Transactions of the VŠB – Technical University of Ostrava, Mechanical Series
No. 2, 2009, vol. LV,
article No. 1698

Martin POSPÍŠILÍK[*], Milan ADÁMEK[**]

AUTONOMOUS AIRSHIP

AUTONOMNĚ PRACUJÍCÍ VZDUCHOLOĎ

Abstract

This paper describes a project of attaching the autonomous monitoring system to a small helium airship. The airship is capable of independent operating inside a closed hall, being driven by means of ultrasonic detectors. It is accommodated to carry different monitoring units providing students with the opportunity to process various experiments and measurements. In the first experiment, the airship will carry WiFi router, camera and IP Relay by means of which the pertinent control of the airship through external web interface is enabled, independently on the ultrasonic detecting system.

Abstrakt

Tento článek se zabývá projektem, který spočívá v umístění autonomního monitorovacího systému na malou heliovou vzducholoď. Tato vzducholoď je za pomoci ultrazvukových detektorů schopna nezávisle se pohybovat uvnitř uzavřené místnosti. Vzducholoď je uzpůsobena k nesení různých monitorovacích zařízení, což studentům přináší možnost provádět s ní různé experimenty a měření. První úloha spočívá v instalaci WiFi routeru, webové kamery a IP relé na gondolu vzducholodi, pomocí nichž bude možné vzducholoď řídit na dálku nezávisle na ultrazvukovém řídicím systému.

1 INTRODUCTION

For a long time airships seemed to be outdone but now they are experiencing a considerable renascence. Nowadays, we distinguish between two main groups of them:

- big ones for outdoor operation,
- small ones optimised for indoor operation.

The big airships are used for example to monitor numbers of animals in reservation or weather state in a particular height. The small ones can hold equipment such as a camera or electromagnetic field gauge. By means of this they can be used in educational institutions.

Let us focus on the small ones that can operate inside buildings. They can be used for several purposes. They are good for advertisement because they attract the attention. But this is not the goal of this project. Knowing the physical advantages of the airships, mainly their capability to float in the air with minimal power consumption, we decided to develop a small autonomous platform that is able to hold various monitoring systems.

The Faculty of Informatics at Tomas Bata University in Zlin deals with education of applied informatics. This is why not only programming but also the application of computing systems is

[*] Ing, Department of Electrotechnics and Measurements, Faculty of Applied Informatics, Tomas Bata University in Zlin, Nad Stranemi 4511, Zlin, tel. (+420) 57 603 3004, e-mail pospisilik@fai.utb.cz
[**] Doc. Mgr., Phd., Department of Electrotechnics and Measurements, Faculty of Applied Informatics, Tomas Bata University in Zlin, Nad Stranemi 4511, Zlin, tel. (+420) 57 603 5251, e-mail adamek@fai.utb.cz.cz

taught there. This project gives the students opportunity to work with a real system, not only a computer model. It incorporates several fields of study: electrotechnics, measurement, algorithm development, automated control and Ethernet data transfer.

2 PHILOSOPHY

For the purpose of our research we obtained a small helium airship the dimensions of which are designed in the view of the fact that it should be operated inside a building. As the lifting capacity of helium is limited, the dimensions are resulting from a compromise among load capacity, length relative to the area of operation and aerodynamic shape. Because of this, the load capacity is quite limited. This leads to the need of optimising the weight of attached appliances, which is mainly inconsiderable in order to maintain a bigger number of such appliances. Thus, there are pretensions on electric circuits designers. Characteristics of the airship are as follows:

- Filling gas: He
- Load capacity: 0,65kg
- Power source: Li-Pol 7,2V, 2,4Ah
- Length: 2,6m
- Max. width: 1,45m
- Volume: 2,7m3

The load capacity considers the Li-Pol accumulator, three motors with servo and a plastic gondola attached to the bladder.

