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EMBEDDED SYSTEMS – CONTROL OF POWER SUBSYSTEMS

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Abstract: The main role of embedded system is to control the product behaviour or control of outside world. Microcontroller as embedded system obtains information through the sensors and makes adequate impact to outside world after sensor data processing. The microcontroller impact is realized through the actuators which convert the electrical energy (or different type of energy) to mechanical work. These processes are executed because of fulfil customer requirements. Microcontrollers as signal controllers work only with low power signals. This paper discusses the possibilities and application of controlling the power subsystems via using the embedded systems.

1 Introduction

An embedded system is a computer system with a dedicated function within a larger mechanical or electrical system, often with real-time computing constraints [1,2]. It is embedded as part of a complete device often including hardware and mechanical parts. Embedded systems control many devices in common use today [3]. Ninety-eight percent of all microprocessors are manufactured as components of embedded systems. Embedded systems range from portable devices such as digital watches and MP3 players, to large stationary installations like traffic lights, factory controllers, and largely complex systems like hybrid vehicles, MRI, and avionics (Figure 1).

Because an embedded system is engineered to perform certain tasks only, design engineers may optimize size, cost, power consumption, reliability and performance. Embedded systems are typically produced on broad scales and share functionalities across a variety of environments and applications.

Embedded systems are managed by single or multiple processing cores in the form of microcontrollers or digital signal processors (DSP), field-programmable gate arrays (FPGA), application-specific integrated circuits (ASIC) and gate arrays. These processing components are integrated with components dedicated to handling electric and/or mechanical interfacing.

Figure 1 Embedded systems application examples

An embedded system's key feature is dedication to specific functions that typically require strong general-purpose processors. For example, router and switch systems are embedded systems, whereas a general-purpose

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computer uses a proper OS for routing functionality. However, embedded routers function more efficiently than OS-based computers for routing functionalities [1,2].

Embedded systems sense quantities from surround and make the actions via using actuators by the following own algorithm (Figure 2).

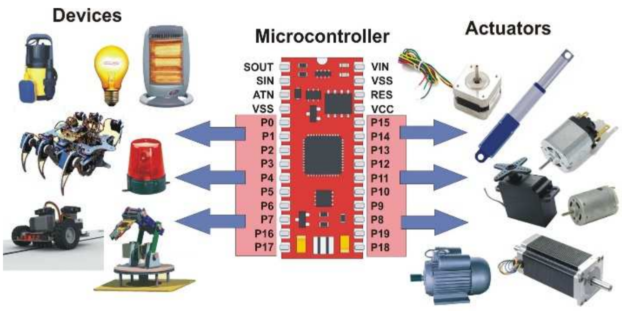

Figure 2 Microcontroller with sensors and actuators

Vane anemometer (Figure 3) is also suitable for wind speed measurement. It uses the propeller on horizontal axis in wind direction.

2 Controlling of power systems

Embedded system realized through the microcontroller includes signal processor. It means that it operates with low voltage and low currents, which are safely for the controller. The maximum current is limited to several milliampers. Direct connection most of actuators to pin of microcontroller causes the immediately damaging of pin al overall microcontroller.

This problem can be solved via using of high power part as transistor, thyristor, triac, relay etc. Inductive loads (DC and AC motors etc.) require big attention in selecting of power parts and circuits. Protection diode is very often used for this purpose (fig. 3).

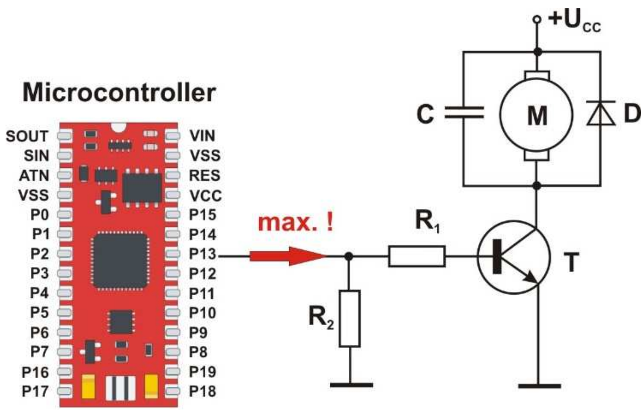

Figure 3 Microcontroller with power transistor and protection diode for inductive load

Simple circuit (Figure 3) is useful for actuator activation (simple switch on of DC motor, relay coil etc.). If it is necessary to control of DC speed rotation, it is possible to make it via using the pulse-width modulation (PWM). PWM is forming of the signal through the duty cycle of the signal (Figure 4). Its main use is to allow the control of the power supplied to electrical devices, especially to inertial loads such as motors. The average value of voltage (and current) fed to the load is controlled by turning the switch between supply and load on and off at a fast rate. The longer the switch is on compared to the off periods, the higher the total power supplied to the load.

