A MECHATRONICS APPLICATION

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Abstract: This paper is concerned with the design and implementation of a mechatronics application. A web cam is orientated by a 3D mechanism. The rotation is performed using step by step motors working under a microcontroller control. A voice recognition module decodes the vocal commands from the operator and sent them to the microcontroller. The motion detection is performed by a PC program. A wireless channel communication, for messages and images, was implemented connecting a mobile phone to the PC. The main function of the system is the long distance surveillance control, but the application was designed also in order to underline the **mec**h**a**tronics interdisciplinary (**m**echanics, **e**lectronics, **c**omputers and **a**utomation).

Key words: mechatronics, motion detection, microcontroller, wireless communication.

SYSTEM ARCHITECTURE

The 80C31 microcontroller (figure 1) is used to build a smart bidirectional serial interface (Ivanescu 2002). Camera orientation tasks received from the computer are accomplished by sending the needed commands to step by step motors. The operator can send few predefined vocal commands to the microcontroller. The command recognition is performed by the Voice Direct 364 module. The microcontroller can use the 5 available outputs to control home electronic system as air conditioning, heating system or garage door. The state of these outputs can be read using the bidirectional communication channel based on the GSM network.

The software application running on the PC allows the definition of more than $N \geq 3$ surveillance areas. One of these areas is the starting area where the camera is positioned when the program is started. Receiving the starting area coordinates, the microcontroller gives the appropriate commands to step by step motors in order to achieve the right camera orientation. In the next step, when the camera stops to move, the image acquisition is started as well the motion detection procedure.

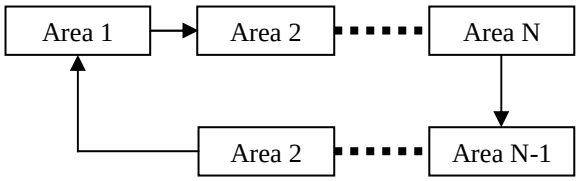

Figure 2 Surveillance areas sequence

After a delay $\Delta t(N)$, the camera is positioned for the next surveillance area (figure 2). The number of surveillance areas N is limited by the computation time because greater is N greater is $\Delta t(N)$ and the effectiveness of the surveillance decreases.

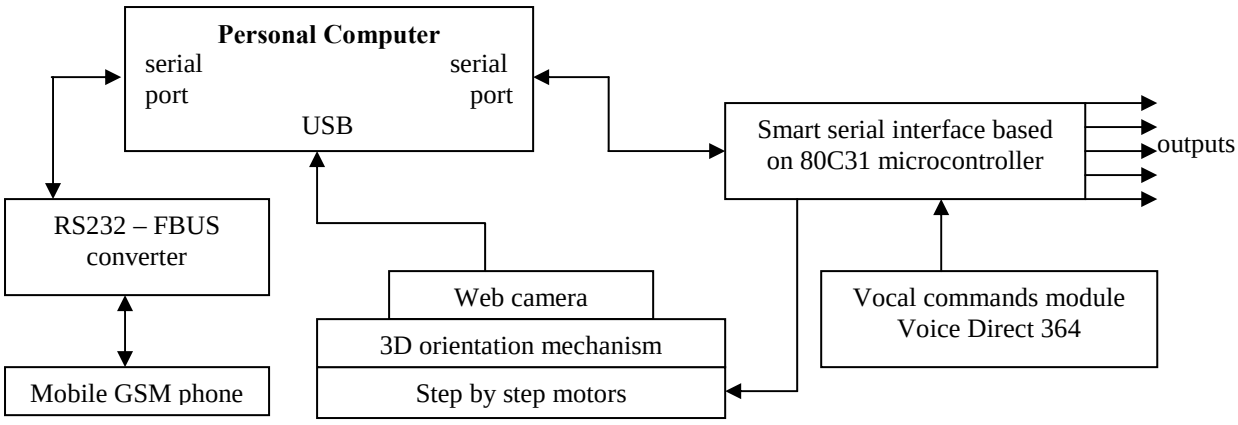

Figure 1 System architecture

When a motion is detected an alarm procedure is started: a SMS is sent to the designed number (the owner, the surveillance company etc.) and the acquired images are stored into computer memory. In order to assure the message receiving, the SMS is repeated until a confirmation is obtained. The confirmation stops the SMS sending but the image storage continues.

