Based on MEMS Sensors Man-Machine Interface for Mechatronic Objects Control

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***Abstract*— The article describes the development of a system for wireless control of mechatronic objects and anthropomorphic robots. The main attention is paid to the man-machine interface on the basis of MEMS sensors.**

Given the structure of the developed system with a description of the main blocks. It describes the communication interfaces used. Substantiates the benefits of the proposed technical solutions.

Keywords*— *Control system; man-machine interface; MEMS sensors; mathematical model; simulation

I. Introduction

The object of the study is a man-machine interface is wireless control mechatronic objects using MEMS (micro-electro-mechanical) technologies.

Human-Machine Interface (HMI) are methods and means of direct interaction between the operator and the technical system that give an opportunity to the operator to manage the system and monitor its operation.

Our purpose is to create working prototype of the human body space position capturing system with human hand moving capture as an example. The data transmits from the MEMS sensors. Then wireless transmission to a computer is used for further processing, visualization and control of robotic systems.

The article describes the creating of the device with 4 modules prototype process, so-called INS (strapdown inertial navigation system), associated with the host computer – single-board Raspberry PI with Linux OS. The connection is organized via the CAN network.

II. The Description of the Created Human-Machine Interface

Developed HMI is a system consisting of a set of sensors, placed in a special suit (the full version) or item of clothing.

Dressed in a special suit human operator is able to control mechatronic object in the distance. Mechatronic object (for example an anthropomorphic robot) imitates the motion of the human operator by performing the technological operations on removal. So, to do it motion sensors are installed in the body areas which are suitable to copy the human movements. Then the information from sensors is processed and going to a special unit which transmits control signals wirelessly to the control object.

Human-machine interface is represented as a hardware and software suite. The hardware suite are INS (which modules attached to various body parts), the communication channel between the modules, processing channel and wireless data transmission modules on a desktop computer. INS contain three-axis MEMS gyroscope, accelerometer and magnetometer.

Software suite includes data from the desktop computer modules visualization program, orientation sensor program and data processing program

III. The Architecture of a Software System

The raw data coming from the three-axis gyroscopes, accelerometers and magnetometers, are read by a bus i2c microcontroller STM32F103C8T6, processed and transmitted via CAN-bus to the single board computer that transmits data to a desktop computer via Wi-Fi PC.

Our choice to use this topology is mainly dictated by the further great modifiability. As an example of such modification one can a lot of reading brunch (e.g., the second arms, legs, or whole body in general) because CAN network can simultaneously be a large number of devices.

The second advantage of this topology is the independence of the modules from each other and also the lack of influence of the modules to each other. The third advantage is the absence of a large load on the processor as each works with only one sensor.

The sensors used 9-axis IMU by InvenSence - MPU9250. They are consist of three-axis MEMS gyroscope, accelerometer and magnetometer. Data complexation (obtained with three different functional purpose sensors) allows to increase the space position orientation accuracy in comparison with solutions using only an accelerometer, a gyroscope or a magnetometer.

For example, if you are using one three-axis accelerometer for positioning of the object on which it is located, in addition to the noise of the sensor itself, the noise be any additional movement, that will provoke additional acceleration excluding gravitational acceleration of the Earth.

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When using a gyro output rate of the system is identified by changing the angle and the output values must be integrated to obtain the angle itself. However, because of the so-called "zero drift" MEMS gyroscopes will accumulate a permanent error. In addition, the signal is discrete. It could be used to solve the problem of so-called "Alpha-beta" or complementary filter. Nevertheless, the drift around the vector acceleration of gravity will remain and accurate orientation needs another vector that will give us a magnetometer.

IV. The Rationale for the Selection of the System Sensors

Among the ready-made solutions options motion capturing have been considered as the use of so-called gages [1-3] (Flex Sensors) which inherently is a variable resistor whose resistance varies with its geometry. Using a standard voltage divider we get different valuesdepending on the geometrical shape of the sensor at the ADC's input. The disadvantage of this design is more than obvious:

- firstly, insecurity, fragility, strong inaccuracy;
- second, the high cost;
- thirdly, it is impossible to determine the direction of change in geometry.

The second option considered was sufficiently widespread movement detectors from game consoles – Kinect, PS Move, Wii Remote.

Kinect has two depth sensor, color camera and microphone array. Proprietary software provides full 3-dimensional detection of body movements, facial expressions and voice.

PS Move is a motion sensing controller as the Wii Remote.

The third option discussed was the project using LED tubes, which use silicone tube LED and photodiode. It is obvious that the upright pipe to a photodiode light reaches the maximum value, and when you change the geometry of this value is changed. Of the minuses – the inability to determine the direction of travel [4].

These options require external registrar movements. Because of this operator becomes tied to a limited coverage area – the area registrar visibility. In addition, you must comply with a number of conditions limiting the scope of the system. From a technical point of view, also require sophisticated motion detection algorithms. Thus, the Kinect system requires the use of image recognition and motion, which drastically reduces the accuracy and reliability of the system while increasing its cost.