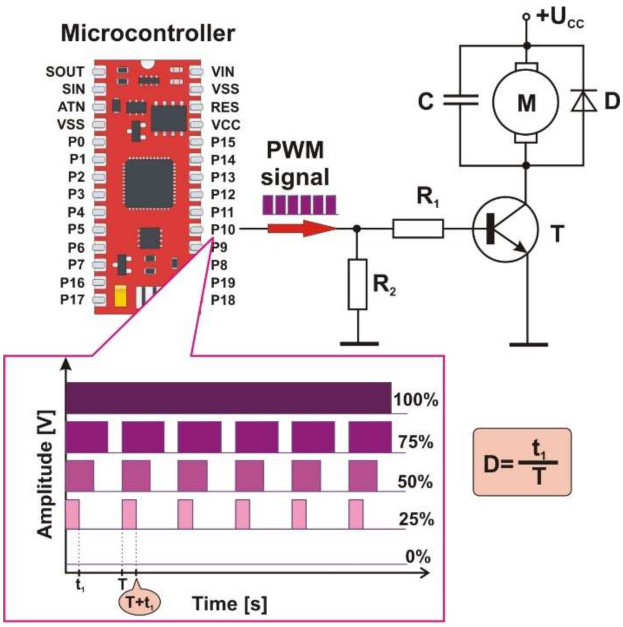

Figure 4 Pulse width modulation principle for controlling of the DC motor speed

Switching frequencies varies from several times per minute in an electric stove; 120 Hz in a lamp dimmer; between a few kilohertz (kHz), to tens of kHz for a motor drive; and well into the tens or hundreds of kHz in audio amplifiers and computer power supplies.

The term duty cycle describes the proportion of 'on' time to the regular interval or 'period' of time; a low duty cycle corresponds to low power, because the power is off for most of the time. Duty cycle is expressed in percent, 100% being fully on. The main advantage of PWM is that power loss in the switching devices is very low. When a switch is off there is practically no current, and when it is on and power is being transferred to the load, there is almost no voltage drop across the switch. Power loss, being the product of voltage and current, is thus in both cases close to zero. PWM also works well with digital controls, which, because of their on/off nature, can easily set the needed duty cycle. PWM has also been used in certain communication systems where its duty cycle has been used to convey information over a communications channel [3].

Many microcontrollers include on-chip PWM controllers. Advantage of PWM is that the signal remains digital all the way from the processor to the controlled system; no digital-to-analog conversion is necessary. By keeping the signal digital, noise effects are minimized.

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Increased noise immunity is yet another benefit of choosing PWM over analogue control and is the principal reason PWM is sometimes used for communication. Switching from an analogue signal to PWM can increase the length of a communications channel dramatically. At the receiving end, a suitable RC (resistor-capacitor) or LC (inductor-capacitor) network can remove the modulating high frequency square wave and return the signal to analogue form [4,5].

The circuit on figure 3 allows only one direction of rotational speed of DC motor. This problem can be solved via using the H-bridge composed from four transistor switches (Figure 5).

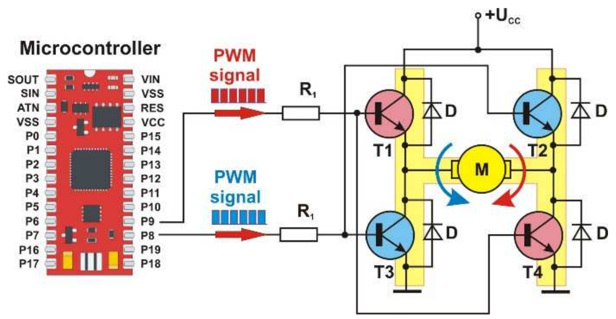

Figure 5 Principle of H-bridge for DC motor control

Connecting of PWM signal to base of transistor T2 and T3 causes that DC motor rotates in one direction and vice-versa connecting of the PWM signal to base of transistor T1 and T4 reverses the direction of DC rotation. PWM signal must be connected only to one output (Figure 4) of controller. Short circuit occurs in case of simultaneously activating of both pairs of transistors.