Using the GSM bidirectional communication channel the surveillance manager is able to sent orders to the system to switch on / off the microcontroller outputs, the surveillance process or the alarm procedure.

The communication between the computer and the mobile phone is performed by an appropriate drive which converts the AT command set to the mobile phone language.

The system functioning could be controlled by vocal commands. This job is performed by the Voice Direct 364 module which is connected to the microcontroller and is configured for single word recognition mode. When one word is recognized an interrupt request is generated to the microcontroller. Accepting the interrupt, the microcontroller receives the word identification and sends it to the main computer where a decision is taken according with a predefined procedure. Even vocal command significance is the switch of a microcontroller output; the decision is taken also by the main computer and not by the microcontroller.

SOFTWARE INTERFACE

The software application was developed in Microsoft Visual C++. Before running the main program, the web camera must be connected, its drive must be installed, the mobile phone must be connected and communication software must be installed.

The software interface has 4 components which communicate between them using Windows message system:

- The Mobile module controls the communication between the computer and the mobile phone. Periodically, this module read the phone state in order to detect the SMS or call receiving. If the SMS is one from the owner then the message is interpreted and a message is sent to the Supervisor module which will start the appropriate action. When a call is received, the system verifies the sender. If the sender is unknown then the call is rejected. If the sender is the owner then the call is interpreted as a confirmation signal and only after that it is rejected. As expected, trying to recognize the vocal commands from the phone speaker using the Voice Direct 364 do not give very good results. The signal offered by the phone speaker does not exactly fit in the bandwidth accepted by the voice recognition module. A more elaborated solution should be designed and implemented to support the ability of the system to send vocal commands by phone, from long distance.
- The Interface module has three jobs:
  - the control of the serial communication between the voice recognition module and computer,
  - the control of the step by step motors which are responsible with the camera orientation,
  - the control of the auxiliary outputs of the system.
- The Motion module is in charge with the motion detection based on frame by frame analyze of the acquired images. When the motion is detected, a message is sent to Supervisor module and the frames are stored in a bitmap format. The file names include the day, the month, the year, the hour, the minute, the second and the 1/1000 of the second of acquisition time.

In the first version of the application, a very simple and fast motion detection method was used. The color changing between frames is detected and associated with a moving object in the scene. The identity of two consecutives frames without moving objects is unexpected because the noise level is not insignificant. A threshold T must be used. If the RGB space is considered then $P_n(R_n, G_n, B_n)$ and $P_o(R_o, G_o, B_o)$ are two pixels in the new and respectively in the old image, but associated with the same spatial position. P_o is now the reference and the origin of the RGB system could be translated in this point. The following differences are computed:

$$R_d = R_n - R_o\,;\; G_d = G_n - G_o\,;\; B_d = B_n - B_o \quad (1)$$

A cube of side T, in the translated system (see the figure 3), is the domain of variance for $P_d(R_d, G_d, B_d)$ associated with nonmoving objects in the scene. When $P_d(R_d, G_d, B_d)$ goes out of the cub then a motion is detected.

