DIGITAL AND LOW-COST DEVELOPMENT OF A POLARIMETER ON A RASPBERRY PI

Manuel Wejner

INTRODUCTION

Digital data acquisition is becoming increasingly important in basic science education. Schools often lack the financial resources to purchase sufficient equipment for the computer-aided acquisition of resources to purchase the necessary equipment in sufficient numbers. In addition, many devices are often designed for professional use in the laboratory, which makes operation equally difficult. Digital polarimeters are among the most expensive measuring instruments that can be used in educational institutions. Even the purchase of an analog meter can be in the high three-digit range. The digital polarimeter presented here is intended to be easily accessible, which is why low-cost components are used (Tab. 1). In addition, the simple self-construction allows the functions of the individual components to be described and explained, which can counteract the black box character for learners.

Component	Price
Raspberry Pi	*40 €*
LED	*1 €*
Light sensor	*5 €*
Servo motor	*5 €*
Polarizer	*10 €*
Lego Bricks	*10 €*

Tab. 1 Components used for the digital Raspberry Pi Polarimeter

DEVELOPMENT

The angle of rotation is measured in a similar way to a photometer via the light intensity or the transmission of aqueous solutions and is detected by a digital light sensor using a yellow LED as the light source. Two polarization filters, which can be purchased cheaply, serve as polarizer and analyser. To be able to determine a rotation angle, the analyser was glued to a servo motor (Fig. 1).For the framework of the polarimeter Lego bricks are used. These serve to stabilize the servo motor, but also as a socket for the LED, which is used to define the light path. The light intensity sensor is placed behind the analyser exactly opposite the LED. For measuring aqueous solutions, a large, transparent plastic jar for peppermint candy with an inner diameter of d = 0.47 dm is sufficient as a cuvette. The diameter is necessary for the later experimental setup as the parameter of layer thickness.