Inductive load as DC motor can cause the problems because inductive load devices (DC motor, relay, solenoid etc.) produce electrical spikes that damage the outputs of microcontroller or also it can be totally damaged. For the higher safety and reliability, it is useful to use electric isolation protection that isolates the signal part of controller from power part of DC motor (Figure 6).

Optocouplers and opto-isolators can be used on their own, or to switch a range of other larger electronic devices such as transistors and triacs providing the required electrical isolation between a lower voltage control signal and the higher voltage or current output signal. Common applications for optocouplers include microprocessor input/output switching, DC and AC power control, PC communications, signal isolation and power supply regulation which suffer from current ground loops, etc. The electrical signal being transmitted can be either analogue (linear) or digital (pulses) [6].

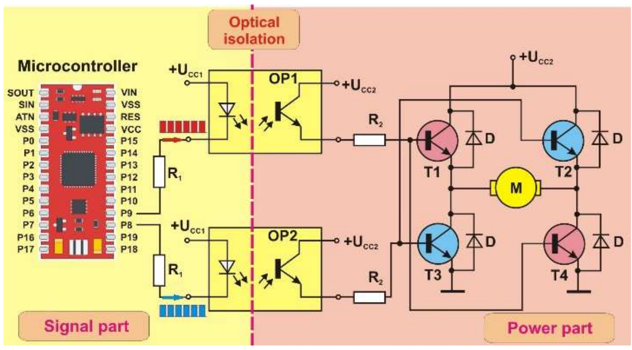

Figure 6 DC motor controlling with H-bridge with electric isolation protection

3 Controlling of RC servo

RC servo is positional servomechanism, which consists of DC motor, positional sensor and control electronic. There are rotational and also linear servos (Figure 7).

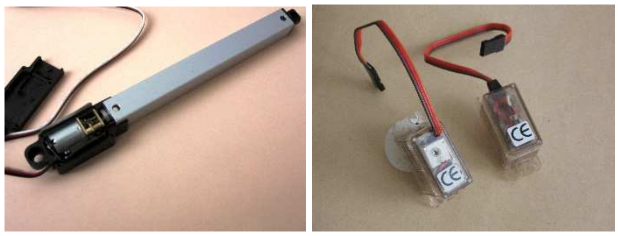

Figure 7 Rotational and linear RC servo

Controlling of these servos is with conventional RC signal. It is pulse-width modulation signal and width of pulse constitutes the value of desired position of angular horn or linear shaft. Pulse width is in range from 1ms to 2 ms and delay between the pulses is in range from 10ms to 20ms (Figure 8).

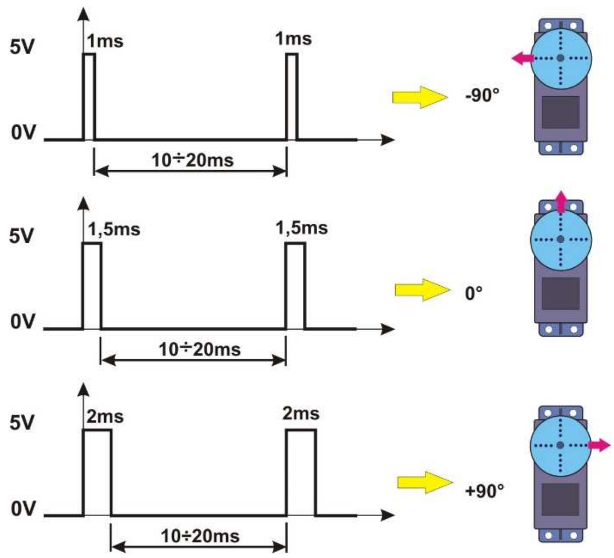

Figure 8 Principle of rotational RC servo controlling

Pulse with width of 1ms means that rotation servo horn rotates to position -90° and pulse with width of 2ms means

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horn rotation to position +90° (Figure 8). Linear servo shaft is moving out to end position for pulse width of 1 ms and pulse with width of 2 ms causes the forward shifting of the linear servo shaft (Figure 9).

