# Data Acquisition for Angular Measuring and Positioning System


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***Abstract* – This paper presents an angular positioning system to rotate a web camera. These systems are used in security systems for supervision. The controller for the positioning system is developed around a microcontroller PIC 18F4455 type. To follow the response of the controller a virtual instrument was developed in LabWindows/CVI. From the front panel can be set two function modes the manual or the automatic. In manual mode the user sets the reference angle for the positioning system. In automatic mode the system detects movements with sensors and rotates a web camera in the direction of the movement.**

**Two different position sensor types for position measurement will be presented, a resistive an incremental type. It will be studied the sensor's accuracy and measurement accuracy.**

**It is presented different control methods which can be used in a positioning system. Further it is developed a classical PI controller and the parameters are established experimentally. A model identification adaptive controller was also developed. Adaptive control is the attempt to redesign the controller while online, by looking at its performance and changing its dynamic in an automatic way. The parameters of the controller are determined by minimizing the error dispersion.**



***Keywords: positioning system, virtual instrumentation, control methods, position sensors.***


## I. INTRODUCTION

Measuring linear or angular displacement and detecting objects is an important requirement in many industrial applications. The positioning systems used widely and for a long time in different automation processes are related to these. To sense the position of an object there are many types of sensors, inductive, photoelectric, capacitive, magnetic field and/or ultrasonic sensors. The propper use of one of these depends on the accuracy, the material of the object, the measuring distance and the output signal. It is very optimal the non-contact detection of targets. In this case the photoelectric infra-red light emitting sensor acts from distance and contains the receiver to. The target either breaks a beam of light or reflects it back to the detector to activate the sensor output. Advantages of photoelectric sensors are longer sensing distance, ability to detect any object material, they can differentiate various color or surface characteristics, and they can operate in different sensing modes such as thru-beam, retro-reflective, or diffuse [1], [8], [12].

The positioning systems can be used in industry to detect the right position of tools or different objects (ex. label, tag) or in security systems for supervision. Positioning systems can be controlled also in different ways, with a classical PID controller or with an adaptive controller. Each has its advantages and disadvantages. The implementation of a PID controller is simple, but the parameters of the transfer function and the constants of the controller needed to be known. The parameters are identified with an "Off-line" method, and the constants are determinated experimentally. The adaptive controller needs complex calculations with high frequency, but the system parameters are unknown; these will be identified with LMS method. The output of the positioning system acts a DC motor which is a common actuator in control systems. The DC motor directly provides rotary motion and, coupled with wheels or drums and cables, can provide transitional motion. Coupling the motor with a web camera, a supervisor system is obtained and with right sensors it detects moving objects and rotates the camera in the right direction.

## II. CONTROL METHODS FOR POSITIONING SYSTEMS

A classical PID controller having a block diagram on the figure 1 can be expressed with:

$$u(t) = k_p \cdot \varepsilon(t) + k_i \int_0^t \varepsilon(t) + k_d \frac{d\varepsilon(t)}{dt} \qquad (1)$$

Where $\varepsilon(t) = ref(t) - u(t)$ is the controller's error and it is the difference between the reference signal and the output of the controller [1].

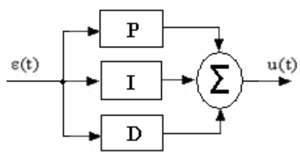


Fig.1. Block diagram of a PID control system.

To implement the controller in a microcontroller the discrete form is used:

$$H_r(z^{-1}) = k_P + k_i \cdot \frac{h}{2} \cdot \frac{1+z^{-1}}{1-z^{-1}} + k_d \cdot \frac{2}{h} \cdot \frac{1-z^{-1}}{1+z^{-1}} \qquad (2)$$

For the positioning system a discrete PI controller was developed using the recursive form:

$$z^{-1} = k$$
$$u(k) = u(k-1) + \frac{k_P + k_i \cdot h}{2} \cdot \varepsilon(k) + \frac{k_i \cdot h + 2 \cdot k_P}{2} \cdot \varepsilon(k-1) \quad (3)$$

Adaptive controllers are modern controller methods used in different processes where parameters may change, sometimes in unexpected ways. By classical controller programmers have to anticipate a variety of possible outcomes and structures into the program so it can respond. Adaptive control systems don't need to be programmed with instructions for different situations, because they can perform them independently. The adaptive controller evaluates continuous its own performance and adjusts itself to better achieve the specific goals. Adaptive control is a feedback hereby observes the process and the performance of the controller and reshapes the controller closed loop behavior autonomously [3], [4].

