A PC-BASED WIRELESS AND REMOTE CONTROL FOR SHAPE JUDGMENT EQUIPMENT USING A ZIGBEE MODULE

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Abstract- To increase manufacturing productivity, industrial automation is required. Additionally, in order to monitor the manufacturing process, a remote online monitoring and control system becomes compulsory. A conventional remote monitoring system often uses a wire connection for communication within a control center; however, it is time-consuming and inconvenient. To overcome this drawback, a wireless design is proposed for the manufacturing process. In this paper, a case study of a remote wireless monitoring network used in a shape judgment system is introduced. In order to connect the server pc and the PLC (a controller of a shape judgment system), a ZigBee wireless module in conjunction with a transparent mode is used. Additionally, the interface of the above system is established with a Visual Basic 6.0. One of the advantages in using a wireless network to connect with a server pc and a shape judgment system is that the server pc is movable. Moreover, the remote monitoring function at the client pc can also be utilized using a TCP/IP protocol. Consequently, a prototype of a wireless network and a remote control for a shape judgment system using a ZigBee module that reduces the cost in electrical power and saves time in the system's installation is exemplified.

Index terms: wireless, PC-based, ZigBee, remote.

I.   INTRODUCTION

In order to increase production in the manufacturing process, Frazelle [1] proposed an automation system in automatic warehousing. Moreover, in order to monitor and improve the current manufacturing progress, a monitoring and control network for the manufacturing system that uses a network is suggested by Suesut *et al.* [2]. Conventional plants often use wired connections to communicate with and control equipment. Chiu [3, 4] developed a PC-based multi-function aquarium remote controlling system and a greenhouse automatic thermal control using a wired connection and TCP/IP protocol in 2010. In addition, Chiu *et al.* [5] Presented a PC-based remote network controlling system with three-axis robot manipulation using a TCP/IP protocol and a wired connection between the controller (PC) and the equipment. In 2012, Cheng *et al.* [6] assessed a web-based remote monitoring system for noise and temperature within an enclosed air compressor using a wired connection.   However, the wired system is expensive and time-consuming. In addition, there is no flexibility for altering equipment allocation in the plant. In order to avoid interference from internet wiring with the existing equipment, a wireless network for the manufacturing system is necessary.

Ikram and Thornhill [7] assessed various wireless communication techniques used in the automation field. They found that the WiMedia had a fast communication speed. Also, both wireless ZigBee and wireless Bluetooth were suitable for short distance communication. Even though there are drawbacks (slow speed and short distance communication) for the ZigBee, because of a simpler system structure and lower electric power exhaust, the ZigBee module is widely used in wireless sensing and is increasingly used in automation monitoring systems. Palanisamy et al. [8] developed a wireless monitoring system for controlling the DC motor, temperature, and lighting using a wireless ZigBee. Palit [9] designed wireless communication sensing networks for tunnels, trains and building. Ding *et al.* [10] established an environmental monitoring system using a wireless ZigBee module. Wang *et al.* [11] presented an intelligent fuzzy controller for air-conditioning with Zigbee sensors. Ropponen *et al.* [12] also developed a low-frequency localization and identification system with a ZigBee network. Moreover, Wang *et al.* [13] developed a visual navigation and remote monitoring system for an agricultural robot using a wireless local area network (LAN), a slave computer, and a host computer.

In this paper, to reduce manpower in a shape-judged system, a remote wireless monitoring and control system for a shape-judged system is assessed and exemplified. To overcome the above drawbacks, a set of wireless ZigBee modulus used to communicate between the server pc and the programmable logic unit (PLC) is adopted. Moreover, a remote control and monitoring system at the client pc using a TCP/IP protocol is also used.

II.   A PC-BASED REMOTE WIRELESS MONITORING AND CONTROL SYSTEM

The connection of the monitoring system is shown in Fig.1. As indicated in Fig. 1, one piece of shape-judged equipment is controlled by the programmable logic controller (PLC). The PLC will communicate with the near field (server pc) via the ZigBee wireless network. Moreover, the remote field (client pc) will audit the shape-judged equipment via the TCP/IP protocol [3, 4, 5].
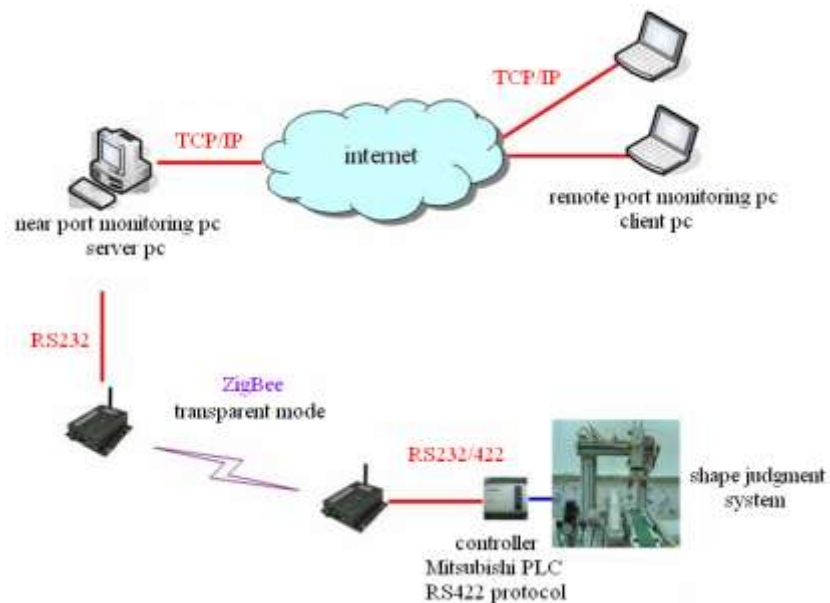