2.1 Orientation

The three-dimensional orientation of the airship is ensured by means of ultrasonic detectors that monitor distances between the airship and objects in its neighbourhood. Information gained through the detectors is then processed and serves to drive electric motors. As the airship embodies a considerable persistence, processing the information is rather complicated. The ultrasonic detectors are dislocated around the surface of the airship bladder. At present we are preparing tests of ultrasonic detectors reliability. If the system of orientation shows deficiencies that cannot be compensated by means of software, we will strengthen the orientation with optical detectors and/or with radio beacon working concurrently with ultrasonic detectors.

Each detector employs an ultrasonic transducer and receiver, both based on piezoelectric effect. Employing a special ceramics, these transducers are tuned to a frequency of approximately 40kHz with a narrow bandwidth, so the detectors are not sensitive to acoustic noise. When a detector is activated through the I^2C bus, it sends a short ultrasonic signal with maximum of power concentrated along the perpendicular to the transducer. Then it waits for the echo. The time between sending and receiving the signal can be expressed according to equation (1):

$$T = \frac{2L}{c} \quad , \qquad (1)$$

where:

T – time between sending and receiving the signal,

L – distance from the obstacle,

c – sound velocity.

As the sound velocity differs with many factors (e.g. temperature) according to equation (2), this measurement is not high accurate, but still accurate enough for our purposes.

$$c = \sqrt{\kappa \frac{p_0}{\rho_0}(1 + \frac{1}{2}\gamma \cdot t)} \ , \qquad (2)$$

where:

c – velocity,

k – Poisson's constant,

r_0 – air density at 0°C,

p_0 – air pressure at 0°C,

g – coefficient of thermal air extensibility,

t – temperature,

γ – temperature coefficient of gas extensibility.

The main problem is that the closer the detected object is the higher is the sensitivity of the sensor for sounds incoming not on the perpendicular. This can cause detection of false echo evoked by multiple reflections. For this reason more detectors are needed and the measurement must be repeated. When repeating the measurements by one detector, the measurement is never the same, because of continuous movement of the airship. As there is different position of the airship in face of the obstacle for each measurement, the probability of detecting the obstacle is higher.

2.2 Motion

To ensure the motion, the airship is provided with three motors. The two main motors are mounted on a gondola under the front part of the bladder. These motors are merged with a shaft that can be slewed with a servo system. These motors haul the airship in a forward direction. As they can be slewed with the servo, the direction of the drawing force can be adjusted from the forward direction to the up/down direction. Also the combination of these directions is possible. While the vector of the drawing force is adjusted with servo, the magnitude of the vector can be adjusted by pulse-width modulation of motors power. The third motor is attached at the tale of the airship in a sagittal way. This motor can be driven in both directions. Depending on the direction of the airscrew rotation, the airship rotates to the left or to the round around its vertical axle when the motor is on. The radius of the rotation can be adjusted by the proportion of drawing force generated by the front two motors and the rear one which can be regulated by driving the power to the motors individually.

2.3 Operating

The first prototype will be supplied with several modules that communicate one with other but globally we aim to design an one-processor controller that would be capable to ensure controlling of the whole airship operation. The philosophy of the whole system is shown at figure 1. The CPU processes the information from ultrasonic detectors (and possibly other detectors) and drives motors through external controller. The airship also carries a WiFi router that allows it to connect to the local LAN network in the building and transfer data or instructions between the airship and some server. By means of this the automatic control can be overridden by manual control performed through a web interface to the appropriate server. The red colour represents the I2C bus, the black one other controlling buses. The power supply circuit has a capability to transmit the information about battery state to the CPU so the user was warned that the battery is running low.

The communication between the CPU and the remote user is provided with an IP Relay. We are also contemplating the possibilities of direct connection of the CPU unit to the WiFi router.

The motors will be driven by PWM modulation, as well as the servo system, that determines its position by means of a negative feedback-driven single-step multivibrator and compares the length of the pulses from the multivibrator to the length of pulses generated by CPU.