Experiences shows that above mentioned convention (Figure 8 and Figure 9) may varies and every producer has different servo characteristic and also every piece from the same producer can has the different behaviour. It is good to make calibration of the servo before using of RC servo in your application. Also loaded servo may has different characteristic.

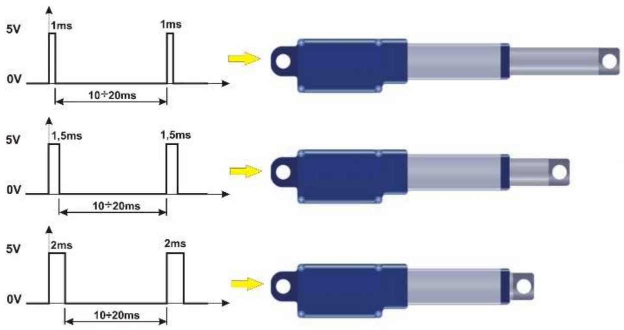

Figure 9 Principle of linear RC servo controlling

Every microcontroller is able to generate the pulses with specified width. Some of them can also generate pulses on background of the main process. Connection of the RC servo to microcontroller is simple. In every case it is more safely insert the resistor for limiting of the current of output signal (Figure 10).

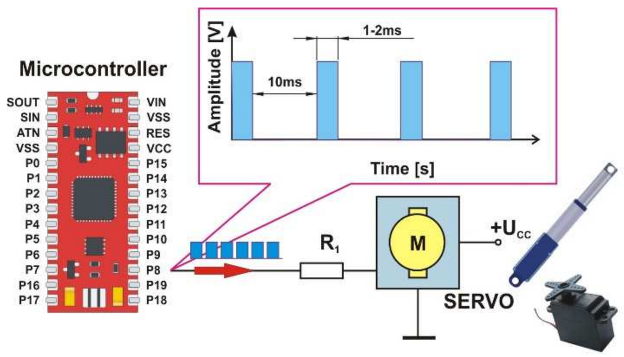

Figure 10 Connection of RC servo to microcontroller

4 Stepper motor controlling

Stepping motor is a brushless DC electric motor that divides a full rotation into a number of equal steps. The motor's position can then be commanded to move and hold at one of these steps without any feedback sensor (an open-loop controller), as long as the motor is carefully sized to the application in respect to torque and speed.

The stepper motor is known by its property to convert a train of input pulses (typically square wave pulses) into a precisely defined increment in the shaft position. Each pulse moves the shaft through a fixed angle.

There are two basic winding arrangements for the electromagnetic coils in a two-phase stepper motor: bipolar and unipolar.

A unipolar stepper motor has one winding with center tap per phase. Each section (A, B, C, D) of windings is switched on for each direction of magnetic field. Since in this arrangement a magnetic pole can be reversed without switching the direction of current, the commutation circuit can be made very simple (e.g., a single transistor) for each winding (Figure 11).