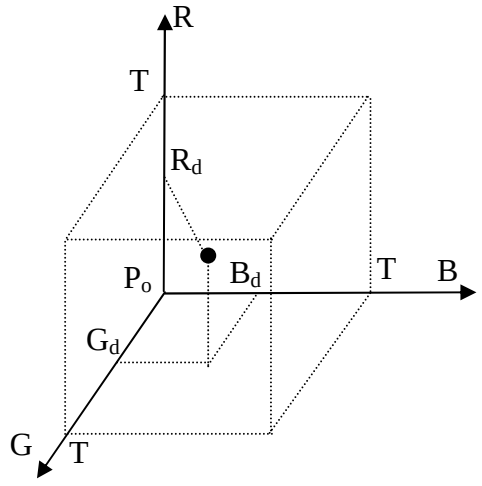

Figure 3 Simple threshold in RGB space

In the next version of the application more elaborated methods for motion detection are to be implemented (Bhat 2001; Saptharishi 2000; Lefaix 2000)

- The Supervisor receives and manages the messages from the other modules and from the human operator using a graphic interface. Receiving messages it takes decision following a predefined strategy. First Supervisor module executes the other three modules. Next step, the Supervisor starts the camera calibration procedure. A number of parameters must be fixed by the

operator: contrast, saturation, brightness, exposure, gain, white balance, light and color boast, anti flicker frequency, optimization for speed or for quality regardinf the image acquisition (Cojocaru 2002). During the application execution, the operator can give orders to the system using a graphic interface (in figure 4).

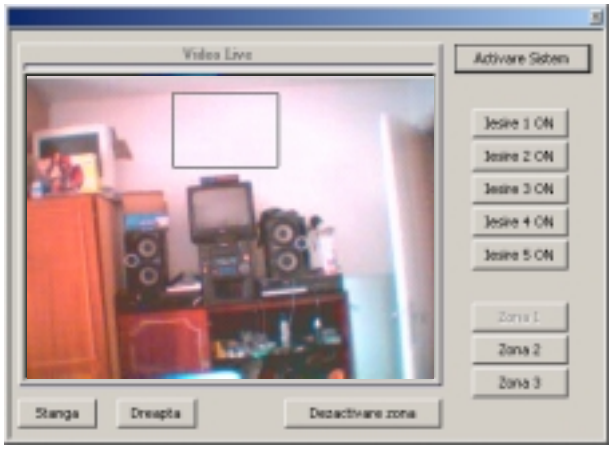

Figure 4 Graphic interface

SMART SERIAL INTERFACE

The diagram which describes the interconnection of functional blocks within the smart serial interface is presented in figure 5.

The main component is the Intel microcontroller 80C31 which communicate with the computer using two types of serial buses (Ball 2002).

Using the RS232 bus no signal conversion is needed. The PC COM ports are implemented using an UART (Universal Asynchronous Receiver Transmitter) which takes the bits from the ISA bus and offers the serial information. Each octet has as predecessors 1 start bit and as successors 1 control bit and 1, 1½ or 2 stop bits. UART is also responsible with the deserialization. EIA (Electronic Industries Association) RS–232-C defines the set of rules for signals, associated functions, electrical specifications and pins. In PCs only a subset of these rules is used. Anyway the voltage levels between -3V and -25V are interpreted as 1 logic, those between +3V and +25V are associated with 0 logic and the values between -3V and +3V are transitory values.

The other choice is to use the industrial bus RS422. In many applications, due to noise reduction, data transmission based on differential signals offers better results. This way RS422 provides data transmission on longer distance and with greater speed than RS232. In simplest way a pair of converters, acting as a RS232 bus extension, assures the conversion from RS232 to RS422 and vice versa.

The Voice Direct 354 outputs are connected to a comparator which is a pyramid of 8 logic gates. The output of comparator is connected to the interrupt line of the microcontroller. A transition from 0 to 1 is generated when any of the 8 outputs of voice recognition module is activated. This transition interrupts the microcontroller which read the 8 outputs and identifies which one caused the interruption. The 5 outputs of the microcontroller are directly activated setting the corresponding bit and they are protected against accidentally voltage signals.

The command for each step by step motor is accomplished using an 8 bits latch. Only 4 bits are used because the motor have only 4 coils. The galvanic separation is assured by an opto-coupler, other way the 12V command voltage could cause serious damages. The motor is commanded in the unipolar manner that means only one coil is powered at one moment when the mechanism is moving and no coil is powered in a static position (figure 6).

