A comparison between using distance sensors for measuring the pantograph vertically movement

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Abstract. In railway transportation the most important problem to solve consists in assuring the safety traffic of people and freight. In this scope some of the geometrical parameters regarding the contact line must be measured. One of this parameter is the pantograph vertically movement, so it must use distance sensors. Present paper studies the performance of two kinds of distance sensors, an ultrasonic distance sensor and an infrared sensor. The performances are studied from the point of view of error distance measurement and the possibility of using a real time acquisition system. The researches were made on a laboratory model for the pantograph realized at the scale 1:2.

1. General description of the application

In order to measure the vertically movement of the laboratory pantograph, a hardware-software system is proposed. The system components are the followings and they are presented in Figure 1:

- Laptop equipped with LabVIEW Development System NI MyRIO
- Acquisition board NI MyRIO 1900, Xilinx processor, FPGA and Real time technology, 667MHz
- LabVIEW application for programming and monitoring
- Distance ultrasonic sensor Parallax Ping
- Distance IR sensor Pololu
- Temperature analogic sensor LM35

Figure 1. The block scheme of the application
2. Hardware application

2.1. NI MyRIO acquisition board
The myRIO Embedded Device features in/out pins on both sides of this device in MXP and MSP connectors. It includes analog inputs, analog outputs, digital I/O pins, LEDs, push button, a Xilinx FPGA, onboard accelerometer, and a dual-core processor. The user can program it with LabVIEW or C. With its onboard devices, this embedded device provides an affordable tool for students and educators.

2.2. Distance ultrasonic sensor Parallax Ping
The Parallax PING ultrasonic distance sensor provides accuracy; the range of distance is varying between 2 cm and 3 meters.

The PING sensor works by transmitting an ultrasonic burst and it provides an output pulse that is assigned to the time required for the burst echo to return to the sensor. By measuring the echo pulse width, the distance to target can easily be calculated.

**Technical characteristics**
- Range: 2 cm to 3 m (0.8 in to 3.3 yd)
- Burst indicator LED shows sensor activity
- Bidirectional TTL pulse interface on a single I/O pin can communicate with 5 V TTL or 3.3 V CMOS microcontrollers
- Input trigger: positive TTL pulse, 2 µs min, 5 µs typ.
- Echo pulse: positive TTL pulse, 115 µs minimum to 18.5 ms maximum.
- Supply voltage: +5 VDC
- Supply current: 30 mA typ; 35 mA max
- Communication: Positive TTL pulse. Package: 3-pin SIP, 0.1” spacing (ground, power, signal)
- Operating temperature: 0 – 70° C.

**Communication Protocol**
The PING sensor detects obstacles by emitting an ultrasonic burst and then the device waits to receive the echo. Controlled by a host microcontroller (trigger pulse), the sensor is emitting an ultrasonic burst with frequency of 40 kHz. The burst travels into the air, reaches an object and then it bounces back to the sensor. The PING sensor generates an output pulse to the microcontroller that will be finished when the echo is detected, hence the width of this pulse corresponds to the distance to the object. Figure 2 presents the time diagram of the sensor functioning.

2.3. Distance IR sensor Pololu
The presented distance sensors represent a popular choice for many projects which require accurate distance measurements. This type of IR sensor is more economically than the sonar rangefinders, it provides much better performance than other IR alternatives. Interfacing to most microcontrollers is like in following: the single analogue output can be connected to an analogue to digital converter for taking distance measurements, or the output can be connected to comparator circuit for detection the threshold. The range for detection of this version is approximately 10 cm to 80 cm (4 inch to 32 inch). The GP2Y0A21 uses a 3-pin JST PH connector that works with our 3-pin JST PH cables for Sharp distance sensors. The time diagram is presented in the Figure 3.

**Technical characteristics**
- Operating voltage: 4.5 V to 5.5 V
- Average current consumption: 30 mA (note: present sensor draws current in wide, short bursts, and the manufacturer recommends connecting a 10 μF capacitor or larger across power and ground close to the sensor to stabilize the power supply line)
- Distance measuring range: 10 cm to 80 cm (4” to 32”)
- Output voltage differential over distance range: 1.9 V (typical)
- Update period: 38 ± 10 ms
2.4. Temperature sensor LM35

The analogue temperature sensor is necessary due to the ultrasonic functioning. The analogue sensor LM35 is rated to operate over a −55°C to 150°C temperature range. The LM35 sensor has the advantage over linear temperature sensors which are calibrated in Kelvin, so the user doesn’t have to subtract a large constant voltage from the output to obtain convenient Centigrade scaling, so it presents a linear scale factor, +10 mV/°C. The LM35 is connected at pin A10 of B connector of NI MyRIO controller.

The relation (1) permits the computing of speed of ultrasonic burst in the air in function of temperature:
\[ v_{\text{avg}}[m/s] = 331.5 + 0.6 \cdot T[\text{\degree C}] \] (1)

The distance measuring system is tested on a laboratory pantograph presented in Figure 4. The pantograph is made on 1/2 scales and it is commanded by a pneumatic system. By functioning of this mechanism, the pantograph-contact line assembly describes a trajectory in the horizontally plan (zigzag) and another trajectory in vertically plan. The distance sensor will acquire in real time the vertically distance [1], [2].