Fig. 1 The connection of the monitoring system

a.   Function of the Shape-judged Equipment

As indicated in Fig. 2 [14], the working pieces in both the circular shape and rectangular shape will be fed into the system at location A via a conveyor. Shape recognition for the work piece using a sensor will be performed at location A. Concerning the circular shape, the work piece will be forwarded to location C by using a bridge type robotic arm; otherwise, the work piece with a rectangular shape will be sent to location D.
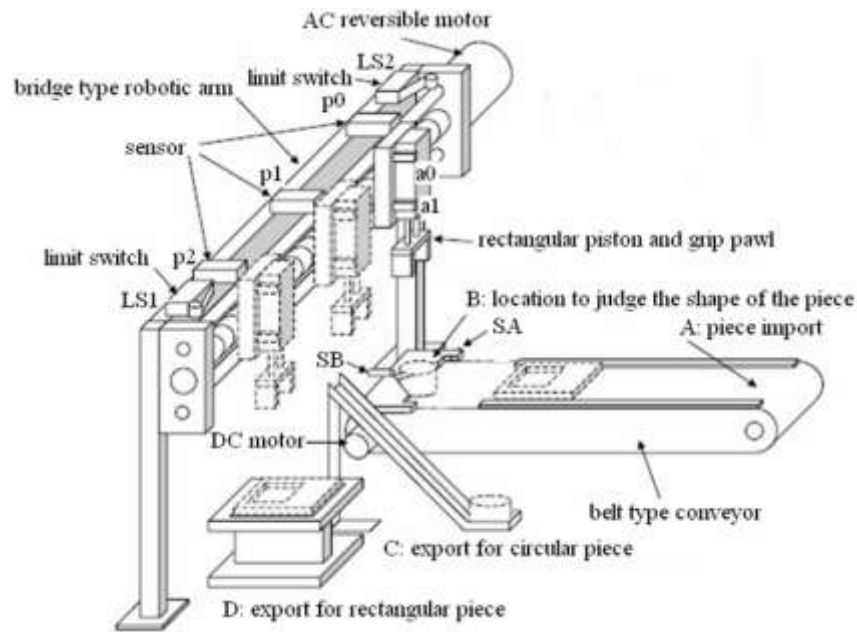
Fig. 2 The shape judgment equipment [14]

b. Shape Judgment Equipment Sensor

The proximity switch used to detect an object has been widely adopted in the automation field. The SA in Fig.2 is a sensor for feeding the working piece. It is a photoelectric sensor. The object is identified by projecting a light ray to on it, reflecting that lighting to a receiver, and judging the received light intensity. Moreover, the SB in Fig.2, a sensor for a circular piece, can identify both circular shapes and rectangular shapes. It is a capacitive sensor. A high frequency magnetic field on the electrode panel will be induced when the object is close to the sensor. The motion and position of the object can be predicted by observing the sensor's variance of capacitance.

c. System Operation and the PLC's Communication Format

An FX2n PLC (Mitsubishi brand) with a 32-bite CPU is adopted for the system. There are sixteen input joints (X0-X7 and X10-X17) and sixteen output joints (Y0-Y7 and Y10-Y17). To facilitate control by the PLC, the X and Y joints are connected to the related sensors and actuators. Moreover, a RS-422 port which is used to communicate with the server pc to read in /write out the PLC program is built into the FX2n PLC. To facilitate the near field monitor, the RS-232 serial interface at the server pc is connected to the RS-422 port at the PLC. In addition, the system's server pc and the PLC will serve as the master and the slave. The master (server

pc) will actively submit the command to the slave (PLC). Also, the slave (PLC) will respond to the message after it receives the command from the master. The slave cannot actively submit the command to the master.

The communication parameters between the server pc and the PLC include the following:

· Transmission format: RS232, asynchronous, and two-way transmission.

· Transmission rate: 9600 bps.

· Parity check: even parity.

· Data bit: 7 bits.

· Stop bit: 1 bit.

· Data comparison: checksum detection.

· Transmission character: ASCII code.

As indicated in Table 1, the command format submitted from the server pc to the PLC is composed of a head code, a command, an address/data, a stop code, and a checking code. The related features are listed below:

Table 1: The command format of the host computer port

The head code	Command code	Address/data	The end code	Checking code
STX (02H)	CMD	DATA	ETX (03H)	SUM

Here, head code (STX) is the first bit of the command string set as 02H. Command code, one bit, is the length of the command code shown in Table 2.

Table 2: The category of command for the host computer port

Command code	Object	Function
0	XYMSTCD	Read the data from the grouped element
1	YMSTCD	Write the data into the grouped element
7	YMSTC	Force single joint to be ON
8	YMSTC	Force single joint to be OFF

The address and data indicate that the object's initial address and numbers in the PLC shall be given before a read/write to the PLC is performed. The end code (ETX) is the last bit of the command format set as 03H. Moreover, the checking code (SUM) is the summation of the related ASCII with respect to the command code, address/data, and end code. The last two bits of the total ASCII data are extracted and serve as the checking code (SUM code).

The PLC will analyze the command (submitted from the server pc), execute the mission, and respond to the server pc. Here, a response will be made when the PLC receives a command code of 0. The response format is shown in Table 3. In addition, the response format for a command code of 1, 7, and 8 from the PLC is ACK (06H) if the PLC can recognize the command. The PLC will respond to the server pc using NAK (15H) if it cannot recognize the command.

Table 3: The response format of the command code 0 for the host computer

Head code	1st data set	2nd data set	…	Last data set	End code	Checking code
STX (02H)					ETX (03H)	SUM

d. ZigBee Wireless Network

The ZigBee is a short-distance communication technique. It is organized using a Physical layer (PHY), a Media Access Control Layer (MAC), and a Data Link. All are specified by the IEEE 802.15.4. Moreover, the logic network, the data transmission, the applied interface specification, and the communication specification for the products are specified by the ZigBee Alliance.

The effective distance for the ZigBee transmission is between 150~200 meters. The data transmission rate is 20K~250K bps. Because it has a lower effective transmission distance and rate than the Wi-Fi and the Blue-tooth, the ZigBee is confined to a lower data transmission field. However, because of low electrical exhaust, large network nodes, and low cost, the ZigBee has been developed for environmental monitoring, automatic control, process monitoring, building automation, and medical sensing.