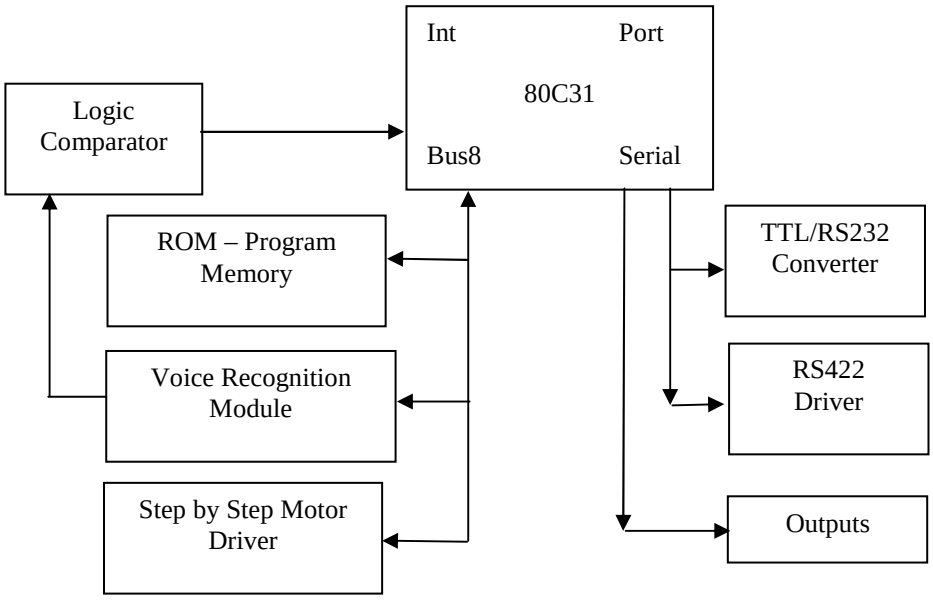

Figure 5 Smart Serial Interface diagram

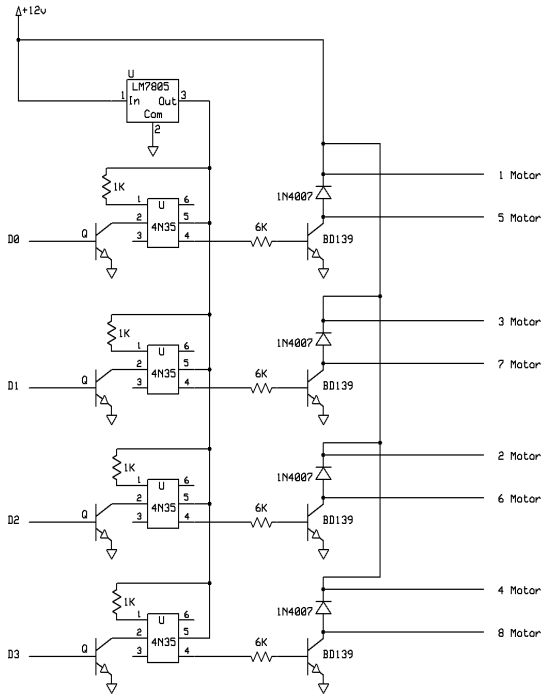

Figure 6 Drive motor scheme

The communication with the computer is performed using a set of predefined commands: e.g. "O2OFF" means the command is "deactivate the output 2" and the answer is "OK" or "MMINUS" means the command is "rotate the motor to the left with one step" and the answer is "OK" or "END" if a limit is reached.

THE MICROCONTROLLER

80C31 (Ibrahim 2000; ST Microelectronics 2000) is a CMOS microcontroller fully compatible with the standard 80C51. 80C31 has 128x8 RAM inside, 32 I/O programmable lines, 1 serial port which can be used also as full duplex UART, 2 counters on 16 bits, 6 interrupts on 2 priority levels and a oscillator, all inside the chip (figure 7).

