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THE 3D LASER RANGE FINDER FOR AUTONOMOUS MOBILE ROBOTS: DESIGN AND CONSTRUCTION

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Summary: *The paper is focus on design of the 3D laser range finder designed for autonomous mobile systems. Next can be sensor module use for indoor and outdoor 3D sensing applications for example exploration, survey, mapping and surveillance at a cost-saving price. The 3D laser has been built on the base of a 2D range finder by the extension with standard servomotor.*

1. Introduction

Laser range finders are sensors that measure the distance to object in the closer surrounding by evaluating the time of flight of an emitted laser impulse. A pulsed laser beam is emitted and reflected if it meets an object. The time between transmission and reception of the impulse is directly proportional to the distance between the scanner and the object (time of flight). Very common in the robotics community is the Sick LMS-291 that we can see in the figure 1.

Figure 1: Sick LMS-291

Its horizontal field of view is 180°, and it can sense objects in distances up to 80 meters with measurement resolution 10mm, depending on the object's reflectivity. The pulsed laser beam is deflected by an internal rotating mirror so that a fan-shaped scan is made of the surrounding area (laser radar). The contour of the target object is determined from the sequence of impulses received. The measurement data is available in real time for further evaluation via a serial interface. Although the horizontal resolution 1° or 0.5° or 0.25° is quite

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large, Sick laser range finder has one important drawback: They can scan only in horizontal dimension, in a plain. A real 3D scanner would be worthwhile, especially in outdoor terrain where the robot moves in 3D.

For that reason, we constructed a tilt unit, which is able to tilt the Sick LMS-291 up and down by 60° each. A three-dimensional image of the environment is retrieved which can be processed further with the appropriate algorithms. The main part of this paper is focus on design and construction of the 3D laser range finder.

2. The 3D laser range finder

The 3D laser range finder (Figure 2) is built on the basis of a 2D range finder by extension with a tilt unit and servomotor. The 2D laser range finder is attached to the tilt unit for being rotated. The rotation axis is horizontal. A digital servo HITEC HS-5745MG is connected on the left side and is controlled by the servo motor controller.

Figure 2: 3D laser range finder

The tilt unit was design in Autodesk Inventor by reason easy production. We can see tilt unit model in the figure 3. Very important is locate the LMS-291 centre of gravity in to the axis of rotation because weight of the Sick LMS-291 is very heavy.

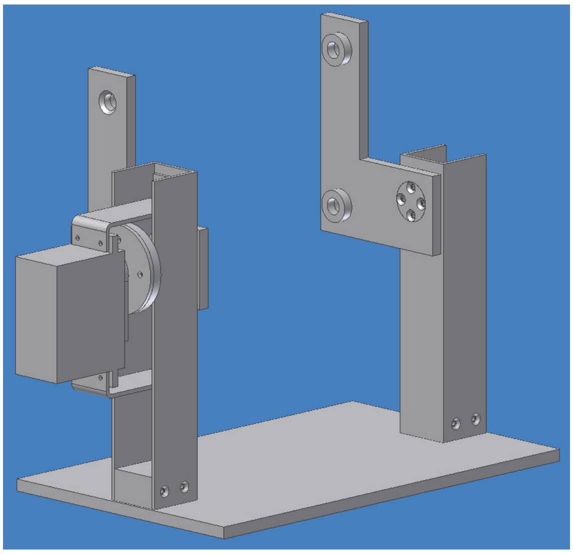

Figure 3: Tilt unit - Model from Autodesk inventor

Architecture description of the 3D laser range finder is in the figure 4. The personal computer (PC) is use for necessary software run. Communication between Sick LMS-291 and PC is led through two signal converters. First converter USB to RS-232 is connecting directly to PC through USB 2.0 bus. Follow the second converter RS-232 to RS-422. These two converters are necessary for Sick LMS-291 connection to PC through the high speed RS-422 bus.

