

Visualization and Communication System for Robotic Head Control

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Abstract – This article describes the design and implementation of visualization and communication system used to control a robotic head. This document also describes the solution for communication protocol used by internal data bus of the robotic equipment and the proposal for communication protocol used to communicate with the visualization system section. Verification method and testing of the proposed cyber head system is described at the end.

Keywords- visualization; communication; robotic head; PXN20; Freescale MQX.

I. INTRODUCTION (HEADING 1)

In the last few years we have seen many advances in robotics in the effort to replace, accelerate, and enhance quality and reliability of human labour and human decision making process. This trend may also be observed in the automation of production lines and in product quality management systems. Another tendency is the deployment of robotic systems in health care, reconnaissance, military systems and in many other systems. A very interesting example is the head of a robotic child called Affetto, which has been specially developed to simulate cognitive development of a human child [1].

The robotic head is equipped with multiple sensors which detect environmental perceptions and with many motion apparatuses to create a real child facial expressions. Another very interesting example is a robotic head that can track a moving object in 3D space [2]. This redundant system is designed to be easily deployed in another robotic system. The excellent ability to track the subject is not closely related to the kinematic model of the robotic head. Also development platform researches, designed to explore the autonomous learning ability of the monitoring system have already been published. Very successful is an anthropomorphic robotic head project with four free axis [3]. The robotic head is equipped with a pair of CCD sensors used to scan the picture, and with speakers and microphones.

The robotic head can be used for support of senior citizens independent life in Smart Home with view to the residents' needs [4]. Seniors citizens preferred voice control of operational and technical functions in Smart Home [5]. There is necessary solve additive noise cancelling in Smart Home real environment [6], [7].

This work focuses on the design and development of control and visualization section, and on innovation and development of the cyber head control system. The cyber head control system is divided into four parts:

- monitoring and processing of surrounding images,
- acoustic signal scanning, analysis and reproduction,
- the head mechanical system,
- control of system data flow and interpretation of data collected by observers through the use of the visualization application.

The common goal of the development team is to design and construct a modular robotic model of a human head, which will be able to detect both visual and audio signals in the environment and appropriately respond to them.

II. COMMUNICATION SYSTEM DESIGN

The communication system of the control and visualization system of the cyber head uses two communication standards. CAN bus was selected to implement communications in the DCS. The second communication channel is used to communicate with DCS computer (or tablet, or other mobile device), where the user application is running. Due to the project requirements, Ethernet communication standard was selected. The base of the cyber head control system consists of five basic modules. The purpose of each module corresponds to the primary function of individual sections. These include video signal processing modules, audio signal processing module, mechanical control module and communication module (Fig. 1), [8], [9], [10], [11]. CAN bus was selected to ensure communication in the cyber head control system. The main reason for this choice was the flexibility, scalability and reliability of this bus. A communication system for the robotic device was created based on a design. Connection between individual DCS components is seen on the block connection diagram (Fig. 2). Under this concept the visualization may be connected to a router wirelessly or via Ethernet. Visualization version for mobile devices is connected wirelessly (no Ethernet connector). Version for PC visualization may use both connection options.

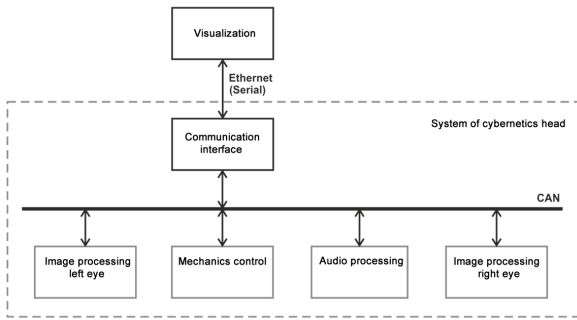


Figure 1. Block diagram of the communication system.

