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Rotation of the flap controlled by the air flow from the fan – educational mechatronic system

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1. Introduction

The designed mechatronic system is intended to serve as an educational device for applying the control algorithm to a real physical model. The construction of the model consists of a vertical and horizontal aluminium arm, which are connected by plastic elements and metal screws. The flap rotates around a pin located on a horizontal arm. The fan attached to the vertical arm generates an air flow that rotates the flap around the pin. An infrared (IR) distance sensor which measures the horizontal displacement of the flap is placed in a suitable position from the flap. A ruler installed in the axis of the IR sensor is used for verification measurement of flap displacement. All plastic elements as well as the flap itself were designed and manufactured using 3D printing.

The physical model is completed by a simple electrical circuit installed on PCB that serves to power the system and to connect the measured signal from IR sensor and the control signal for the fan speed with the DAQ (data acquisition) measurement hardware. The DAQ hardware communicates via a USB connection with a computer and LabVIEW software, where a graphical user interface (GUI) is created. Software also enables the creation of a suitable algorithm for automatic system control.

2. Electrical circuit for the model

A computer cooling fan (ARCTIC S4028-15K) is used as an actuator of the system (basic parameters: fan speed 1150-15000 RPM, PWM controlled, 12 V DC / 0.47 A). The flap displacement is measured by IR distance sensor (SHARP GP2Y0A41SK0F) that is powered by 5 V DC and gives a voltage analog output signal.

The voltage to PWM converter module is built into the electrical circuit which creates a PWM signal for the supply voltage of the fan (0-100 %; 0-12 VDC) using a control analog voltage of 0-5 V DC. This control voltage is created either manually using a potentiometer or digitally via DAQ hardware and software. Manual or software control mode can be selected using a rocker switch.

The electric circuit is powered by a 12 V DC power adapter and a step-down voltage converter (12 V to 5 V) is designed for the needs of IR sensor and PWM module. The last part of the electrical circuit is the filter capacitor for the measured signal of IR sensor.

The physical model is completed by a simple electrical circuit that serves to power the system and to connect the measured signal from IR sensor and the control signal for the fan speed with the DAQ measurement hardware, see Fig. 1. The DAQ hardware communicates via a USB connection with a computer and LabVIEW software, where a graphical user interface (GUI) is created.

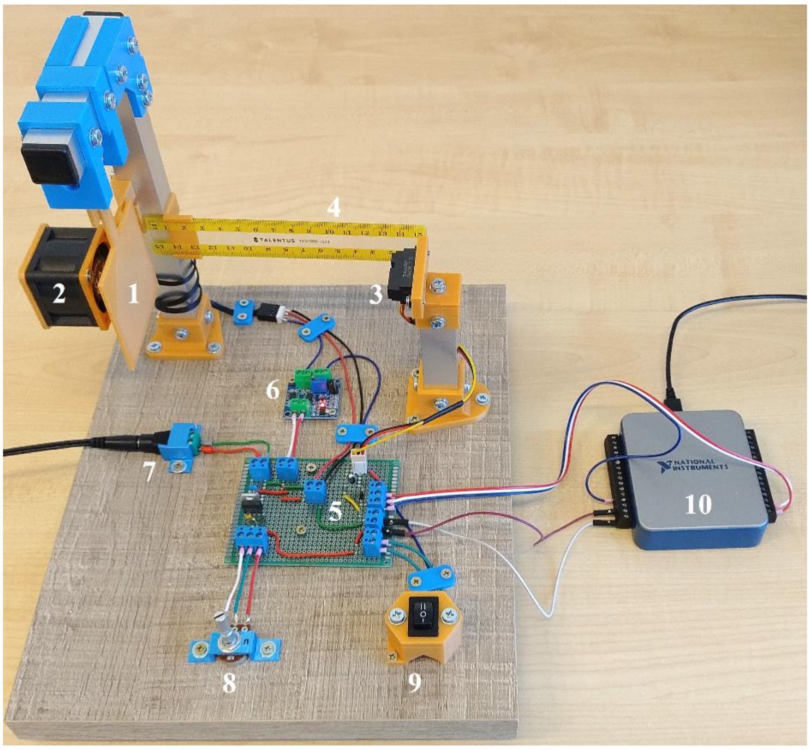

Fig. 1. Components of the mechatronic syste: 1 – flap, 2 – fan, 3 – IR sensor, 4 – ruler, 5 – PCB, 6 – PWM module, 7 – power supply connector, 8 – potentiometer, 9 – rocker switch, 10 – DAQ hardware

3. System testing

The air from the fan rotates the flap around the pin and the IR sensor measures the change in its horizontal displacement *x*. The sensor is located at a constant vertical distance of 75 mm from the pin. The flap rotation angle *φ* can be calculated according to the relationship as shown in Fig. 2. Displacement measurement is nonlinearly dependent on the electrical voltage at the sensor output as shown in Fig. 3. By approximating the measured data with a polynomial function, we obtain a function for calculating the measured distance:

$$x = 45.932\,U^3 - 323.37\,U^2 + 810.5\,U - 679.54 \tag{1}$$

The installed ruler can be used to verify the distance measurement.