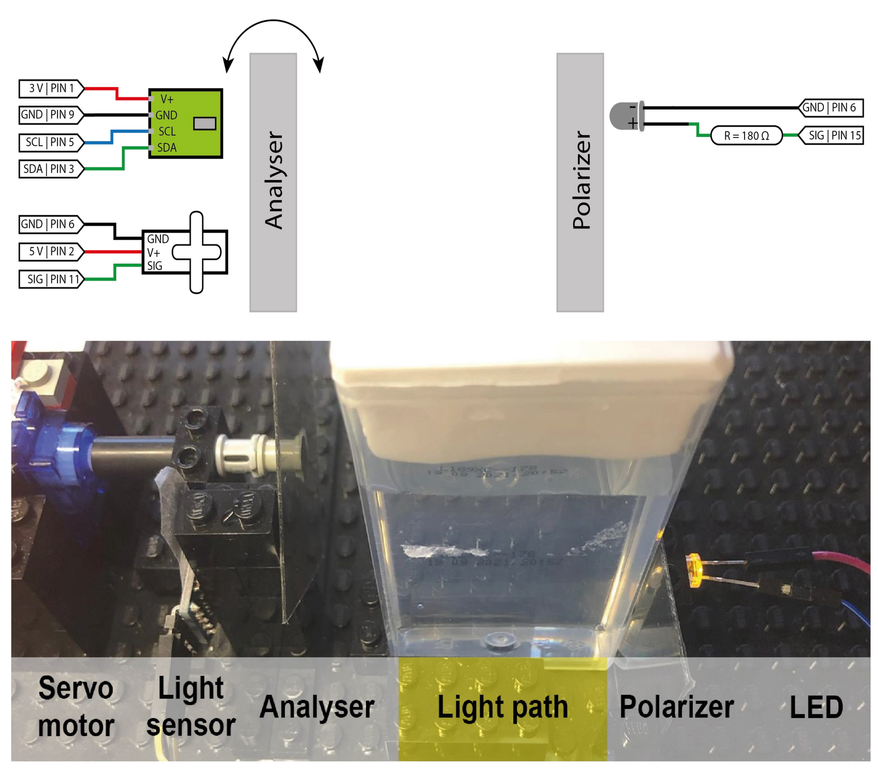

Fig. 1 Schematic wiring (top) and buildup (bottom) of the digital polarimeter

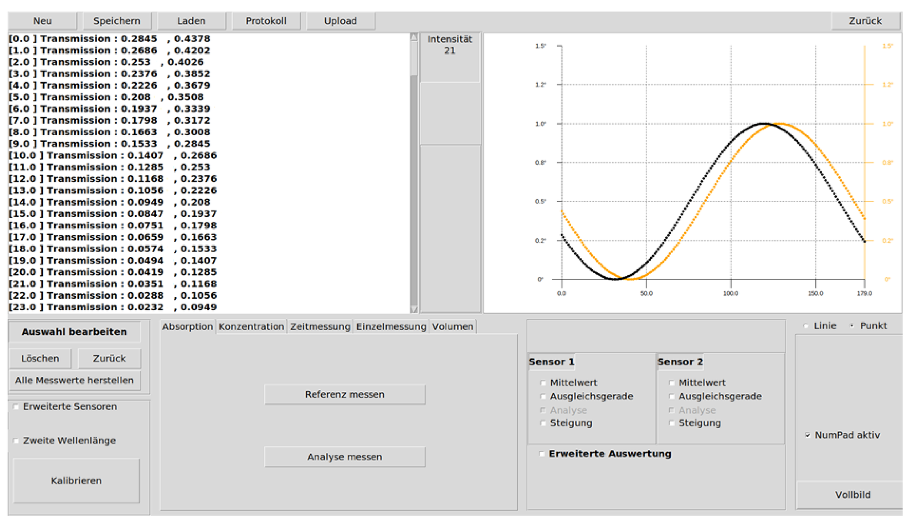

Fig. 2 Graphical User Interface (GUI) with example messure

To control the sensors of the digital polarimeter, the already existing software LabPi was used [1]. It has a user interface tailored to teaching, which was developed for the Raspberry Pi. The software was first adapted and tuned to the functionality of the digital polarimeter. LabPi thus takes over automated processes, such as rotating the analyser and recording the measurement points. The software finally displays these in tabular and graphical form. The curve progressions and measurement data can be compared directly in the software and differences can be visualized and displayed on the graphical interface or the measurement data can be exported for further analysis (Fig. 2).

MEASURE

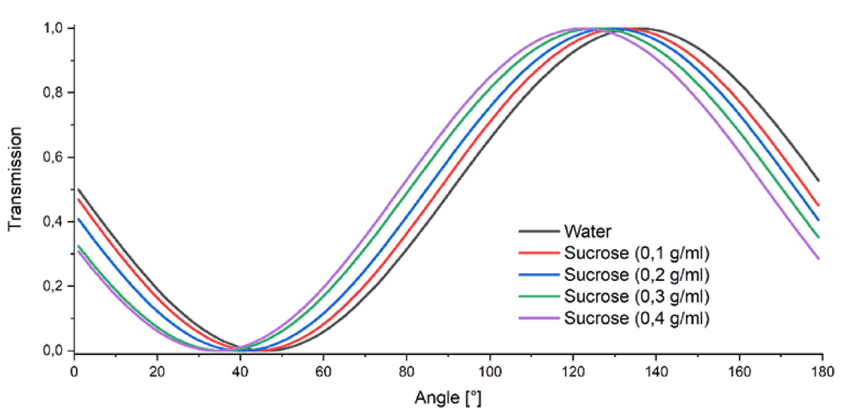

Fig. 3 Transmission of water and different sucrose solutions by angle

Sucrose solution	LabPi	Specific rotation	Deviation
0.1 g/ml	*3°*	*63.8°*	*-3.87 %*
0.2 g/ml	*6.5°*	*69.1°*	*4.14 %*
0.3 g/ml	*10°*	*70.9°*	*6.81 %*
0.4 g/ml	*13°*	*69.1°*	*4.14 %*
Ø	-	*68.3°*	*2.81 %*

Tab. 2 Specific rotation of sucrose solutions measured with LabPi

Sucrose solution	Analog	Specific rotation	Deviation
0.1 g/ml	*12.65°*	*63.3°*	*-4.74 %*
0.2 g/ml	*27.75°*	*64.4°*	*-3.05 %*
0.3 g/ml	*38.65°*	*64.4°*	*-2.99 %*
0.4 g/ml	*52.40°*	*65.5°*	*-1.36 %*
Ø	-	*64.39°*	*-3.03 %*

Tab. 3 Specific rotation of sucrose solutions measured with an analog polarimeter

The angle of rotation is determined by rotating the analyser and recording the intensity values by LabPi and is also reproduced as transmission. This allows a complete sinusoid to be mapped when the analyser is rotated by 180°. The extremes of this curve represent the measuring points for determining the change in the angle of rotation. The extremes, which are uniform in amplitude due to transmission, also help in the visualization of different sugar solutions. Depending on the concentration of the sugar solution and the layer thickness of the cuvette, the phase of the sinusoidal curve is thus shifted. The difference between the extreme points of the solutions to be measured allow the rotation of the polarized light to be determined (Fig. 3). To calibrate the digital polarimeter, the zero point for the angle of rotation was determined with distilled water.

To determine the precision of the digital low-cost polarimeter, the specific rotation angle of sucrose was determined via a concentration series. In parallel, the same solutions were measured with a conventional, analogue laboratory polarimeter by Krüss Optronic [2].

The table shows the calculated specific rotation angles in comparison. The deviations are related to the literature value (α = 66.47°) [3]. The angles recorded with the analogue polarimeter appear about four times as large as those of the digital polarimeter. This is primarily related to the choice of layer thickness, which corresponded to 2 dm for the standard cuvette and 0.47 dm for the plastic can.

OUTLOOK

Both the polarimeter and the LabPi software are still under development. Especially for the polarimeter, further adaptations of the software are planned. At the current state, the determination of the specific angle of rotation is still dependent on office applications. In the future, this shall also be done via the software LabPi, whereby the results can be switched on optionally with only a few steps. In the future, it will also be possible to perform time-dependent measurements and concentration determinations with the aid of adjustable parameters. At the hardware level, further adjustments will be made to enable even more precise measurements before piloting with learning groups.

REFERENCES

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