The memory system could be extended using TTL compatible memory modules. The 80C31 has not a memory program, an external ROM is connected by 8 bits latch because the data bits and the low address bits are multiplexed.80C31 has separated spaces for data and program (64 kB maximum segment). A number of special use registers (SFR) can be directly addressed in the higher part of the memory.

The low part of internal memory can be directly addressed and is divided intro 3 segments:

- 4 banks of registers between the addresses 00h and 1Fh (4x8x1=32 octets)
- a bit level addressable area between 20h and 2Fh (16 octets)
- free zone between 30h and 7Fh

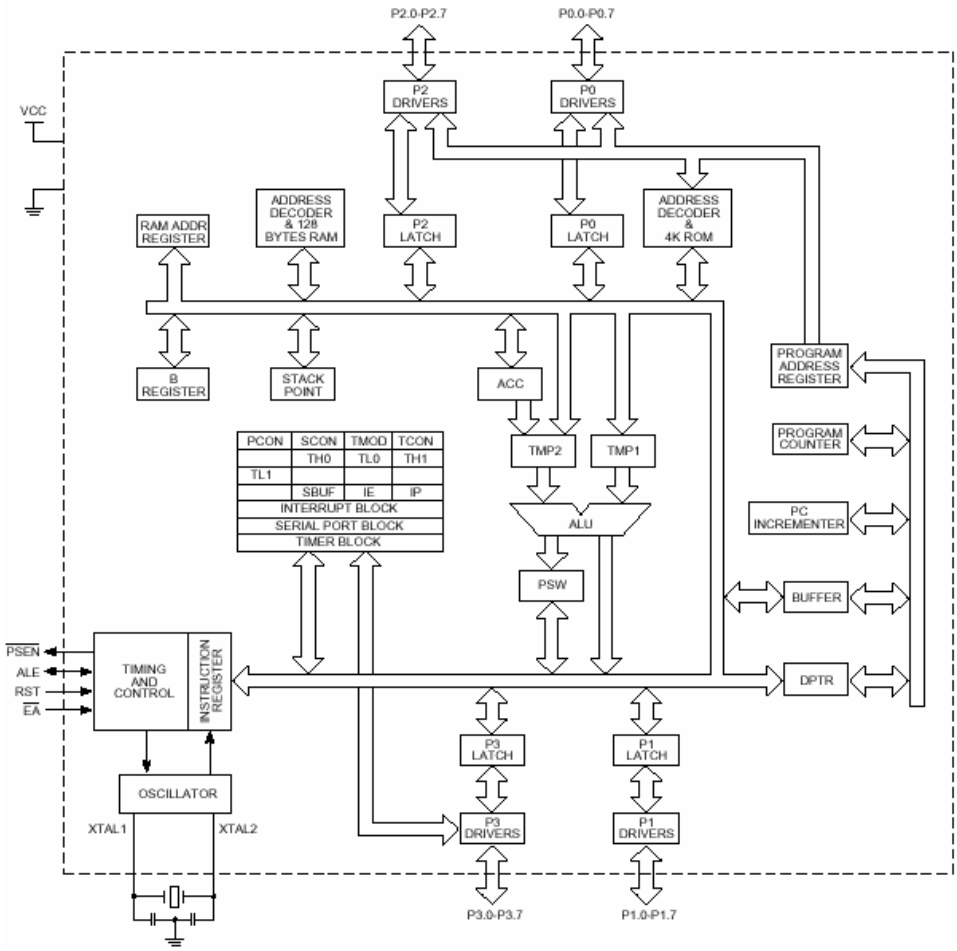

Figure 7 80C31 Microcontroller architecture

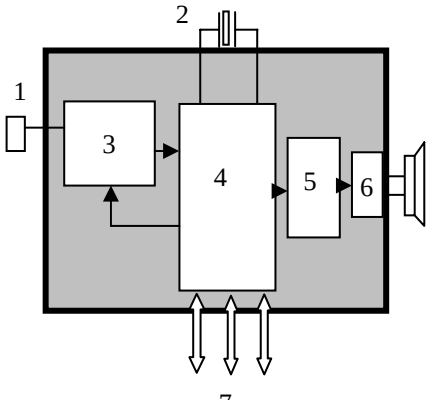

Figure 8 Voice command module 1 – microphone; 2 – oscillator; 3 – amplifier processing; 4 – neural network; 5 – voice generator; 6 - PWM