The ZigBee wireless module used in this paper is the IP-Link series (Helicomm brand). It provides the system with a RS-232/RS-485 interface. In addition, the ZigBee uses a full mesh in

the network structure. It also has Master/Slave characteristics and can perform a two-way communication. A frequency range of 900MHz and 2.4GH (free of charge) is also used.

The IP-Link provides three kinds of modes: a binary protocol mode, a transparent-broadcast mode, and a transparent – P2P mode.

· Binary protocol mode:

Based on the command format of the ZigBee, a binary command is written by the user. The data packet submitted from the pc (server pc) will be transmitted to the IP-Link Master via the RS-232/RS-485 protocol. Thereafter, according to the communication format, the IP-Link Master will send data to the specified IP-Link Client. The IP-Link Client will routinely send back data to the IP-Link Master. The related data will also be forwarded to the pc (server pc) via the RS-232/RS-485 protocol.

· Transparent-broadcast mode:

Aside from the ZigBee's command format, the user can freely submit the data to the IP-Link Master via the RS-232/RS-485 protocol. The IP-Link Master will then send the data to all the IP-Link Clients linked in the ZigBee network. Similarly, all the IP-Link Clients will be preset to send back the data to the IP-Link Master. Also, the IP-Link Master will forward the data to the pc (server pc) via the RS-232/RS-485 protocol.

· Transparent – P2P mode:

Aside from the ZigBee's command format, the user can freely submit the data to the IP-Link Master via the RS-232/RS-485 protocol. The IP-Link Master will then send the data to the specified IP-Link Clients. The IP-Link Client will be preset to send back the data to the IP-Link Master. The related data will also be forwarded to the pc (server pc) via the RS-232/RS-485 protocol.

The transparent P2P mode is adopted in this paper. The ZigBee wireless network can also function as the wireless RS-232/RS-422 tunnel.

e. Monitoring Host PC

The monitoring host pc includes a near port (server pc) and a remote port (client pc). An interface programmed by the VB 6.0 is used to link both the server pc and the client pc.

· Server port:

The server port (server pc) provides two paths of communication: one is between the server pc and the PLC via the serial RS-232 protocol; the other is between the server pc and the client pc via the TCP/IP. Multiple client pcs can be logged into the server pc simultaneously.

· Client port:

A monitoring interface will be provided on the client pc's screen. The user can operate the interface dialogue to send the command to the server pc via the TCP/IP protocol. Moreover, the server pc will also execute the command to implement the near port equipment.

III.   EXPERIMENTAL RESULTS

The experimental work for the wireless network and a remote control for a shape judgment system have been performed using the interface of the server pc shown in Fig. 19. First, a rectangular piece is placed in the feeding place. As indicated in Figs. 3 and 4, a rectangular piece is detected, identified, and gripped by the gripper. Figs. 5-8 indicate that the rectangular piece is transported to the targeted discharging place (p2) by the robotic arm.
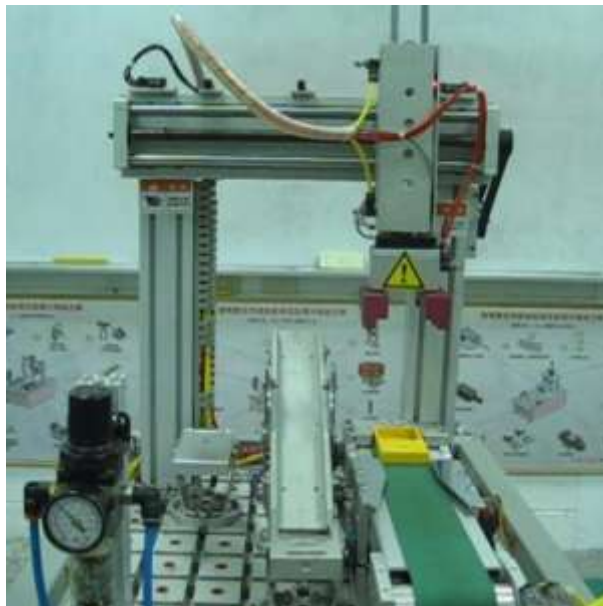

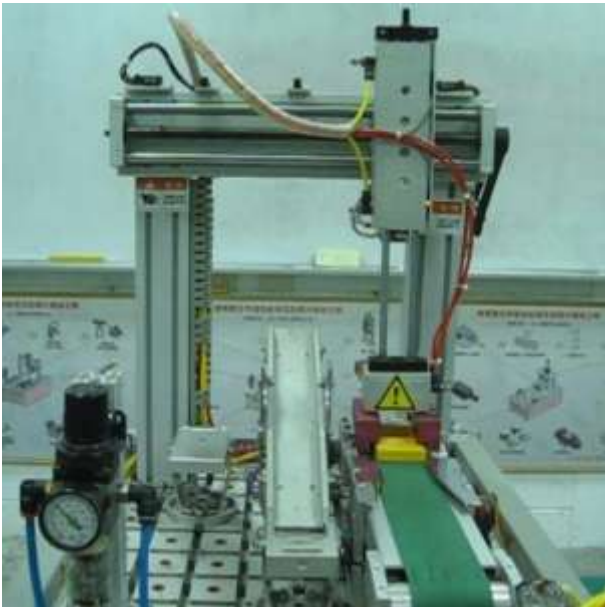Figure 3. Detection of a rectangular piece

Figure 4. Gripping of a rectangular piece

Figure 5. Movement of a rectangular piece (step 1)