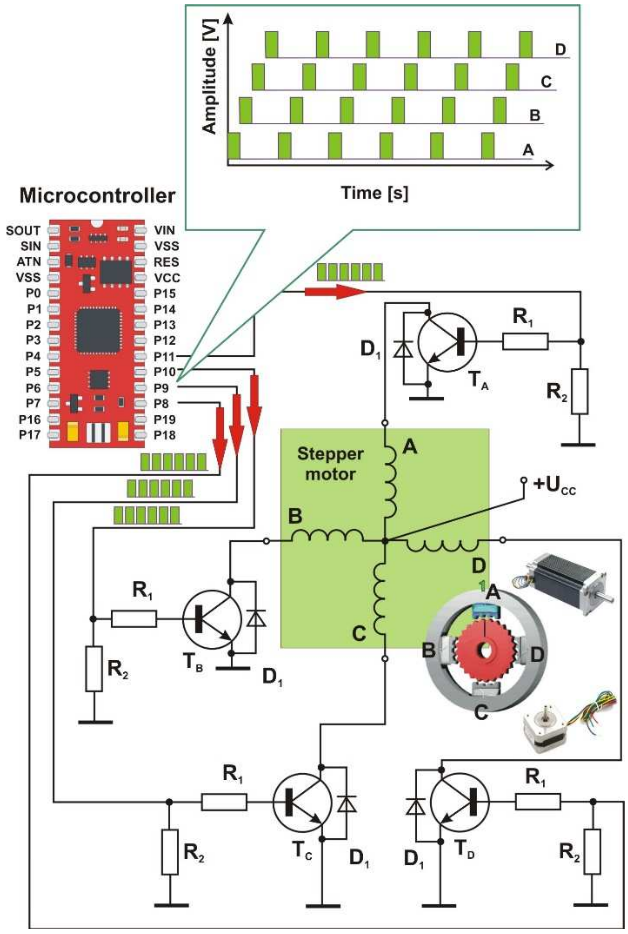

Figure 11 Controlling of the unipolar stepper motor

Bipolar motors have a single winding per phase. The current in a winding needs to be reversed in order to reverse a magnetic pole, so the driving circuit must be more complicated, typically with an H-bridge arrangement (however there are several off-the-shelf driver chips available to make this a simple affair). There are two leads per phase, none are common [7,8].

Measured data are relatively stable and it is close to the reference value. Blower has been adjusted to ten different values and it brought the ten various values of airflow velocity. From this data the averages have been done for comparing the results with reference value. It is shown on figure 8.

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5 Applications

Controlling applications of embedded systems is almost unlimited. The biggest advantage is the small dimensions of the microcontroller which enables to include the microcontroller into controlled machine (Figure 12).

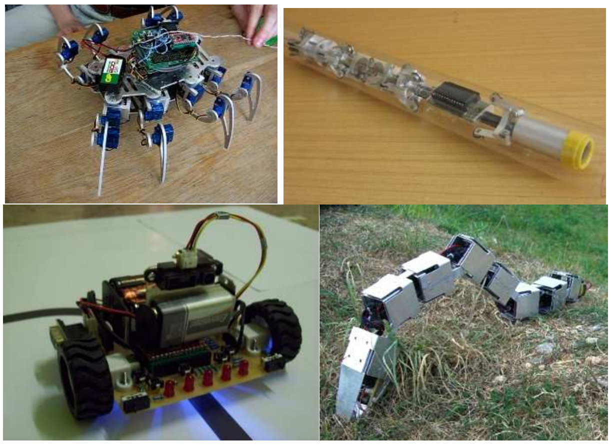

Figure 12 Embedded system applications

6 Conclusion

Embedded system is equipment which enables to make mechatronic system. It gives intelligence to products and also many new functions. Also new type of products can be developed thanks to embedded systems as CD players, Segway, drones, airbags, ABS, ESP and other automotive systems in cars, military systems, service robots, ATM machine, planetary rovers etc [9-24].