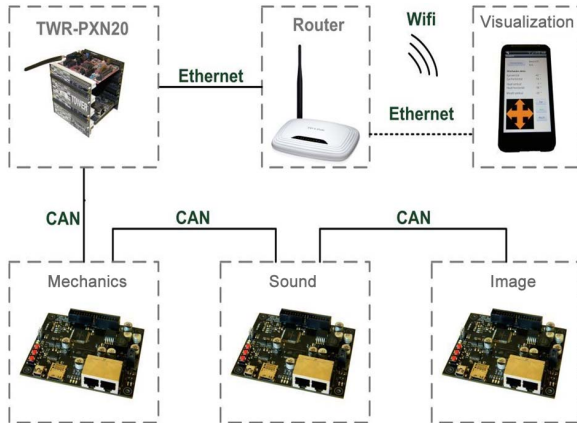


Figure 2. Interconnection of DCS modules.

In this communication system data messages are transmitted via TCP protocol (Fig. 3).



Figure 3. TCP segment data message structure.

The application uses 11bit message identifier (CAN2.0A). Table 1 shows the basic division of identifiers for individual modules.

TABLE I. MODUL ADDRESS TABLE

HEX	MSG ID											MSG NAME
	10	9	8	7	6	5	4	3	2	1	0	
0x100	0	0	1	0	0	x						MECH GENERAL ID
0x0c0	0	0	0	1	1	x						SND GENERAL ID
0x080	0	0	0	1	0	x						VID1 GENERAL ID
0x040	0	0	0	0	1	x						VID2 GENERAL ID
0x7c0	1	1	1	1	1	x						PXN GENERAL ID

Message identification ranges for each module are listed in Table 2.

To ensure a rapid responses of all participants involved in the communication network - where the robotic head system is connected, it is recommended to use short messages. Individual queries and communication protocol messages are divided according to the nature of the message. Separation is based both on the assumption that future communication systems will be developed and

expanded further, and therefore, the messages are divided according to modules:

- Mechanic system module - messages start at 0x014 address.
- Audio processing module - messages start at 0x028 address.
- Image processing module - data of the first module start at 0x03C address and the second module at 0x050 address.
- Communication module - messages start at 0x064 address.

TABLE II. TABLE SHOWING MESSAGE IDENTIFIER RANGE

Module	Transmitting			Receiving		
	min.	-	max.	min.	-	max.
MECH	0x120	-	0x128	0x100	-	0x108
SND	0x0e0	-	0x0f1	0x0c0	-	0x0d1
VID1	0x0a0	-	0x0b0	0x080	-	0x090
VID2	0x060	-	0x070	0x040	-	0x050
PXN	0x7e0	-	0x7e0	0x7c0	-	0x7c0

Another method used to divide messages is to divide variables (result values) and static parameters, which is based on the assumption that the variables will be transmitted more often than configuration parameters. Table 1 shows the complete list of individual message identifiers.

TABLE III. DATA MESSAGE IDENTIFIATORS

MSG ID		MSG NAME
HEX	DEC	
0x014	20	MECH GENERAL ID
0x015	+1	MECH VALUES
0x016	+2	MECH PARAMS
0x028	40	SND GENERAL ID
0x029	+1	SND VALUES
0x02A	+2	SND PARAMS
0x03C	60	VID1 GENERAL ID
0x03D	+1	VID1 VALUES
0x03E	+2	VID1 PARAMS
0x064	100	VIRTUAL
0x065	+1	SYSTEM INFO

III. USER INTERFACE - VISUALIZATION

User interface - visualization is used to display predefined data to the user in a clear form. The robotic head system is primarily equipped with visualization software developed on software platform .NET Framework 4.0 (Windows OS) in C#. This visualization has all the tools necessary to manage and control the system according to project specifications. Additionally, it also contains several types of displays that show the desired variables, recordings and evaluation statistics. The secondary visualization system is a visualization for mobile devices running Android OS. This visualization is designed for simple control of the robotic head system and for basic

diagnostics. The application structure is evident from the block diagram (Fig.4).

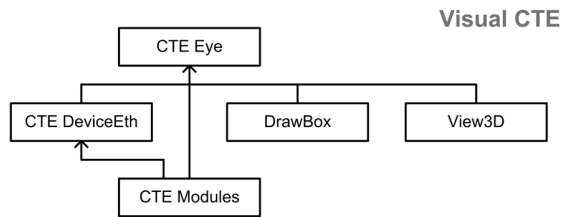


Figure 4. Visualization application block structure.