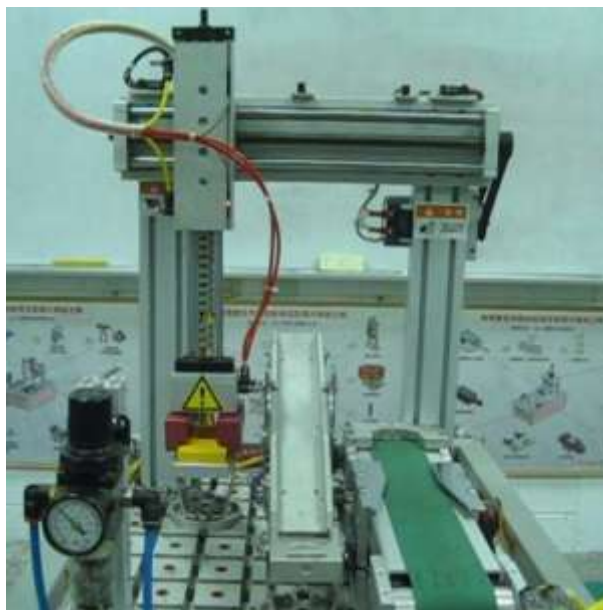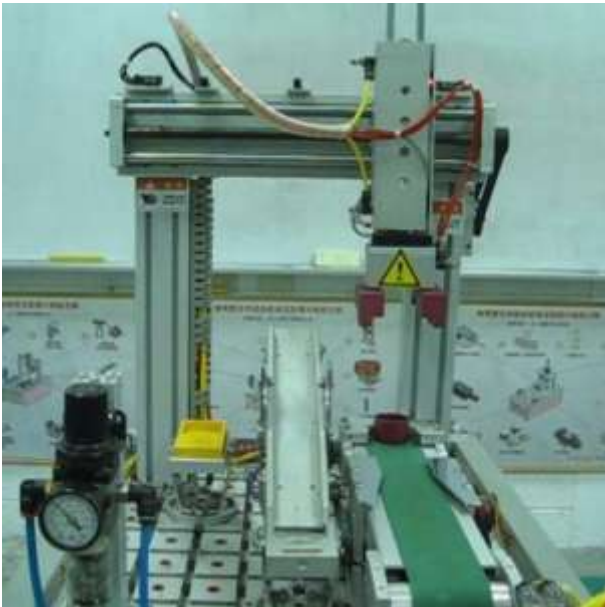Figure 6. Movement of a rectangular piece (step 2)

Figure 7. The discharging place (p2) for a rectangular piece

Second, a circular piece is placed into the feeding place. As indicated in Figs. 8 and 9, the circular piece is identified and then gripped by the gripper. Thereafter, the robotic arm catches the object and forwards the circular piece to the discharging place (p1) of a circular piece via a slideway as shown in Figs. 10-12.

Consequently, the shape judgment system can automatically identify the shape of the working pieces and transport them to the targeted discharging place.
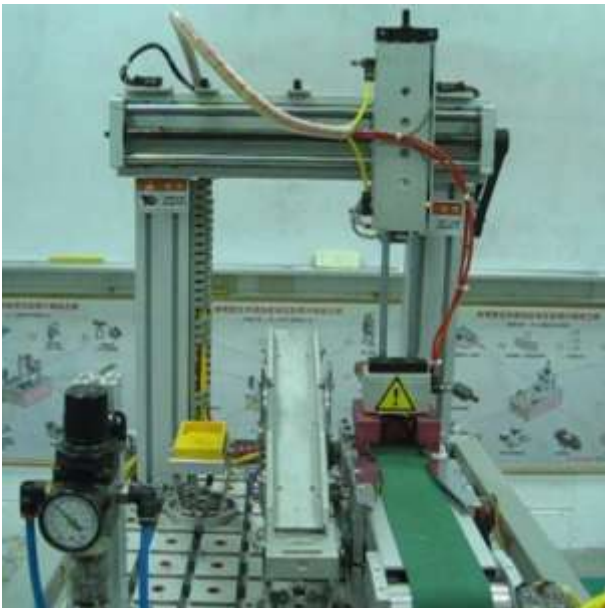
Figure 8. Detection of a circular piece

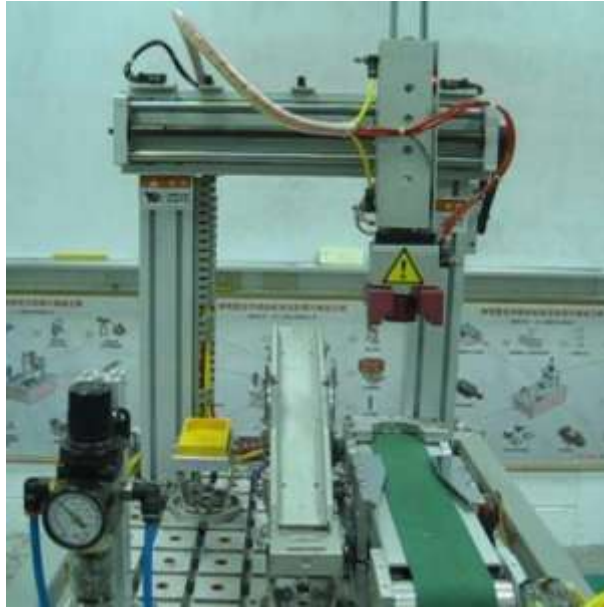Figure 9. Gripping of a circular piece
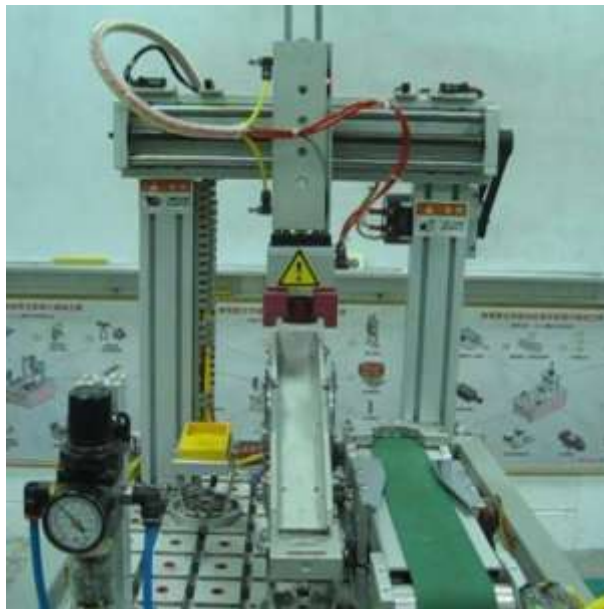
Figure 10. Movement of a circular piece (step 1)
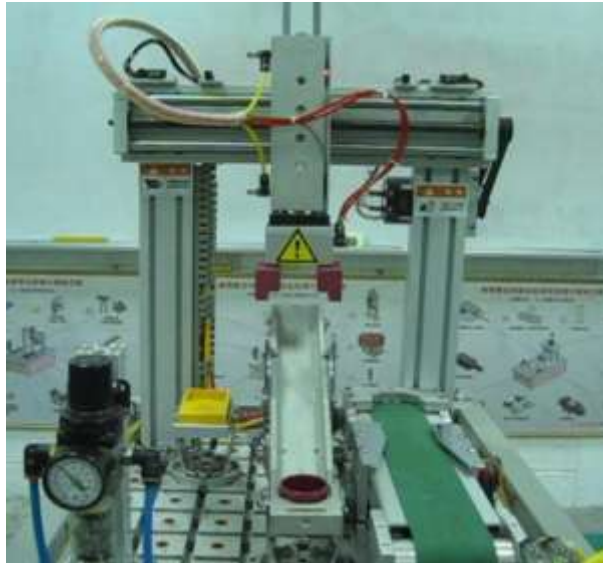