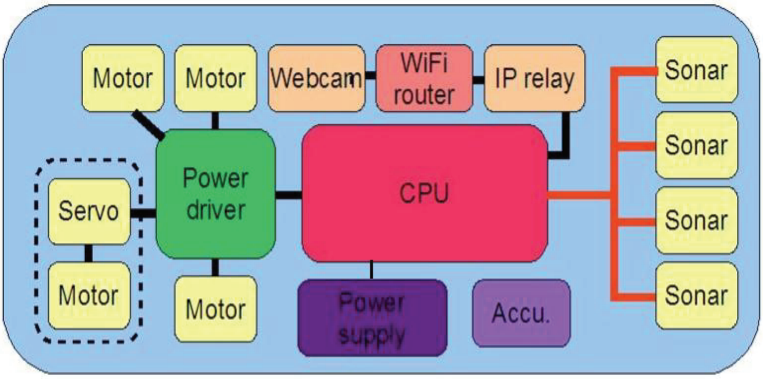

Fig. 1 Block diagram of the target project state

The figure 2 shows us the possibilities of the web interface. After logging on, the authorized user will be able to watch picture transmitted from web camera and to control the airship by means of several buttons or keyboard arrows. Moreover, he will be informed about the state of the battery.

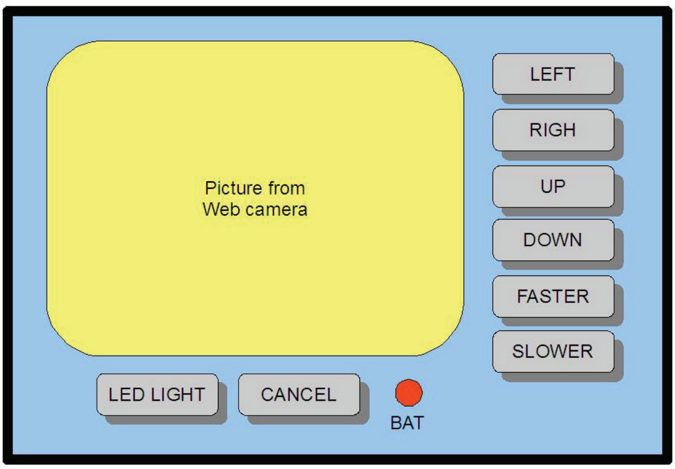

Fig. 2 Possibilities of the web interface

3 ACTUAL STATE

The project is quite new thus the development is not finished yet. At present, we are equipped with the airship that carries a radio controlling system, the ultrasonic sensors testing kit and the monitoring testing kit. This allows us to investigate these subjects:

- manipulability of the airship in a closed hall,
- impact of the airship persistence on the airship trajectory,

- behaviour of ultrasonic detectors and their reliability in detecting obstructions.

In the next step the rear motor will be driven with an MCU processing signals from the ultrasonic detectors while the operating staff will be able to drive the front two motors. This shall examine the controlling algorithm in a horizontal plane enough and minimise the danger of accident in case of extemporaneous situation.

3.1 Ultrasonic detectors testing kit

For the very first tests we provided our airship with RC controlling system, so it can be controlled as an aeromodel. It will hold our testing kit with ultrasonic detectors. There are 9 ultrasonic detectors mounted at the bladder of the airship to detect distances between the airship and the surrounding obstacles. The testing is performed with 9 ultrasonic detectors SRF09 connected to a microcontroller AT Mega. This microcontroller communicates with all the detectors and displays the distances measured by all of them on an LCD display. The LED module is to be attached at the bottom of the gondola. As the airship is driven inside a hall, the LEDs on the module will signalise the particular obstacle has been detected. Firstly, detecting at horizontal plane will be performed, so the LEDs will indicate the suggested direction.