The core of the rendering application called Visual CTE is the CTE Eye component, which contains the entire window structure of the visualization application. CTE Eye implements user access in visualization. CTE DeviceEth block represents a library for communication with the real device. CTE Modules block includes implementation of data variables for individual robotic head modules. The purpose of the visualization application requires a graphical display of the current rotation position of the robotic head. Among other things, 3D head model is used for this purpose, which is controlled in the same identical way as the real model. 3D model rendering is done with View3D library. Another very important user library is DrawBox, which allows rendering of detected objects through the use of the image processing module and use in other application. Visualization application consists of various visualization forms. Each visualization form is equipped with different controls used for the implementation of the desired objective of the visualization process.

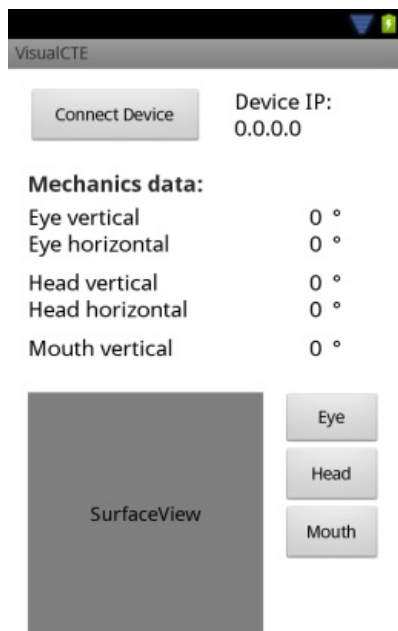


Figure 5. GUI visualization for Android.

Visualization application designed for Android OS and therefore for mobile devices. It has been designed as a very simple and transparent system used for basic controlling and setting of the robotic system. Visualization consists of three basic components. The first part is the main activity which forms the GUI

(Fig. 5), and which implements methods used to input user requirements and for visualized data output. The second part is the programming communication interface with communication module CTEDevice, which implements all tools necessary for compiling, transmitting and receiving data from the communication channel. The third and last part is the interface, which is used to identify devices connected to the subnet.

I. MEASUREMENTS AND VERIFICATION OF THE ROBOTIC EQUIPMENT

Testing of the robotic device along with communication and visualization system is divided into several separate parts. The first tests were carried out on the actual communication module. Mostly FREESCALE MQX properties were tested. The second step of the test was to verify the communication system. This step included verification of communication via CAN bus and Ethernet. A very important test performed on the communication module, was the verification of how data in the module are generated and parsed. The penultimate test was to check the HTTP server that runs on the communication module. The last category of tests aimed to verify the complete functionality of the system. Because of the large amount of information, only parts selected for testing and verification of the cyber head are described.

A. TWR-PXN20 testing with FREESCALE MQX

Implementation of FREESCALE MQX in the communication module has been tested on an ongoing basis during the firmware development. FREESCALE MQX did not crash by itself during the development. Targeted testing of FREESCALE MQX was focused on the processing speed of some key operations. Selected key properties and measurement results are shown in Table 4.

TABLE IV. TABLE SHOWING SELECTED FREESCALE MQX PROPERTIES

Attribute	Time of duration(μ s)
Creating of fibers	137,037
Cancellation of fibers	7,338
Event creation	10,225
Creating of semaphore	11,037
Creating of mutex	14,412
Locking of mutex	6,675
Unlocking of mutex	6,612

B. Complete robotic equipment testing

Verification of the entire robotic equipment using communication and visualization system was conducted in three phases:

The first phase focused on verifying the accuracy of data communications across the entire communication system. This phase has been conducted continuously, while the robotic equipment was being put into operation. Testing was conducted

in the following way. All modules were connected to the communication system without any peripherals (mechanical system servos), and the visualization application was sending specific messages. On the module side, correct implementation of incoming data was verified using debug mode.

The second testing phase verified the complex behaviour of the robot equipment. Testing was conducted with a complete assembly of the robotic equipment (Fig. 6).

A complete assembly represents connected visualization, router, communication module and mechanical control module. VisualCTE and VisualCTE ~ (Lite) were used to control the movement of the robotic head. The actual position of the robot head was checked visually.