Figure 11. Movement of a circular piece (step 2)

Figure12. The discharging place (p1) for a circular piece

IV. RESULTS AND DISCUSSION

a. Results

The hardware and software of the system implemented with a prototype are described below:

· Setup of the shape-judged equipment:

Two pistons (piston A and piston B) are included in the system. Piston A is responsible for moving the robotic arm up/down. Piston B is responsible for the fastening/releasing of the work piece via the gripping palms. The related air-driven loop diagram is depicted in Fig. 13. Moreover, two motors are applied in the system: one is the DC motor used to actuate the conveyer; the other is the reversible AC motor used to rotate the bridge-type screw pole which can move the robotic arm horizontally. The related motor's circuit diagram is shown in Fig. 14. The planned PLC's joint allocation is also shown in Table 4.
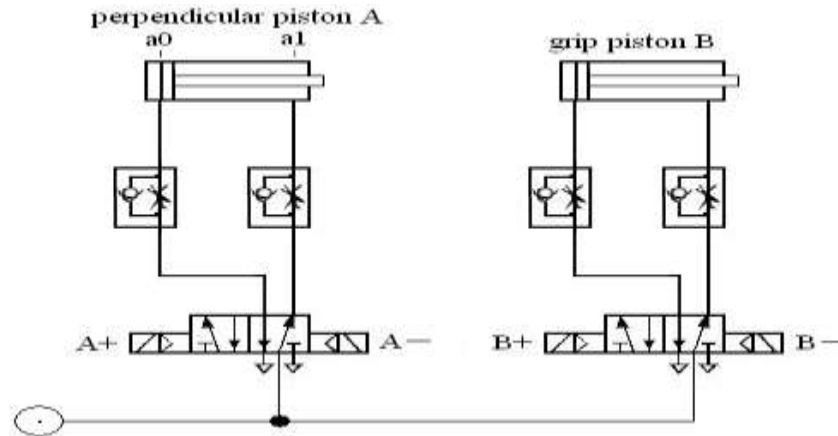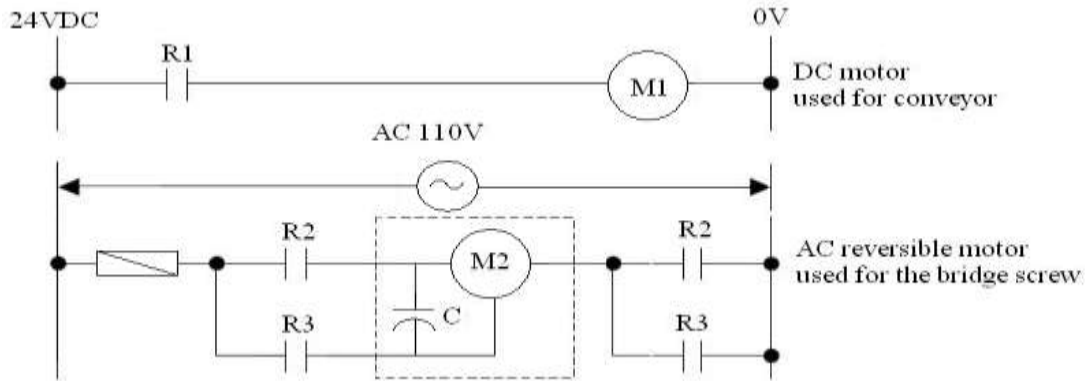
Figure13. The related air-driven loop diagram

Figure14. The motor's circuit diagram

Table 4 Planning of PLC's joint

Input point		Output point	
X0	St: start up	Y0	M1 + : conveyer's motor ON
X1	P0: location of the robotic arm	Y1	M2 + : robot arm move left
X2	P1: location of the robotic arm	Y2	M2 - : robot arm move right
X3	P2: location of the robotic arm	Y3	A + : perpendicular piston move forward
X4	SB: sensor for circular piece	Y4	A - : perpendicular piston move backward
X5	SA: sensor for rectangular piece	Y5	B + : air-driven grip palm ON (catching)
X6	a0: upper LS of the piston	Y6	B - : air-driven grip palm OFF (loosen)
X7	a1: lower LS of the piston	Y10	GL: green light ON

X10	EMS: emergent stop	Y11	RL: red light ON
X11	COS1: reset	Y12	YL: yellow light ON
X12	COS2: step by step procedure		