There are several types of adaptive control; the most significant are the model reference adaptive controllers (MRAC) and the model identification adaptive controllers (MIAC). The MRAC is a closed loop controller and his parameters can be updated whenever to change the response of the system. The output of the system is compared to a desired response from a reference model. The control parameters are updated on the base of this error. So the parameters converge to ideal values and the controller response to match the response of the reference model.

For positioning system can be used the model identification adaptive controller (MIAC) with minimal dispersion, which is less accurate but needs less memory too. The parameters of the controller can be determined if the parameters of the process are known. The method refers to the parametrical identification of the process. The parameters of the controller are computed by minimizing the error dispersion using a recursive extended least-square identification algorithm [2].

If the parameters of the process are unknown, identification occurs before the determination of the optimal command. This process control mode is called indirect adaptive control because the parameters of the controller are determined in each step of sampling. The model parameters will be changed slightly each time a new set of measurement data is read. No deliberate process disturbances or test signals are needed to make the identification work. These „indirect self-tuning" controller types are flexible because they let us use and combine more identification and regulation methods [2], [3].

Figure 2 presents the general scheme of an MIAC.

For parametrical identification of the process the most commonly used method is the „on-line" least mean squares method. This method is based upon minimizing the weighed square error. The algorithm of the recursive parameter identification requires the initial vector parameters. The parameter identification success depends upon choosing these initial values.

In our case the command signal and the position of the web camera was memorized. With a program in Matlab using the LMS method the system was identify. The transfer function of this system is:

$$H(s) = \frac{1}{\theta_1 s^2 + \theta_2 s + \theta_3} \quad (4)$$

Where $\theta_1$, $\theta_2$, $\theta_3$ are the system parameters. The transfer function of the controller was determinated experimentally because the parameters of the motor and the mechanic elements were unknown.

With the determined values in the identification process the controller's parameters are computed, for each sampling step, by the criteria of the minimal dispersion [5].

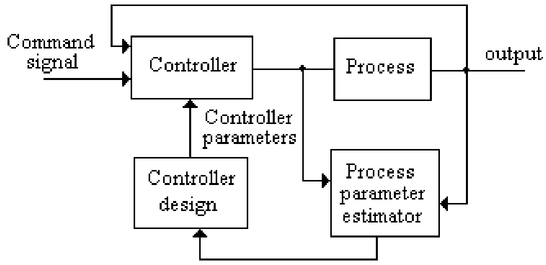


Fig.2. Block diagram of a model identification adaptive controller.

## III. Angular Positioning System

The block diagram of the angular positioning system is presented in figure 3.

The position sensor returns an electrical signal proportional to the movement and to the position of the actuator element motor and web camera. Two position sensors were used, a resistive type and an incremental disc.

The resistive position sensor was a simple 5kΩ potentiometer with a maximum rotation angle 320°. The advantage of the resistive position sensor is that it is very easy to use and gives a voltage which is always proportional to the position, at start, or even if the system is disconnected and connected again. The output voltage of the resistive sensor varies between 0.35V and 4.65V. The voltage is converted in angle θ(k) in every step by the microcontroller using the A/D converter. The rotation of the positioning system is between +45° and -45°, corresponding to the number ±440given by the A/D converter. The actual position in degrees is calculated with: $\theta(k) = \frac{N_k \cdot 90}{440}$ where $N_k$ is the conversion result for the measured voltage.

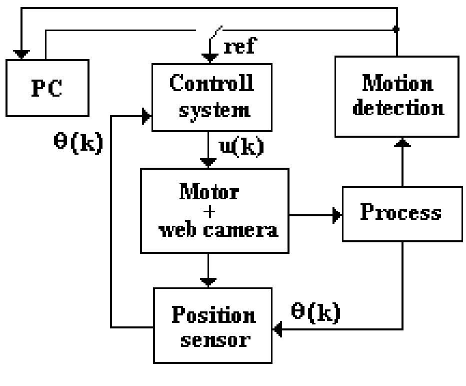


Fig.3. Bloc diagram of the angular positioning system.

The incremental sensor (encoder) disc gives impulses which are counted and converted in an angular displacement. The incremental sensor gives 1200 impulses per rotation, the resolution is q=3.33imp/grad or 0.3°per impulse. The actual position is calculated with: $\theta(k)=\frac{N}{q}$ where N is the counted impulses. The disadvantage of this sensor is that the previous position needs to be memorized. At the beginning the system must have an initial (start) position. The initial position is set at the middle of the supervising area. The system can be also reset to this position [6], [9].

