven fields are created in ThingSpeak software. The tool number in the table corresponds to the name of the tool holder in the tool magazine. Each tool holder will carry one tool, for example, T1 tool holder will carry a face tool, and T3 tool holder will carry a boss tool, and so on. Based on the NC programming, the cutting tool changes automatically after executing a certain operation. When a specific cutting tool approaches to execute a machining operation, the infrared sensors detect it.

TABLE I
Monitoring the Cutting Tool Status Using ThingSpeak Application

ThingSpeak Monitoring of CNC Vertical Milling Machine						
Field No	**Tool No**	**Cutting Tool Name**	**Date**	**Start time**	**End time**	**Machining time in mins**
1	T1	FACE TOOL	Dec 9,2019	4.37. 02	4.39. 48	2.46
2	T3	BOSS TOOL	Dec 9,2019	4.40. 00	4.47. 12	6.12
3	T2	POCKET TOOL	Dec10, 2019	8.32. 02	8.34. 21	2.19
4	T5	SLOT TOOL	Dec10, 2019	8.34. 30	8.39. 12	4.42
5	T4	DRILL TOOL	Dec10, 2019	8.50. 08	8.54. 49	4.41
6	T9	DRILL TOOL	Dec10, 2019	9.00. 33	9.05. 12	4.39
7	T8	CHAMFE R TOOL	Dec10, 2019	9.08. 32	9.13. 08	4.36

(a)

(b)

Fig. 6 (a) Screenshot of monitoring the cutting tool status using ThingSpeak application for pocket and slot tool and (b) Summary of the cutting tool status for various cutting tool types

The table shows the start and finishes times of each tool tracked by ThingSpeak software, as well as the machining time required for each cutting tool to accomplish an operation. In the cloud, ThingSpeak in one central location maintains all information. A key is used to secure private data. This allows data to be stored and visualized in channels, which can be set to private or public. In addition, the channels can be configured for easy data analysis.

In the ThingSpeak channel, the state of each cutting tool is clearly shown. When the numeric value is 1, the tool is in the application; when it is 0, the cutting action has not occurred. Figure 6 (a) depicts an example of monitoring tool status with ThingSpeak. The pocket tool T2 and slot tool T5 status are displayed. The operation of the pocket tool begins at time 8.32.02 and ends at 8.34.30. During that period, the status in ThingSpeak shows status 1, indicating that the tool is in the active stage. The Slot operation status is 0, indicating that the tool is not in use. When the pocket operation is completed, its status changes to 0, and the sensor detects the slot tool. The slot becomes active and displays status one from the time 8.34.30 until 8.39.12. All of the cutting tools are monitored in the same way, and the results are shown in real-time on the ThingSpeak channel. Figure 6(b) shows a summary of the cutting tool status for the various cutting tools.

IV. Conclusion

Modern manufacturing relies on CNC machines to produce several products in a variety of industries, from automotive to aeronautical. Intelligent systems for monitoring can be developed using it. We developed a standard technique for designing wireless sensor networks for tracking the status of cutting tools in CNC machines in this paper. Sensors used in milling cutting tool systems detect the presence of particle photons with infrared wavelengths.

A study is carried out using the software ThingSpeak to determine the machining time and the cutting tool status. Each cutting tool's machining time is tracked in real-time by the ThingSpeak software, based on fields defined for various devices. As part of future work, collaboration robots will be used in monitoring and machining five-axis CNC machines.

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