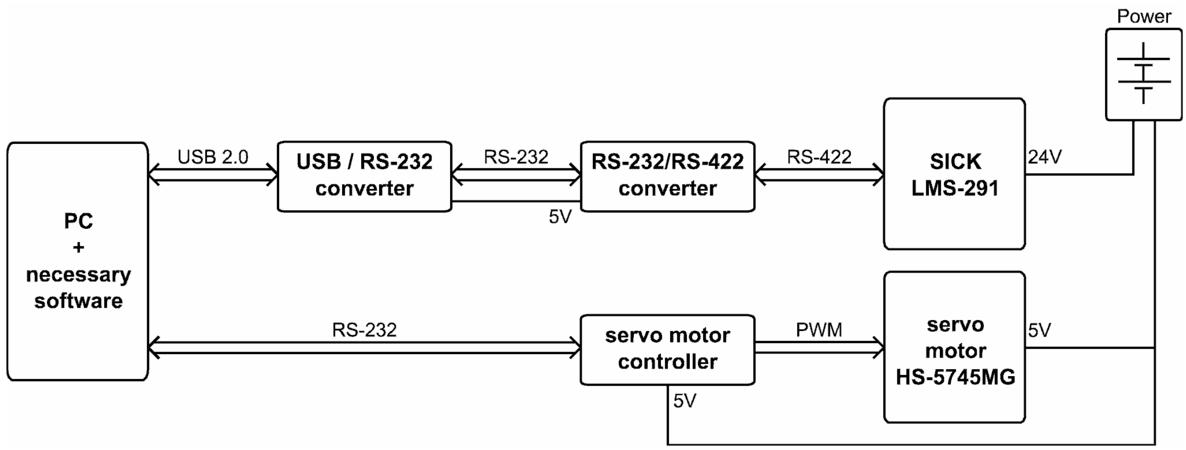

Figure 4: Architecture description

Tilt unit rotation is establishing via standard digital servo HITEC HS-5745MG. His detailed specifications are in the table 1. This is controlled by servo motor controller from PC through standard RS-232 bus.

Control System	Pulse Width Control 1500usec Neutral
Operating Voltage	4.8 - 6.0V
Stall Torque (4.8V)	15Kg.cm
Stall Current (4.8V)	4000mA
Dead Band Width	2usec
Dimensions	59x29x52mm
Weight	161g

Table 1: Servo HS-5745MG detailed specifications

4. USB to RS-422 converter

The LMS-291 sends measured data of the defined scan range 75 times per second. In the 180˚/0.5˚ resolution mode, there are 361 measurement values (2 bytes per value plus framing) per scan. Due to the large quantity of data generated by the LMS-291, it is only possible to transfer all acquired data in the 500 Kilo baud communications mode. In lower speed communications modes, only a subset of the actually acquired data is transferred via the serial interface. This means, for use the full capabilities of the LMS-291 is necessary to use the RS-422 high-speed serial interface card for PC communication.

We have been created two converters. First (Figure 5) is able to convert signal from USB 1.1 / 2.0 to RS-232 with TTL levels. The converter use single chip FT232R. It is a USB to serial UART interface. Data transfer rates is from 300 baud to 3 Mega baud (RS-422 / RS-485 and at TTL levels) and 300 baud to 1 Mega baud (RS-232). The converter use USB Bus power and no other power supply need.

Figure 5: USB to RS-232 converter

Input	USB 1.1 / USB 2.0 full speed compatible
Output	RS-232 / TTL levels
Speed	300 baud to 3 Mega baud
Supply	USB supply (5V)

Table 2: USB to RS-232 converter parameters

Second converter (Figure 6) is able to convert signal from RS-232 to RS-422 and can be connect directly to SICK LMS-291 scanner. The converter use chip SIPEX SP491. The SP491 is good for sending and receiving data at a rate of up to 5 Mega baud. In this case, maximum rate is limited to 3 Mega baud by the FT232R (USB to RS-232 converter). The converter is power up from USB to RS-232 converter and no other power supply need.