A fourth option was to use the orientation sensors. Advantages are obvious – a fairly accurate position determination, including direction of rotation and movement, etc. As to the pluses include the price – now such sensors are very common and their prices vary in the broadest range. Of the minuses – a problem with the connection, read and data processing.

Because of the options considered were chosen digital sensors that provide output data in digital form and passes them on various bus interfaces. As an option, you can use the analog sensors.

IV. Description of Selected MEMS Sensors

Microelectromechanical systems or MEMS for short are devices made for bulk micromechanics technology, formed by local etching of the substrate, doping, deposition of material on it, etc.

Today, a great application got sensors based on the type of capacitor [2]. Inside such a sensor (Fig. 1) is located sinker on the hanger and a capacitor or piezoelectric plates. In the event of acceleration (Accelerometer considered. In case of consideration of the gyroscope acceleration values on the axes are translated into the rotation angle values. The sensor device itself is identical) sinker is shifted relative to the sensor.

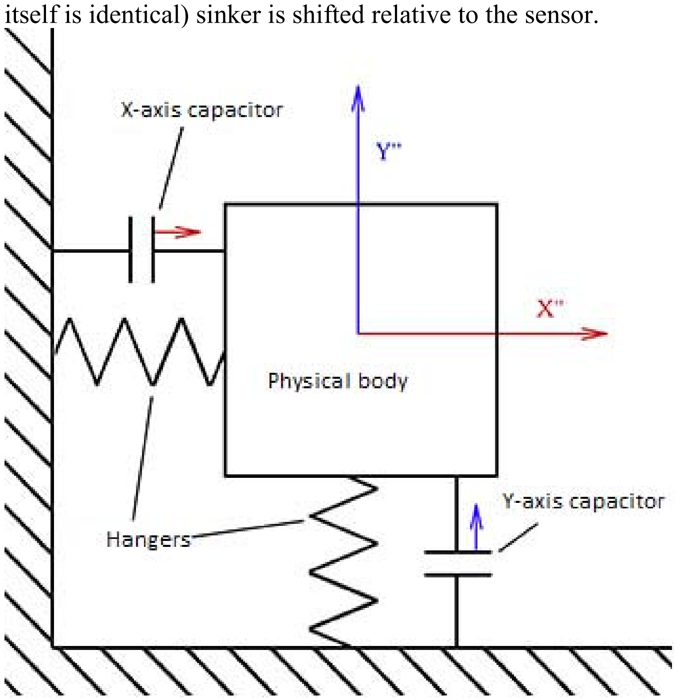

Fig. 1. Block diagram of the system

Capacitor plates fixed to the sinker. It moves relative to the fixed electrode portion. Capacity changes at constant charging voltage – this change can be measured and displacement of the sinker can be calculated.

In another case, the piezoelectric element is changing geometry and generates a voltage proportional to the force of impact to it. Whence, knowing its mass and suspension settings, it is easy to find the desired acceleration. MPU9250 is 9 axis IMU (fig. 2) including a 3-axis accelerometer, 3-axis gyroscope and 3-axis magnetometer [5].

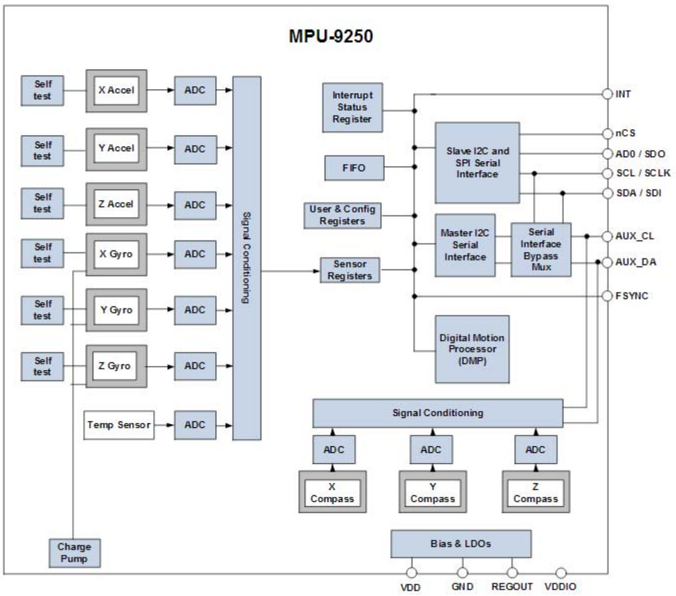

Fig. 2. Block diagram of the system

The gyroscope has a digital output and has a maximum resolution of 2000 rad / s, data is transmitted in 16 bit mode. there is a maximum measuring range of the settings (250, 500, 1000, 2000 deg / sec). In operation consumes 3.2mA in "sleep" mode, about 8 µA. As of the settings it is possible to set the low pass filter.

The accelerometer also has a digital output, similar to the gyroscope. The data are given in the 16 bit mode. Custom mode with maximum measurement range to 16g. The device consumes 450 µA. The settings available in the same low-pass filter and a programmable interrupt.