· PLC program:

The related design diagram of the PLC's control program is shown in Fig. 15.
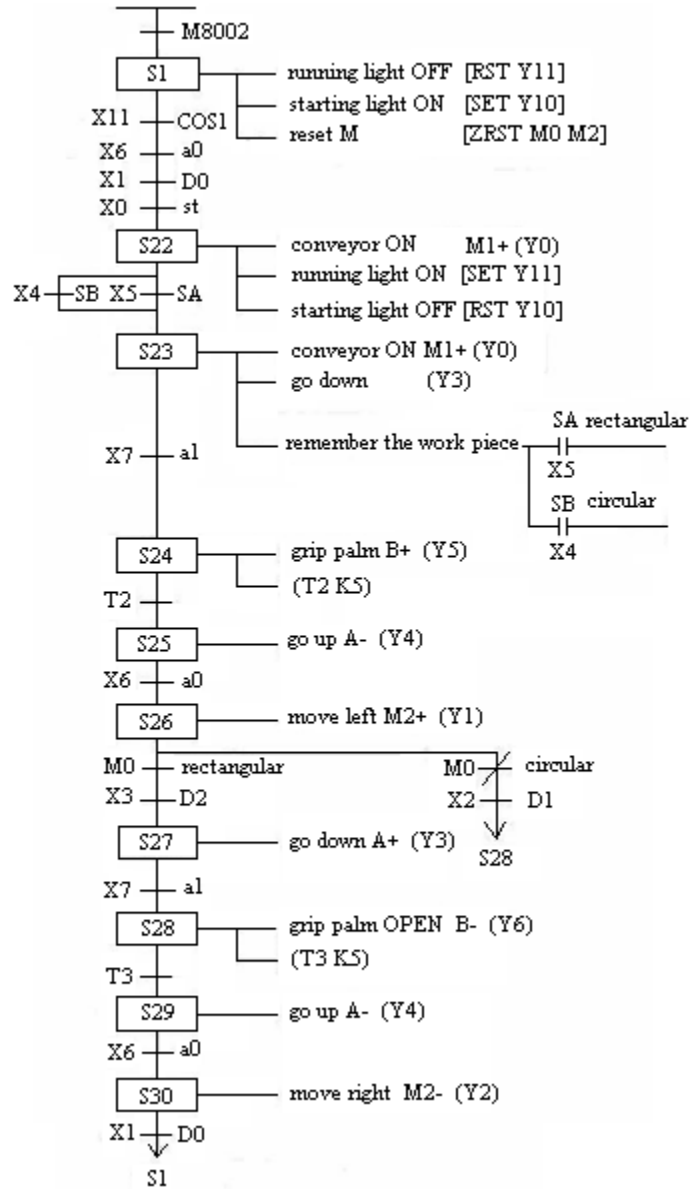

Figure 15. The design diagram of the PLC's control program

· Planning of the interface joints between the PC and the PLC:

In order to monitor and control the PLC via the server pc serial communication, the M joints of the auxiliary relays are added to the PLC program. The M joint is connected in parallel with the related push button (X joint). The related planning of the interface joints is shown in Table 5.

Table 5 PLC planning of M joint (auxiliary relay) in the PLC

Button	Auxiliary joint
st	M100
EMS	M101
COS1	M102
COS2	M103

· Setting for the ZigBee wireless module:

The parameters of the ZigBee wireless module (IP-Link) should be initialized in advance by using tool software before the system is started. The IP-Link connected to the RS-232 at the server pc is defined as the Master. The related parameter setting is also shown in Fig. 16. As indicated in Fig. 16, the Master is selected at the Node Type column and the Node ID is automatically preset at 0. In addition, in order to setup the IP-Link to the Client that is connected to the RS-232 at the PLC, the parameter setting process is performed and shown in Fig. 17. As indicated in Fig. 17, the Client is selected at the Node Type column and the Node ID is preset as any number except 0. Moreover, the setting for other parameters such as the Channel and the Net ID preset in the IP-Link Master and the IP-Link Client should be the same. Also, the Mesh is selected from the Topology column. Consequently, as indicated in Fig. 18, the transparent mode will be established when serial communication is setup.
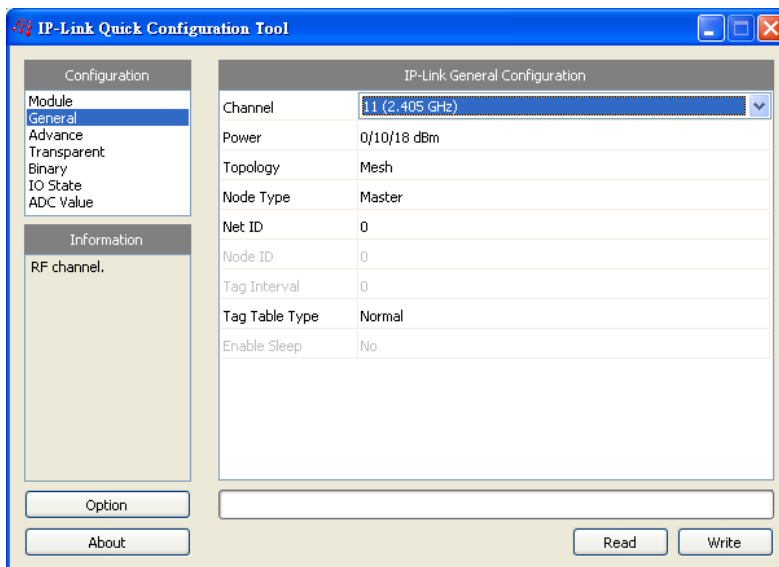
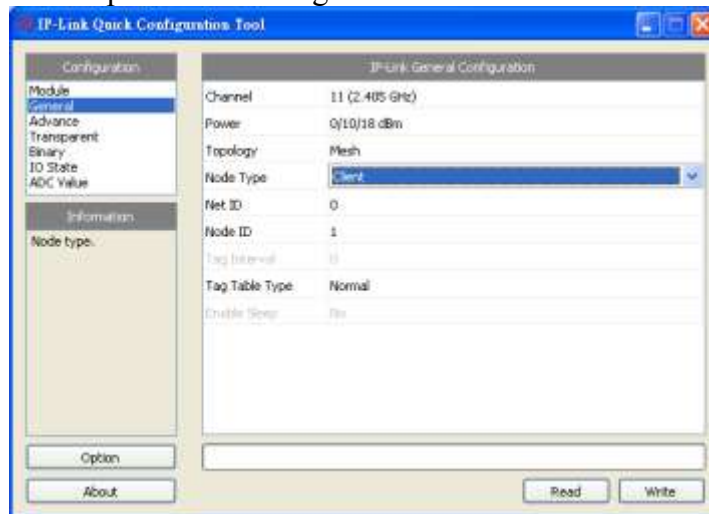Figure 16. The parameter setting for the IP-Link Master at the server pc