3. Software application for acquiring the ultrasonic sensor
LabVIEW MyRIO programming environment permits a reliable communication between hardware and software elements. The front panel of the application for measuring the distance using the ultrasonic sensor is presented in Figure 5. The real time communication ensures the acquiring of the temperature signal. A numerical filter is designed in order to cancel the acquisition noise. Therefore, the optimal value for the temperature window length is 100 samples. The application shows in real time the temperature value in Celsius, Fahrenheit and Kelvin degrees. The source code of the application is accomplished into a While structure for continuous acquisition. The block scheme of the project application is presented in Figure 6 and the block scheme of the Virtual instrument in Figure 7.

Figure 4. Figure with short caption (caption centred)

Figure 5. Front panel of the ultrasonic sensor application
Software application is realized as a LabVIEW project that is able to group and call together LabVIEW files or files not specific to LabVIEW, also it creates build specifications, and deploy or download files to real time targets. The project application calls in this case a virtual instrument which deploys acquiring data from distance and temperature sensors, NI MyRIO target which ensures the real time communication between sensors and the virtual instrument and an auto-populating folder which serves to data saving [3], [4].

The first sequence is realized for acquiring the temperature using the analogue input AI0 of NI MyRIO.

The second sequence of the virtual instrument contains subroutines for acquiring data from distance sensor. The communication between the distance sensor and the MyRIO controller implies a single wire which is connected on DIO1 pin of the C connector. The I/O pin is configured to work properly using a structure with six cases presented in the followings:

Initialize – Initializes the session for acquiring the distance sensor. The DIO1 pin is getting ready to open the session using Smart Open.vi subroutine available in MyRIO library.

Trigger pulse – Generates the start pulse to the distance sensor. Using a sequence structure, the application waits 2µs, and then generates a 5µs pulse with Write.vi subroutine.

Rising edge – First, the application waits for the echo hold off for 750µs, then reads the information from the sensor

Falling edge – In function of the duration of the sensor pulse (115µs – 18.5ms), the application is ready to calculate the distance
Calculating the distance – The application uses the temperature information provided by the first sequence and the distance can be computed and displayed on the front panel.

Stop – MyRIO session must be closed.

The second structure uses the temperature acquired into the first sequence. The first sequence is placed into a While structure whose timing is set to 1000μs. In order to cancel the acquisitioning noise, a numerical filter is designed. The window length of this filter can be adjusted from the front panel, but it was observed the 100 samples ensure the maximum quality for the temperature signal. If the window length is increased, the measuring time is reduced, but the temperature measuring error increases due to the increased noise amplitude. The user is able to adjust the number of measuring set/sample. For example, the application can take 5 sets of measurement into 20ms and the average is considered to be the result into an interval of 100ms. The measurements are perturbed by the acquisitioning noise, so a smoothing filter is designed. This filter takes into consideration also the previous measuring results [5].

In Figures 8 and 9 the distance variation when the window length is L=10 samples and 5 samples is presented.

**Figure 8.** Variation of the unfiltered and filtered instantaneous distance with window length L = 10 samples using ultrasonic sensor

**Figure 9.** Variation of the unfiltered and filtered instantaneous distance with window length L = 5 samples using ultrasonic sensor
4. Software application for acquiring the IR sensor

Data used for generation the voltage-distance characteristic can be reached into a matrix which can generate the variation on the front panel of the IR sensor application (Figure 10). By choosing the factor and the interpolation type, the appropriated matrix can be generated. It realizes the interpolated characteristic. The matrix for interpolated data is presented in Figure 11.

This application is able to run in simulated and also in measuring mode. The functioning regime can be chosen from the front panel of the application. When the measuring mode is chosen, the application can acquire the signal from the IR sensor and to display the distance variation on the front panel. When the simulated mode is chosen, the application can display the variation by selecting the simulated voltage from the appropriated rotary button. In Figure 12 the variation of the distance in the measuring mode is displayed. The same numerical filter which has been presented in the previous application is used in order to cancel the acquisition noise.

**Figure 10.** The front panel of the IR sensor application

**Figure 11.** Matrix with interpolated data
5. Conclusions
This paper describes two software applications which use two types of distance sensors. From the distance variations, the following conclusions can be taken:

The ultrasonic sensor presents a linear characteristic which depends on the ambient temperature. The update period is 20ms. The IR sensor has a nonlinear characteristic which is not dependent on the ambient temperature. It presents a better update period: 16.5 ± 4 ms.

The unfiltered variation of the distance in both cases presents acquisition noise. The filtered variations which uses the window length \( L = 5 \) samples presents a better accuracy, the lower limit 40cm and the higher limit 60cm are reached to each movement period. Increasing the window length, it can be observed that the error is also increasing due to the increased noise amplitude.

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