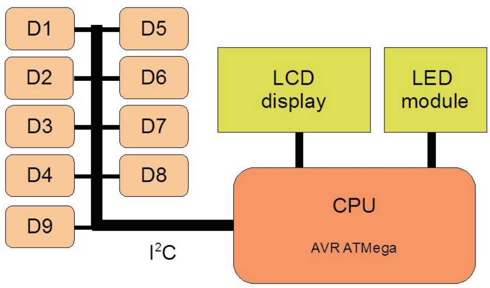

Fig. 3 Ultrasonic detectors testing kit

3.2 Monitoring testing kit

The first project deals with mounting a web camera to the airship. A block diagram of the testing kit is shown at figure 4. The kit includes a web camera, an IP relay, a WiFi router and an LED module. The camera transmits the picture through the WiFi router to a server. Authorised user can watch this picture. This user can also send several commands to the testing kit. When the command is received, the appropriate LED on the LED module is switched on for a short time that can be set. This gives us the information that the command was properly processed transmitted and processed with the IP relay and it is possible to use the signal generated by the IP relay to control other processes.

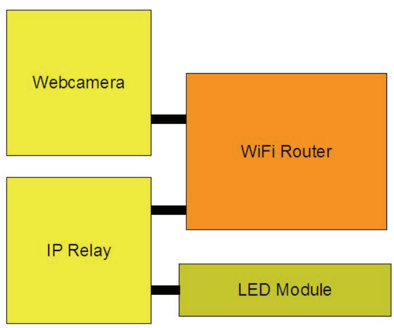

Fig. 4 Monitoring testing kit

3.3 Power supply

Currently we use a light-weight Li-Pol battery to power the airship. The nominal voltage is 7,2V. This is sufficient for supplying the servo system, motors and the radio-controlling unit. Other voltages needed to supply IP camera, WiFi router and other appliances will be gained by means of a switching supply.

For distribution of energy from the accumulator battery we need switching power supply, which has low weight, is capable to deliver sufficient current and to protect the accumulator from deep discharge.

4 CONCLUSION

The project deals with a problem of automated operating of a small airship inside a building. This airship can be used for monitoring its neighbourhood. At the university, it serves as a real system the students can develop their projects on.

ACKNOWLEDGEMENT

The authors gratefully acknowledge the support of this project from the Tomas Bata University in Zlin.

REFERENCES

[1] MAHDAL, M. Wireless Technologies and Their Applications. In *9th International Carpathian Control Conference ICCC´2008*. Sinaia, Romania, May 25 - 28, 2008, pp. 388 – 391. ISBN 978-973-746-897-0.

[2] FORMÁNEK, I. *Základy automatizace*. Logické řízení. 1. vyd. Ostrava : VŠB-TU Ostrava, 2006. 86 s. ISBN 80-248-1012-3.

[3] BABIUCH, M. Implementation of User-friendly Programming Environment for Standalone Micro-controllers. In *Proceedings of 3rd International Carpathian Control Conference*. Ostrava : VŠB-TU Ostrava, 27. - 30. 5. 2002, p. 471-475. ISBN 80-248-0089-6.

[4] NOVÁK, P. 2007. *Mobilní roboty*, 1. díl, Praha: BEN – technická literatura, 2007, 248 p., ISBN 80-7300-140-1.

[5] ĎAĎO, S., KREIDL, M. 1999. *Senzory a měřicí obvody*, Praha: Vydavatelství ČVUT, 1999, 315p., ISBN 80-01-02057-6.

[6] CHUDÝ, V., PALENČÁR, R., KUREKOVÁ, E., HALAJ, M. 1999. *Meranie technických veličín*, Bratislava: Vydavateľstvo STU, 1999, 672 p., ISBN 80-227-1275-2

[7] FRADEN, J. 2004. *Handbook of modern sensors*, New York: Springer-Verlag, Inc., 2004, 589 p., ISBN 0-387-00750-4.