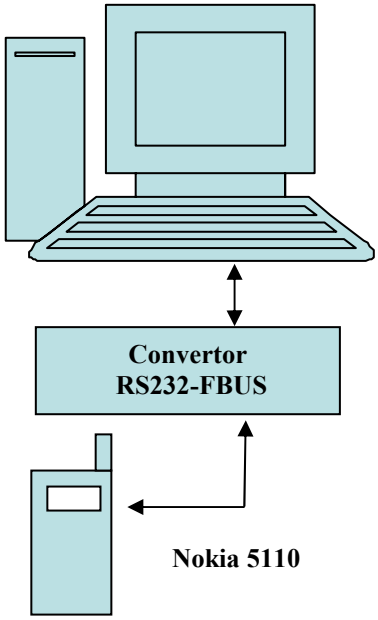

Figure 9 Connecting the mobile phone

THE VOICE RECOGNITION MODULE

The voice module (Voice Direct364) is a speaker-dependent speech recognition IC (figure 8). It maps spoken commands to system control functions using sophisticated speech recognition technology. Using easy - to - learn, intuitive techniques, the users train the module, which performs speech and sound prompting and speaker – dependent speech recognition. The module can also be controlled by an external host processor (slave mode) or operate in a pin-configurable stand-alone mode. It incorporates and includes an analog – to - digital signal converter, analog control signals, fully automated speech prompting and recognition (neural network recognition engine and speech/sound generator), DAC output for the speech synthesis, external serial EEPROM and parallel ROM, and Digital I/O interfaces. The module employs a sophisticated neural network to recognize trained words or phrases with greater than 99% accuracy, it records and accesses trained speech in voice recognition templates. Each word to be recognized must first be trained. During training it builds up a template representing the individual speaker's unique sound pattern for each specific word or phrase to be recognized. Templates are stored in serial EEPROM. During recognition a new pattern is produced and compared to the stored templates to determine which word was spoken. It initiates automatic training of up to