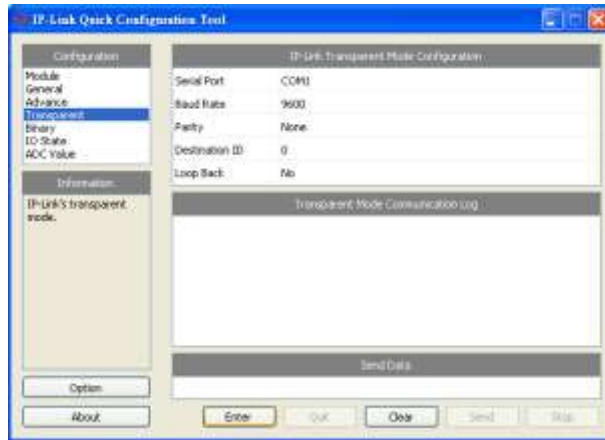Figure 17. The parameter setting for the IP-Link Client at the client pc

Fig. 18 The complete transparent mode with a serial communication setup

· Communication program between the server pc and the PLC:
The interface of the server pc is designed and shown in Fig. 19.

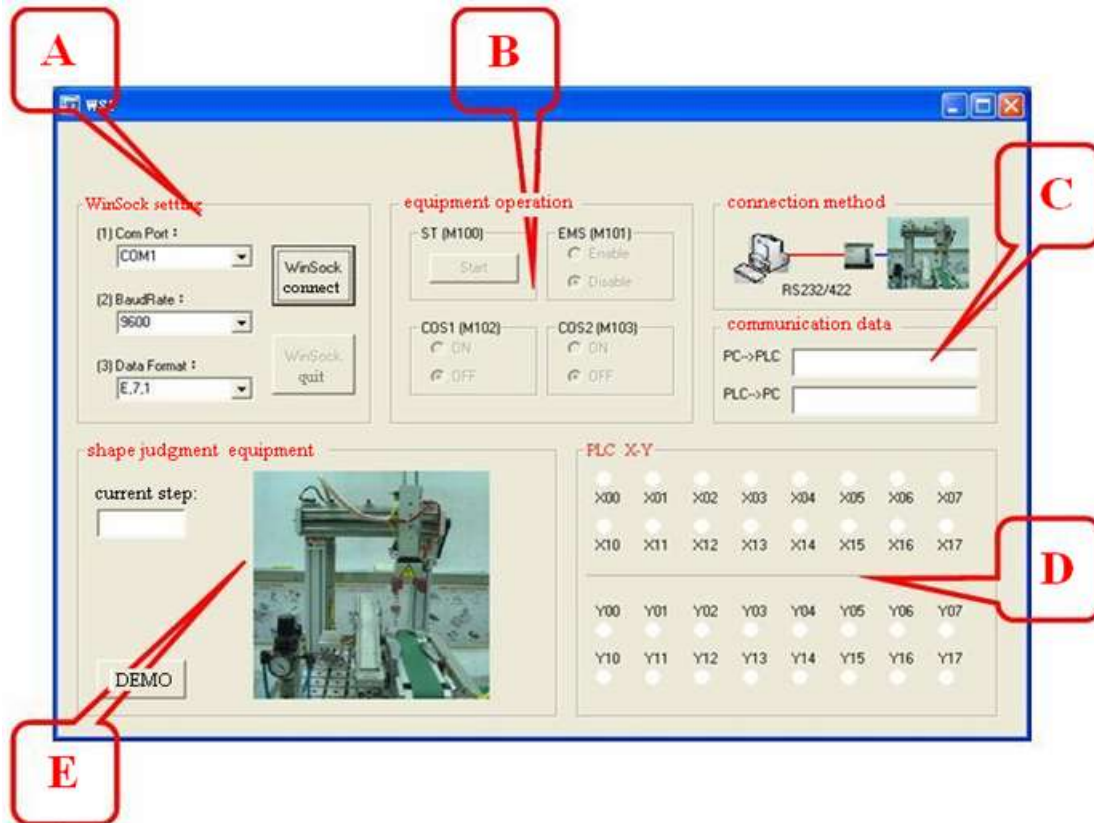Figure 19. The interface of the server pc

The PLC will be monitored by serial communication and the related controlled area will be divided into five regions (A~E). For the Area A, with regard to the setting of the serial communication parameters, COM Port is selected. The transmission speed is 9600 bps. Additionally, in order to meet the communication format of the Mitsubishi PLC, even parity,

seven bits of data, and one bit of stop bit are selected. With regard to the Area B, a command zone, the M100~M103 can be forced ON or OFF to actuate the actions (start, emergent stop, reset, and step control) by using the PLC's command 7 and 8 shown in Table 6.

Table 6 The command information of the PLC's M joints forced by the pc.