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References

[1] Embedded system, From Wikipedia, the free encyclopedia, [Online], Available: https://en.wikipedia.org/wiki/Embedded_system [24 Mar 2020], 2016.
[2] Embedded System. Techopedia Inc, [Online], Available: https://www.techopedia.com/definition/3636/embedded-system [24 Mar 2020], 2016.
[3] HUANG, J., PADMANABHAN, K., COLLINS, O. M.: The sampling theorem with constant amplitude variable width pulses, *IEEE transactions on Circuits and Systems*, Vol. 58, pp. 1178-1190, 2011.
[4] BARR, M.: Pulse Width Modulation, *Embedded Systems Programming*, Vol. 2001, No. 10, pp. 103-104, 2001.
[5] BARR, M.: *Introduction to Pulse Width Modulation (PWM)*, Barr Group, [Online], Available: http://www.barrgroup.com/Embedded-Systems/How-To/PWM-Pulse-Width-Modulation [24 Mar 2020], 2001.
[6] *Optocoupler Tutorial*. Electronic tutorials by AspenCore, Inc. [Online], Available: http://www.electronics-tutorials.ws/blog/optocoupler.html [24 Mar 2020], 2019.
[7] LIPTAK, B. G.: *Instrument Engineers' Handbook*: Process Control and Optimization. CRC Press, 2005.
[8] JONES, D. W.: *Friction and the Dead Zone*, http://www.divms.uiowa.edu/~jones/step/physics.html#friction
[9] KONIAR, D., HARGAŠ, L., HRIANKA, M.: *Application of standard DICOM in LabVIEW*, Proc. of 7th conf. Trends in Biomedical Engineering, Kladno 11.-13. 9. 2007, 2007.
[10] VITKO, A., JURIŠICA, L., KĽÚČIK, M., MURÁR, R., DUCHOŇ, F.: Embedding Intelligence into a Mobile Robot, *AT&P Journal Plus*, No. 1, pp. 42-44, 2008.
[11] BOŽEK, P.: Robot path optimization for spot welding applications in automotive industry, *Tehnicki vjesnik - Technical Gazette*, Vol. 20, No. 5, pp. 913-917, 2013.
[12] DUCHOŇ, F., BABINEC, A., KAJAN, M., BEŇO, P., FLOREK, M., FICO, T., JURIŠICA, L.: Path planning with modified A star algorithm for a mobile robot, *Procedia Engineering*, Vol. 96, pp. 59-69, 2014.
[13] PÁSZTÓ, P., HUBINSKÝ, P.: Mobile robot navigation based on circle recognition, *Journal of Electrical Engineering*, Vol. 64, No. 2, pp. 84-91, 2013.
[14] ABRAMOV, I. V., NIKITIN, Y. R., ABRAMOV, A. I., SOSNOVICH, E. V., BOŽEK, P.: Control and Diagnostic Model of Brushless DC Motor, *Journal of Electrical Engineering*, Vol. 65, No. 5, pp. 277-282, 2014.
[15] KONIAR, D., HARGAŠ, L., ŠTOFAN, S.: Segmentation of Motion Regions for Biomechanical Systems, *Procedia Engineering*, Vol. 48, pp. 304-311, 2012.
[16] AL-DHAHER, A.H.G: Integrating hardware and software for the development of microcontroller-based systems, *Microprocessors and Microsystems*, Vol. 25, No. 7, pp. 317-328, 2001.
[17] FISHER, D. K., KEBEDE, H., A low-cost microcontroller-based system to monitor crop temperature and water status, *Computers and Electronics in Agriculture*, Vol. 74, No. 1, pp. 168-173, 2010.
[18] QIN, Y., YU, B.: Heuristic Education of Microcontroller Unit Principle and Applications, *Procedia Engineering*, Vol. 24, pp. 708-712, 2011.
[19] KARAVAEV, Y. L., KILIN, A. A.: Nonholonomic dynamics and control of a spherical robot with an internal omniwheel platform: Theory and experiments, *Proceedings of the Steklov Institute of Mathematics*, Vol. 295, No. 1, pp. 158-167, 2016.

[20] VIRGALA, I., MIKOVÁ, Ľ., KELEMEN, M., HRONCOVÁ, D.: Snake-like robots, *Acta Mechatronica*, Vol. 3, No. 4, pp. 7-10, 2018.
[21] MIKOVÁ, Ľ., VIRGALA, I., KELEMEN, M.: Embedded systems, *Acta Mechatronica*, Vol. 3, No. 2, pp. 1-5, 2018.
[22] KELEMENOVÁ, T., FRANKOVSKÝ, P., VIRGALA, I., MIKOVÁ, Ľ., KELEMEN, M., DOMINIK, L.: Educational models for mechatronic courses, *Acta Mechatronica*, Vol. 1, No. 4, pp. 1-6, 2016.
[23] LIPTÁK, T., KELEMEN, M., GMITERKO, A., VIRGALA, I., HRONCOVÁ, D.: THE CONTROL OF HOLONOMIC SYSTEM, *Acta Mechatronica*, Vol. 1, No. 2, pp. 15-20, 2016.
[24] KURYŁO, P., PIVARČIOVÁ, E., CYGANIUK, J., FRANKOVSKÝ, P.: Machine vision system measuring the trajectory of upper limb motion applying the Matlab software, *Measurement Science Review*, Journal of Institute of Measurement Science of Slovak Academy of Sciences. Bratislava. Vol. 19, No. 1, pp. 1-8, 2019.