In automatic operating mode to detect a motion in the supervising area infrared photodiodes are used. Position sensing photodiodes provide quantitative information about the position of an incident light beam or spot image. An important factor by position sensing is the relationship between the diameter of the light spot and the dimension of the detector. If the light spot is smaller then the spaces between the detectors, the difference will represent a dead zone where the beam will be lost resulting erroneous position detection. In the supervised area seven photodiodes are placed, each at 15° one from the other. The dead zones are compensated by the supervising angle (54°) of the web camera. The signal from the photodiodes represents the reference input to the controller [8].

The web camera used has 1.3MegaPixel camera with auto focus. The image is clear and good quality when the camera is moving.

The web camera is turned to the required position by a dc motor controlled in PWM mode through a H bridge L298 type.

The L298 type circuit contains two H bridge whereof one is used. At the Enable input is applied the PWM signal and through IN1 and IN2 the sense of the motor is set. All this are generated by the microcontroller. The period of the PWM signal is set to $T_{PWM}$=820µs and the duty cycle varies propper to the output of the controller (control signal) and it is limited approximately at 40% from power supply to reduce the velocity and protect the motor. [12], [11].

The angular positioning system is controlled in two ways, using a PI controller or using an adaptive controller. In both cases a microcontroller PIC18F4455 type was used. The sensors signal conversion and the motor control signal is also ensured by the microcontroller [11].

The output of the classical PI controller was calculated with the following equations:

$$\begin{aligned} er(k) &= ref(k) - \theta(k) \\ I(k+1) &= I(k) + \frac{er(k)+er(k+1)}{2} \\ u(k) &= k_p er(k) + k_i I(k+1) \end{aligned} \quad (5)$$

Where *er(k)* is the error of the controller, *ref(k)* reference angle (set from the front panel or given by the motion sensor), *θ(k)* output (angle) of the system, *u(k)* controller output signal at step *k*, *I(k+1)* integrator part of the controller at *(k+1)* and $k_p$ and $k_i$ has been established experimentally.

To develop an MIAC the initial parameters θ(0) of the process need to be known. This are calculated with an "off-line" identification method. After that a recursive identification algorithm is used before to calculate the controller's parameters then the control signal u(k). The recursive identification algorithm uses the following equations [5]:

$$\begin{aligned} \theta(k+1) &= \theta(k) + K(k+1)\cdot\varepsilon(k+1) \\ \varepsilon(k+1) &= y(k+1) - \varphi^T(k+1)\cdot\theta(k) \\ K(k+1) &= \frac{F(k)\cdot\varphi(k+1)}{\lambda+\varphi^T(k+1)\cdot F(k)\cdot\varphi(k+1)} \\ F(k+1) &= \frac{1}{\lambda}\cdot(F(k) - K(k+1)\cdot\varphi^T(k+1)\cdot F(k)) \end{aligned} \quad (6)$$

The flowchart of the angular positioning system using an adaptive controller is presented on figure 4.

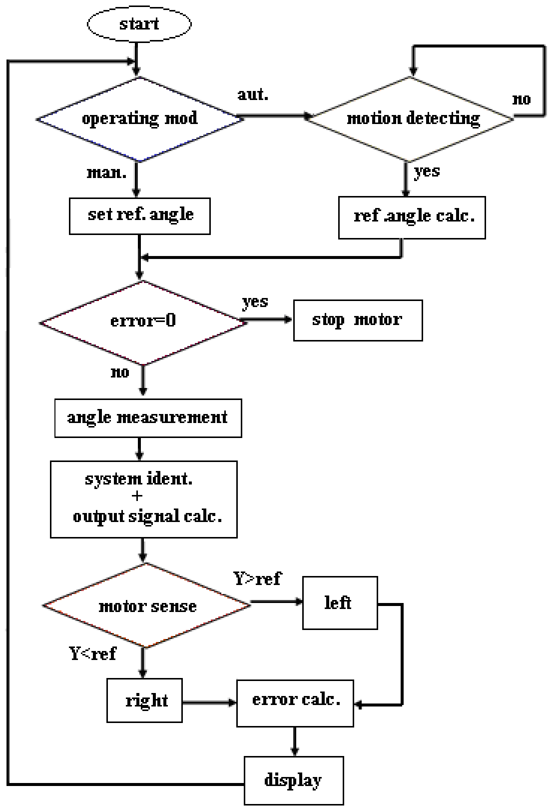


Fig.4. Flowchart of the angular positioning system.

To follow the measuring and the position of the system a graphical interface was developed in LabWindows. Through this interface the operating mode can be set to manual or automatic. The changes of the controller's output and the position of the motor can be followed and the reference angle can be set in manual operating mode [10].

On the graphical display of the angle variation we can follow the answer of the system (second order system).