The magnetometer is used in the sensor device is a third-party and internally connected to the accelerometer and gyroscope on i2c bus. The data issued by this device have a resolution of 14 bits and a maximum measurement range of 4800 mT. When using the magnetometer consumes 280µA at a frequency of 8 Hz polling registers. It has adjustable measuring range.

V. Development of the System Topology

Figure 3 shows a block diagram of the system under development.

Controller STM32F103, mounted on each of the modules acts as a sensor to readout unit MPU9250 primary processor and the data [6]. After filtering and processing data transmitted through the CAN transceiver module to the network. Raspberry Pi is used to receive parcels with CAN modules and forwarding the last over WiFi to desktop computer.

It should be noted that alternative embodiment the one microcontroller, and a large number of sensors connected to it, has its drawbacks. To begin with the implementation complexity, as using the same probes, we obtain an address on the bus, or at most two, depending on the type of IMU. To solve this problem requires the use of additional shift registers for switching between the sensors. The second drawback is the lack of modularity – a very difficult system to add or remove one or more measurements of the shoulders. The third – a large CPU load, low speed operation.

For communications between integrated circuits and devices the system uses the following data interfaces:

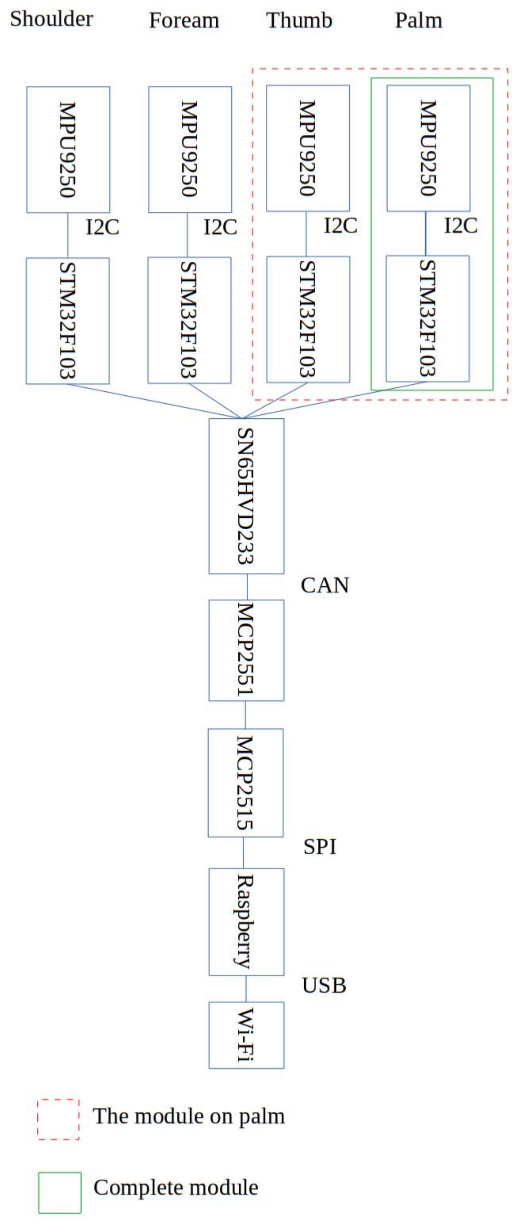

Fig. 3. Block diagram of the system

I²C - consistent asymmetrical bus for communication between integrated circuits in electronic devices. The bus uses two bidirectional communication lines (SDA and SCL). It is used to connect low-speed peripheral components with processors and microcontrollers. I2C is used to connect the sensors to the microcontroller MPU9250 STM32F103. The choice fell on the I2C is due to the fact that the magnetometer, built at the sensor is a separate unit, which has its I2C address. For ease of survey and the initialization processing, it was decided not to use SPI, despite its higher data rate due to complexity of configuration of the compass operation on this bus. In addition, the system is not imposed on the essential requirements for higher data rates.

CAN (Controller Area Network - Controller Area Network) – a standard industrial network focused primarily on the networking of the various actuators and sensors. Transfer Mode – serial, broadcast, packet. CAN is used by us to communicate with each other INS blocks and single board computer Raspberry Pi. The choice of the protocol is primarily dictated by the ease of network organization transceivers cheapness and high speed data transmission.

For a communication system with a remote object using Wi-Fi IEEE 802.11b /a/g/n 2.4GHz. Raspberry PI is connected via SSH. Communication range is from 20 meters.

VI. Conclusions

Summing up all the information, the use of our proposed design using miniature connectors and the miniaturization of the whole construction output we get ready device that finds wide application in robotics, gaming, medical, military vehicles and industry.

We have developed a system having a plurality of HMI advantages, among which are the modularity – the ability to connect a huge number of separate modules in a network, reliability – independence of modules of one another, compactness – module size is 30x12mm allowing modulo example set for each finger.

The system allows the direction of movement and rotation identification, to determine the complete position and orientation in space of each module separately. The system has a sufficiently low power consumption as a whole, and has a low cost of the final potential of the device.

At the stage of preparation of the article, the system is in the prototype stage of development.

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