Auxiliary joint		content
M100	ON	STX + "76408" + ETX + CheckSum
	OFF	STX + "86408" + ETX + CheckSum
M101	ON	STX + "76508" + ETX + CheckSum
	OFF	STX + "86508" + ETX + CheckSum
M102	ON	STX + "76608" + ETX + CheckSum
	OFF	STX + "86608" + ETX + CheckSum
M103	ON	STX + "76708" + ETX + CheckSum
	OFF	STX + "86708" + ETX + CheckSum

Area C shows both the command message (submitted from the PC to the PLC) and the response message (sent from the PLC to the PC). Regarding Area D, it is used to show the online status (ON or OFF) of the X joint and the Y joint of the PLC. Status can be obtained by submitting the command 0 from the PC to read the data from the X object and Y object. The related information is shown in Table 7. Regarding Area E, a zone is designed to show the status of the current action by posting the equipment's photos on the zone. This will facilitate a convenient observation point.

Table 7 The command information of the PLC's X and Y elements which will be read on the pc.

Grouped element	content
X0-X17	STX + "0008002" + ETX + CheckSum
Y0-Y17	STX + "000A002" + ETX + CheckSum

The monitoring program will implement serial communication by using the MSComm in the VB6.0 program. Here, the setting of the serial port is MSComm1.CommPort = 1 and the setting of the serial communication parameter is MSComm1.Settings = "9600, E, 7, 1." In addition, to open the serial port, the setting will be MSComm1.PortOpen = True. Moreover, the data submission and the data reception are set as MSComm1.Output = DataString and RspString = MSComm1.Input, respectively. Consequently, the setting for closing the serial port is MSComm1.PortOpen = False.

· Program design of the server pc and the client pc communication:

TCP/IP communication between the server pc and the client pc is performed using the Winsock in the VB6.0 program. The server pc can be connected with multiple client pcs. The related communication diagram is shown in Fig. 20.
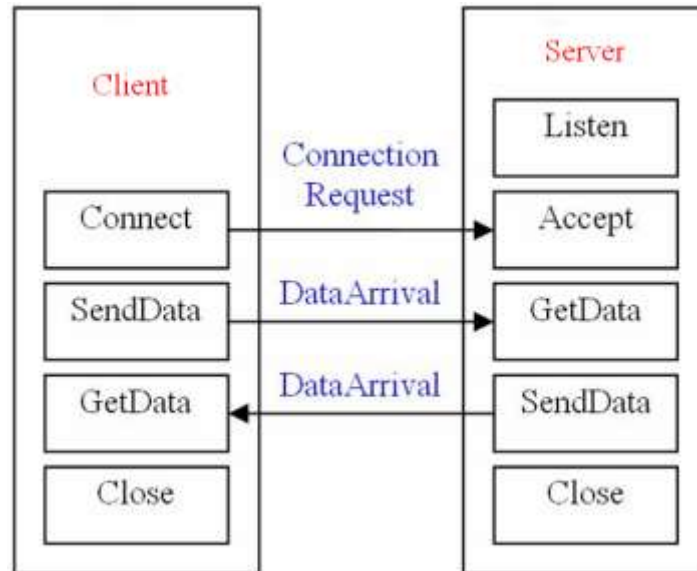

Figure 20. The communication diagram between the server pc and the client pc

Because the server pc establishes a connection platform (function) for the client pc, a condition of "Listen" for the server pc is necessary. The server pc will wait for a connection from the client pc after "Listen" is ready. Moreover, because one WINSOCK object at the server port is used to provide a connection for one client only, for a multi-client network; multiple WINSOCKs are used in the server pc's program. Therefore, multiple WINSOCKs will be produced by using the "Load" command. One of the WINSOCKs (Winsock1 (0)) is responsible for serving as the "Listen" function. A "Local Port" will be preset as the "Listen" port.

To connect at the client pc, the WINSOCK in the client pc will submit a connection request to the server pc using "Connect" via the WINSOCK object. The server pc's "Port Number" (at "Listen") needs to be assigned as the WINSOCK's "Remote Port."

For "Accept" at the server pc, the server pc will receive a Connection Request event from the client pc when the client pc submits a "Connect" request. The server pc will accept the client pc's connection request by using "Accept" via a new WINSOCK.

For "SendData" at the client pc, the client pc can send the data to the server pc by using "SendData" when the internet connection between the server pc and the client pc is completed.

For "GetData" at the server pc, the server pc will receive a Data Arrival event from the client pc when the client pc sends data to the server pc. At the same time, the server pc will also receive data by way of "GetData."

For "GetData" at the client pc, the client pc will produce a DataArrival event when the server pc sends data to the client pc. Simultaneously, the client pc will also receive data by using "GetData."

For "Close", the connection is ended using "Close" when the purpose of the communication is achieved.

b. Discussion

A monitoring system is used to wirelessly control shape-judged equipment using the ZigBee wireless module. It can also remotely control equipment at the client pc when connected to the server pc via a TCP/IP internet. The resulting interfaces and dialogues are shown in Fig. 21. As indicated in Fig. 21, area A is the WinSock parameters' setting zone for the client pc.

Figure 21. The interface of the client pc

V. CONCLUSION

It has been shown that a near port/remote port monitoring and control online system for shape-judged equipment is established using the internet in conjunction with a ZigBee wireless module and serial communication techniques. The monitoring system's structure is based on the PC. The interfaces of the server pc and the client pc are programmed using the VB6.0 program. In addition, the server pc will communicate with the PLC using the ZigBee wireless module. Therefore, shape-judged equipment can be wirelessly monitored and controlled online. Moreover, the shape-judged equipment can also be remotely monitored and controlled at the client pc using a connection between the server pc and the client pc via a TCP/IP internet.

The user can obtain the current status of the X joint and the Y joint on the monitoring screen (at server pc/client pc). The related actions such as start, emergent stop, reset, and step motion will be implemented by the user via the M joint. The corresponding photo of the action posted on the screens (at server pc/ client pc) will also be updated simultaneously.

Consequently, an online monitoring system that can remotely and wirelessly control shape-judged equipment indeed provides an economical way to reduce manpower.

ACKNOWLEDGMENTS

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