The third phase measured the time demand of firmware algorithms of the communication module used for processing, evaluating and forwarding data from the CAN bus to Ethernet and back.

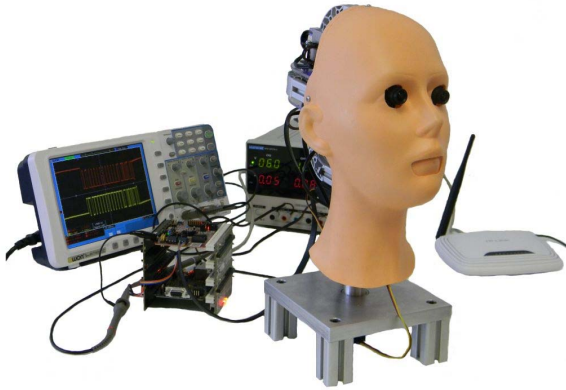


Figure 6. Worksite - robotic head testing.

Measurement results reflecting the data processing time in reception (parsing) and during transmission (generation) are given in Table 5.

TABLE V. MEASURING ETHERNET DATA PROCESSING TIME

Module	Time of data processing (ns)					
	Receiving			Transmitting		
	min	avg	max	min	avg	max
MECH	7812	9375	9400	8313	9150	9250
SND	14100	14150	14313	11175	11275	11363
VID	7075	7075	7262	6888	7012	7063

Table 6 shows the measured data processing times during receiving and transmitting via CAN bus. This table shows only the data processing times for the mechanic control module and for audio processing.

TABLE VI. MEASURING CAN DATA PROCESSING TIME

Module	Time of data processing (ns)					
	Receiving			Transmitting		
	min	avg	max	min	avg	max
MECH	6913	6913	219337	10075	10125	11712
SND	8738	8738	9825	8588	8588	9838

DISCUSSION

The main objective of this work was to demonstrate the operability of the robotic equipment including the connected communication and visualization system. The work was divided into several phases:

- Verification the robotic equipment - measurement of basic properties of the communication module. The measured values describe the selected properties of FREESCALE MQX and are listed in Table 4.
- Verification of communication via TCP and UDP. The correct response of the communication module was determined by testing of all types of messages and queries. The result of the verification therefore confirmed the correct communication function.
- Verification of the interpretation of the meaning of transmitted data. It was mainly the verification of algorithms used to generate and parse values from the transmitted data frame. The result of the testing showed that data are transmitted in the correct manner.
- Verification of HTTP server. The HTTP server file system, which was implemented in the communication module firmware generated HTML and XML files, and their availability has been verified.

Verification of the robotic equipment with communication and visualization system aimed to verify the overall functionality of the device. All components of the control system were connected and controlled from the visualization. The device correctly communicates in both directions and properly adjusts user-selectable parameters, as demonstrated by tests.

CONCLUSION

The main objective of this work was to design and implement communication and visualization system of the robotic head. A development kit TWR-PXN20 was selected for the design in conjunction with the TWR-SER used as hardware for the communication module control system. FREESCALE MQX operating system was used for the selected HW platform. The OS was equipped with a user firmware which controls communication protocols of the control system. These communication protocols were tailored to control the robot head. Further, a visualization system was created in C# for Windows in Java for OS Android. Both visualization systems were designed based on the objectives of the project. The main aspect was to achieve modularity in order to ensure easy expansion of the visualization application. The design and implementation of the visualization and

communication system were successfully verified. This work produced a modular, redundant communication and visualization system with proven performance.

ISBN:978-1-62841-251-2,
DOI:10.1117/12.2063090.

ISSN: 0277-786X,

ACKNOWLEDGMENT

This paper has been elaborated in the framework of the project Opportunity for young researchers, reg. no. CZ.1.07/2.3.00/30.0016, supported by Operational Programme Education for Competitiveness and co-financed by the European Social Fund and the state budget of the Czech Republic. This work is partially supported by the Science and Research Fond 2014 of the Moravia-Silesian Region, Czech Republic and projects SP2015/154, SP2015/181 of Student Grant System, VSB-TU Ostrava.

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