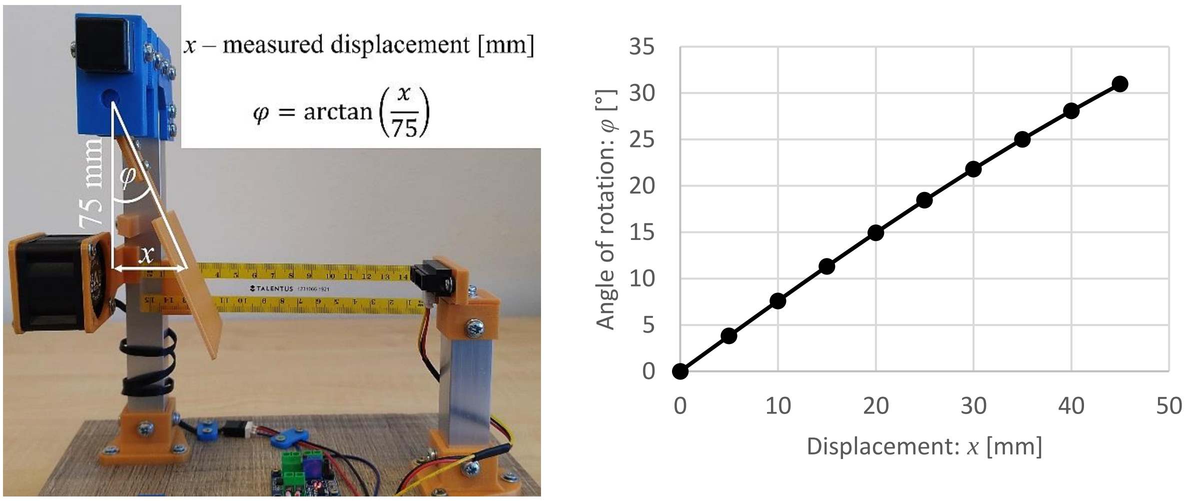

Fig. 2. Determining the flap rotation angle and its dependence on flap displacement

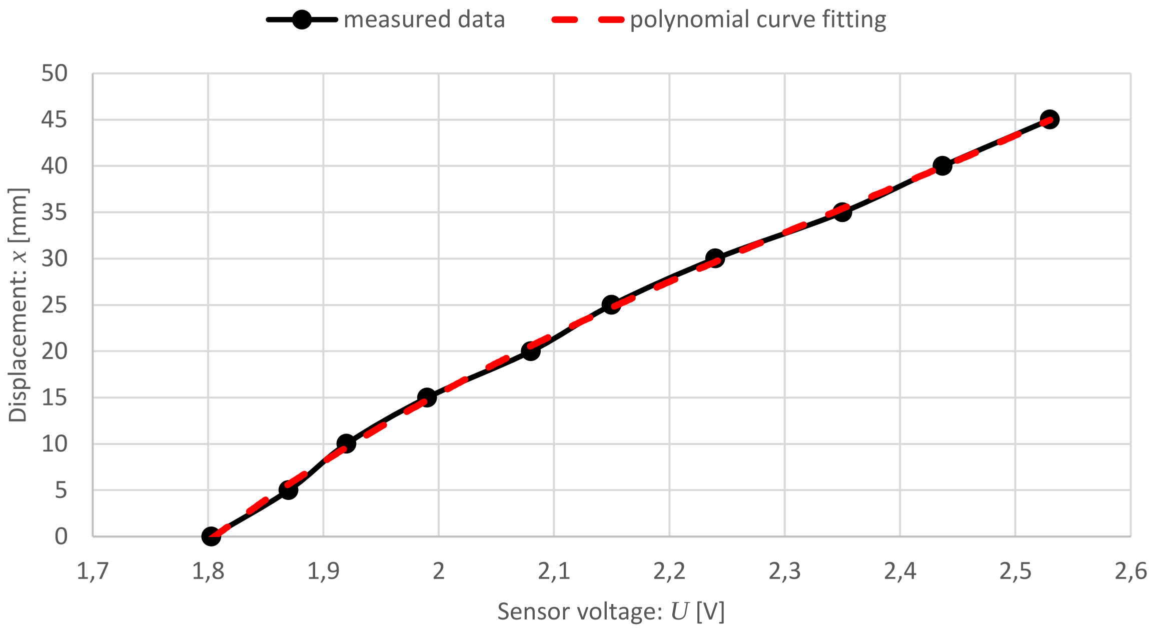

Fig. 3. Dependence of the measured distance on the output voltage of the IR sensor

Fig. 4 shows the graphical user interface (GUI) for system control created in LabVIEW software. The fan speed is set with a slider - PWM duty cycle is modified. Measured horizontal displacement of the flap and calculated value of its rotation angle are plotted on the graphs.