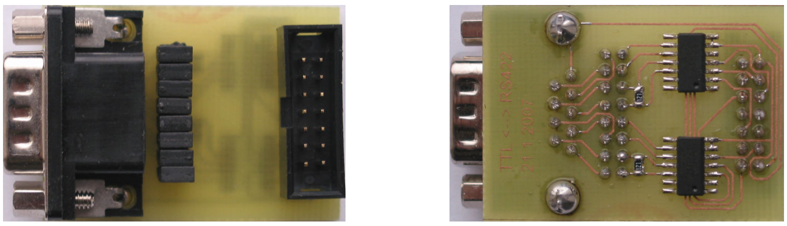

Figure 6: RS-232 to RS-422 converter

Input	RS-232 / TTL levels
Output	RS-422
Speed	up to 5 Mega baud
Supply	5V from USB to RS-232 converter

Table 3: RS-232 to RS-422 converter parameters

5. Servo motor controller

Special small servo motor controller (Figure 7) is used for digital servomotor control. It accepts RS232 serial data signal from a host computer and outputs PWM (pulse width modulated) signal to control up to twelve RC servo motors (servos used in radio-controlled model airplanes, cars, etc.). Unused servo pins can be reconfiguring for digital output to drive on/off devices.

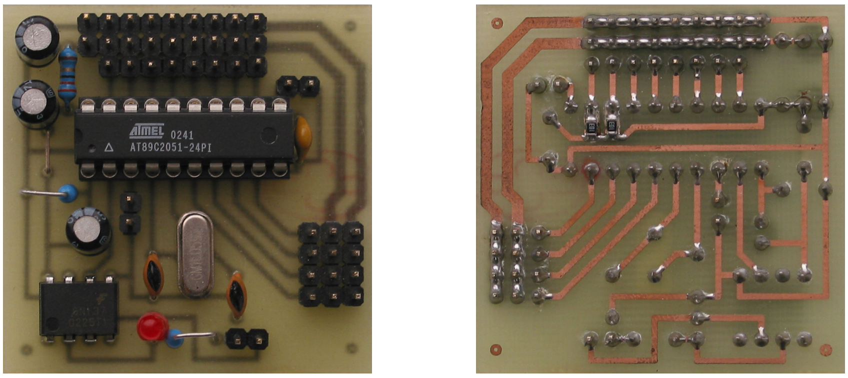

Figure 7: Servo motor controller

The servo motor controller requires only two connections to a host computer. Serial data and signal ground. In the input of the servo motor controller is the photo-coupler SHARP 6N136 that is serves as the galvanic separation.

When the controller is first powered up, it will move all servos to the centre position. To command a servo to a desired position requires sending three bytes (Table 4) at the appropriate serial rate (2400 or 9600 baud, depending on the setting of the jumper J1).

Byte 1	Byte 2	Byte 3
Sync marker (255)	Servo # (0..11)	Position (2..254)

Table 4: Servo motor controller command

The first byte serves for data transfer synchronizing, and therefore no other byte can use value 255. The second byte is the servo number within the range 0-11. Last byte is the required position. Value 0 and 1 has a special function. If position is set on value 0 then output is disabled (voltage on this output is 0V) and if position is set on value 1 then output is enabled (voltage on this output is 5V) so other devices (no only servos) can be connected to this output. For servo control are values 2-254 when 128 is the middle position and 2 and 254 are the outer positions. Command bytes must be sent as individual byte values. So sending a 255, 4, and 150 would move servo 4 to position 150, sending 255, 11, and 35 would move servo 11 to position 35.

Communication speed can be set by the J1 jumper. With no jumper J1, the servo motor controller receives serial data at 2400 baud. With jumper the baud rate is 9600 baud. In either case, the data are sent as 8 data bits, 1 stop bit and no parity.

We can set the range of the servos movement by the J2 jumper. If the J2 jumper is disconnected then the length of output PWM signal is 0.95-2.05ms. If the jumper is connected then the length of output PWM signal is 0.4-2.6ms. The narrower range is usable without danger that will not be able to use all mechanical servo movement range.

6. Conclusions

This paper has presented design and construction of cheap 3D sensor for autonomous mobile robots. The 3D laser range finder is built on base of an ordinary 2D range finder and for connects to PC uses high speed 500 Kilo baud interface. Future work will be concentrate on these aspects:

- Implementation of feedback from servomotor
- Use stronger servomotor, preferably with IRC sensor for feedback
- Increase of servo driver resolution
- Connect servo driver through USB 1.1 / 2.0 bus
- Make software for control 3D laser range finder

7. Acknowledgements

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8. References

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