In automating operating mode the yellow LED is signaling a motion in the supervising area and the red LED is signaling the position of the motor and web camera. In figure 5 is presented the graphical interface of the system.

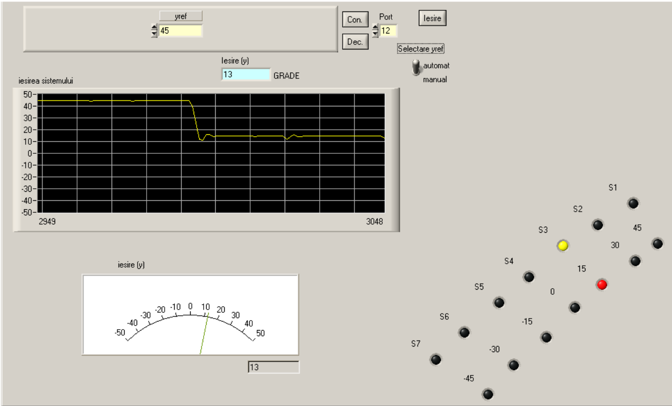


Fig.5. The graphical interface of the system.

## IV. THE ERRORS OF THE POSITION SENSORS

The system error depends on the accuracy of the sensor and data processing. The error of the incremental sensor is $0.09 grad^{-1}$. This means that the angle measuring error establishes the positioning system's error. In the table below the errors for each position in degree are presented.

TABLE I.
THE CALCULATED ERRORS FOR EACH ANGLE POSITION.

| α[°] | $N_{id}$ | $N_{re}$ | Δx | ε[°] |
|---|---|---|---|---|
| 45 | 149.85 | 135 | 14.85 | 4 |
| 30 | 99.9 | 90 | 9.9 | 3 |
| 15 | 49.95 | 45 | 4.95 | 1 |
| 0 | 0 | 0 | 0 | 0 |
| -15 | -49.95 | -45 | -4.95 | 1 |
| -30 | -99.9 | -90 | -9.9 | 3 |
| -45 | -149.85 | -135 | -14.85 | 4 |

The average error value is ±2.28 degree, accepted for an angular positioning system.

The average sensibility of the resistive sensor, calculated through measurement, is 23.4[Ω/grad]. The influence of the A/D converter can be neglected; the sensibility of the converter is 0.2 degree.

It can be observed that the incremental sensor is more indicated because of better accuracy.

## V. POSITIONING SYSTEM SIMULATION

The angle positioning system can be modeled as a second order system with the following continuous transfer function:

$$H_P(s) = \frac{0.0018}{s^2 + 0.9990 \cdot s + 0.0012} \qquad (7)$$

The discrete form of the transfer function:

$$H_P(z) = \frac{8.708 \cdot 10^{-6} \cdot z + 8.422 \cdot 10^{-6}}{z^2 - 1.905 \cdot z + 0.9049} \qquad (8)$$

For simulation the system was identified and the continuous transfer function (7) was obtained. Figure 6a shows the system output *(y)* and the estimated signal after identification ($y_{est}$). Figure 6b sows the error variation [7].

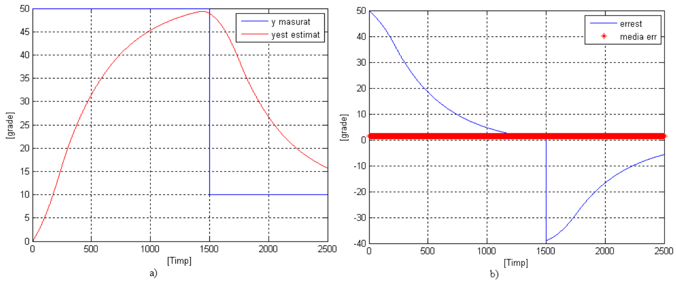


Fig.6. Simulation results for the output of the system and the error variation.

## VI. CONCLUSIONS

Different configurations were realized for an angular positioning system. Two angular position measuring sensors were studied: a resistive type and an incremental type, and it were also studied their influence upon angle determination accuracy. The incremental sensor offers a greater precision due to its resolution, but by perfection the resistive sensor the same accuracy can be obtained.

Two controller types were developed for the positioning system's command. The first is a classic PI controller. This needs that the transfer function and the controller parameters to be known. The other controller is a model identification adaptive controller. This latter doesn't need the parameters, they are determined while running, by the recursive parameter identification algorithm.

For the monitoring of the positioning system a graphical interface was developed in LabWindows, it is having the function to select the operating mode.

Finally to observe the function of the identified system, a system simulation was made using the determined transfer function.

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