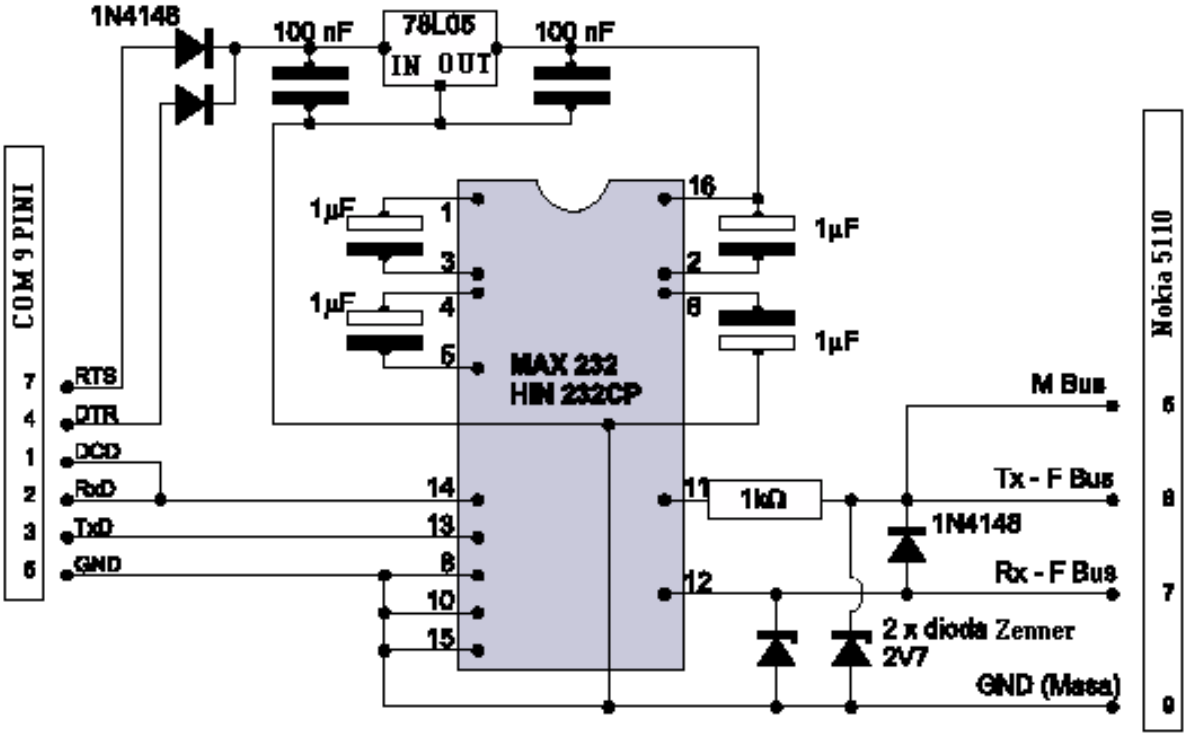

Figure 10 Signal converter based on MAX232

15 individual words or phrases. A word or phrase must be shorter than 2.5 seconds and may not contain silences longer than 0.5 seconds. For our application the use of omni directional capacity electrets microphone, with a minimum sensitivity of –60dB, appears to be compulsory.

MOBILE PHONE INTERFACE

Because 1 logic corresponds to different voltage levels, 2.7V in mobile phones in 5V in computers, a conversion is needed. FBUS is a bus for mobile phone; it is similar with RS232, but has different voltage levels. Taking that into account, it is easier to connect the phone using the RS232 serial bus from the computer structure.

A RS232-FBUS converter will adapt the voltage levels between the two buses (figure 9). This operation is performed in two steps:

- a MAX232 chip is used to obtain less than 5V for 1 logic and 0V for O logic from the initial levels varying between -25V and +25V (figure 10).
- having two stable voltage levels but still greater than 2.7V, the problem is solved in easier way with a Zenner diode.

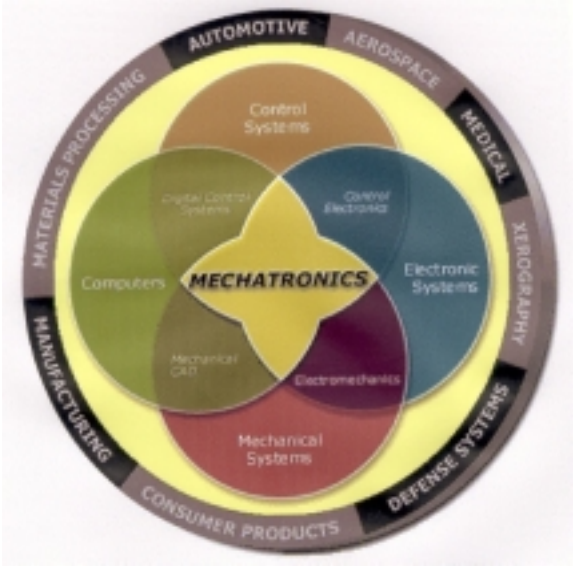

Figure 11 Mechatronics domains

CONCLUSIONS

The main function of the system is the long distance surveillance control, but the application was designed also in order to underline the **mec**h**a**tronics interdisciplinary (**m**echanics, **e**lectronics, **c**omputers and **a**utomation) (figure 11).

This application should offer a useful support in lab activity for some disciplines in the curriculum area of Mechatronics, such as Microcontrollers and Pattern Recognition and Image Processing.

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