Due to the principle of creating the air flow by the fan as well as the flow around the flap, the whole system is considerably non-linear.

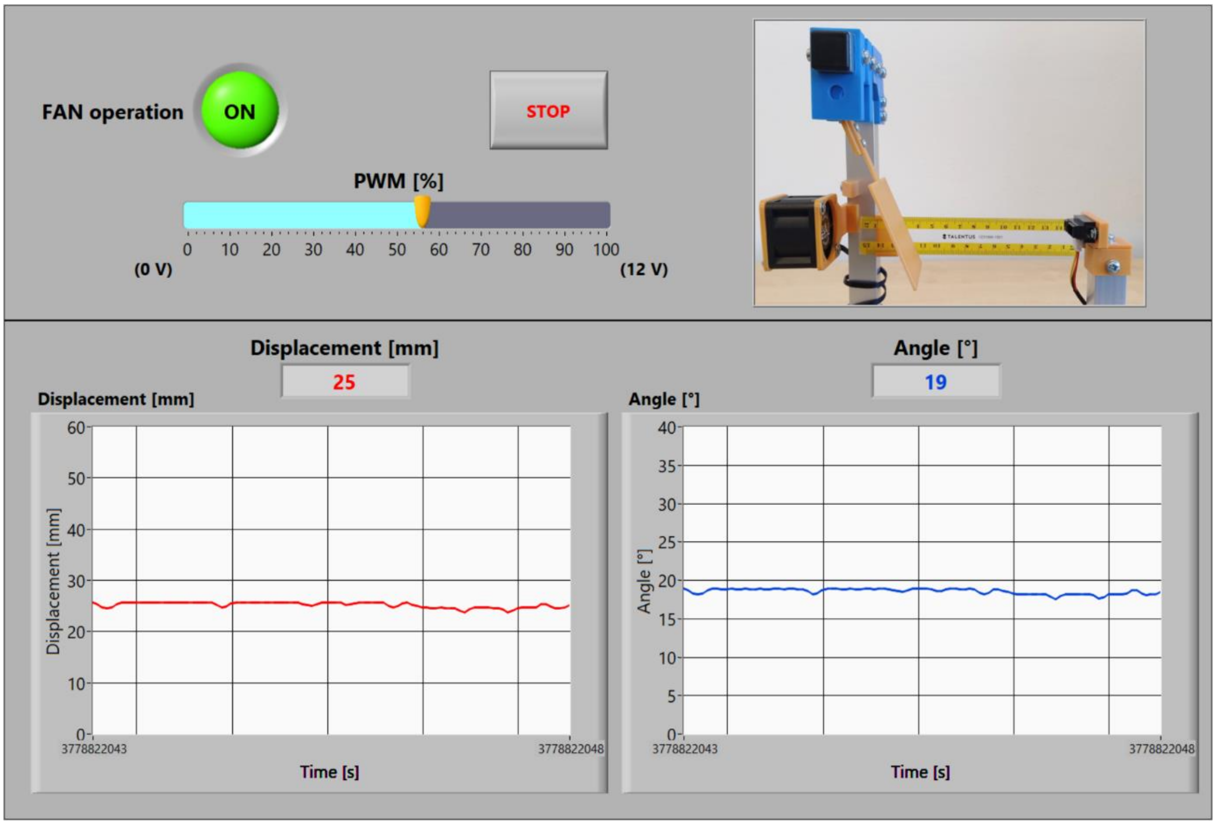

Fig. 4. Graphical user interface – LabVIEW software

4. Conclusions

A simple mechatronic system made using 3D printing and suitable electronic components was presented. This system enables practical control of the flap rotation by means of flowing air from the fan. The flap horizontal displacement change is measured by an IR distance sensor and the fan speed is controlled by a PWM signal.

A suitable controller with a programmed control algorithm can be used for the automatic control system. This model is suitable as an educational system in the field of mechatronics and cybernetics.

In the future, it would be appropriate to create a mathematical model of the system using its experimental identification.

Acknowledgements

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