Development of Ultrasonic Device for High School Lab Activity

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Abstract: Using the methods of comparative analysis and those for the development of educational and technical means, a model of a device for obtaining ultrasonic characteristics is proposed. The comparative analysis showed that ultrasound measurement systems can be divided into three main groups: using an oscilloscope, using a Data Logger and stand-alone measurement systems. Summarized, the factors that affect measurement accuracy can be divided into two main groups - essential, which must be compensated for, and minor, which can be neglected. Pedagogical aspects in the development and use of ultrasound devices are reviewed. It has been found that they can be successfully used in project-based and problem-based learning. Multimedia learning can be successfully combined with game-based learning. A laboratory setup is proposed, in which, in addition to the ultrasound system, an oscilloscope is used. Despite the shortcomings of this configuration, it has the potential to be used in more than one academic discipline.

Keywords: Ultrasonic, Doppler, Lab activity, Quality assessment, Pedagogical approaches.

1. Introduction

Practical and laboratory exercises aim at learning new knowledge for students. With the development of science and technology, the requirements for the technical and technological means necessary to obtain this knowledge also increase (Georgieva et al., 2015).

Under European programs, experienced productions have been acquired in Bulgarian universities, mainly from producers in EU countries.

https://doi.org/10.58503/icvl-v17y202222

In Bulgaria, there are long-standing traditions in training in the use of systems for the analysis of objects from various fields such as agrarian, food production and energetics.

For the effective use of laboratory experimental setups, there is a need to adapt them to the teaching methods in Bulgaria (Doncheva et al., 2018).

Pedagogical goals that can be fulfilled by the implementation of such technical means are related to familiarizing students with solving measurement and data analysis tasks for various objects of production. This is achieved by solving and implementing real tasks from industrial production.

According to a study by Batista et al. (2014) educators use mobile devices to a greater extent to deliver learning through mobile applications, video resource sharing and virtual learning environments.

Modern requirements in the production of food products are a prerequisite for directing scientific research to new and precise methods for measuring and managing technological processes in this area.

Ultrasonic techniques are an alternative to traditional measurement methods, as they can be used online, directly on the production line, they are non-destructive and have a potentially low cost of technical means for their implementation.

Ultrasound, which is essentially a mechanical wave, interacts with substances in food products. The variety of types of ultrasonic waves allows them to be used in different aspects.

The ultrasonic non-contact measurement method is suitable for the analysis of food products in the various stages of their production. Through this method, the recommendations for hygienic production can be met. The parameters of the ultrasonic signal correlate to a large extent with the physico-chemical and organoleptic indicators of food products.

One of the modern learning technologies with wide, even mass application, are multimedia technologies. Multimedia presentations are the main tool in them. Their meaning and purpose are: to illustrate the learning content; their content to be adopted quickly and effectively by the trainees; to maintain attention; content to be easily understood; to aid its memorization; to provoke the learner's activity.

The aim of this study is to propose an ultrasonic device that is appropriate for educational purposes. To solve this problem, next tasks have to be done:

- To propose a comparative analysis of existing ultrasound devices from the point of view of the technical principle of operation;
- To analyze the pedagogical aspects for their application in training;
- To propose an ultrasonic device suitable for e-learning and distance learning in this field.

2. Methods

In the present study, the method of comparative analysis was used. It is a process in which the measuring instruments studied are compared. It is a method by which it can be determined whether the results obtained in the study complement or improve those known from the available literature.

Benchmarking allows identifying good practices, prioritizing opportunities for improvement, and improving performance against learner expectations, as well as bypassing traditional change cycles. It also helps to choose a sufficiently accurate and efficient way of doing the activity, to study how lower costs can actually be achieved (Knippe, 2002).

The main problem that the authors of the available publications note is that it is necessary to look for ways to reduce the influence of factors that have a negative effect on measurements with ultrasonic sensors. Through such results, it will be possible to propose an ultrasonic system suitable for application directly on the production line, in real cheese production.

3. Types of the developed ultrasonic devices

Ultrasound measurement systems can be divided into three main groups: using an oscilloscope, using a Data Logger, and stand-alone measurement systems.

Table 1 shows the advantages and limitations of the more common ultrasonic characterization systems.

From the study of various systems for obtaining ultrasonic characteristics, sensor systems using an intermediate unit of an oscilloscope or a Data Logger have the advantage. The speed and resolution of analog-to-digital conversion and the number of discrete values of one measurement depend entirely on the capabilities of the intermediate measurement module. A common disadvantage of an oscilloscope and data logger system is that there is the possibility of noise being superimposed on the analog signal en route from the sensor module to the intermediate measurement module.

In the case of stand-alone sensor systems, the advantage is that they have the ability to work with ultrasonic sensors for different frequencies, through one sensor module. With them, the possibility of superimposing noise on the received analog signal is minimized. There is an opportunity to create a fully automatic measuring system and high mobility.

4. Factors that affect measurement with ultrasonic devices

In addition to the type of measurement system, obtaining ultrasonic characteristics is influenced by a number of factors. These factors are divided into two main groups - essential, which must be compensated for, and minor, which can be neglected.

Table 2 shows the factors affecting the measurement accuracy, the type of their influence and the literature sources in which they are analyzed.

Table 1. Comparative analysis of ultrasound systems

Type of the system	**Advantages**	**Limitations**	**Source**
System with oscilloscope and memory card	It is used independently without the need for a personal computer	An operator is needed to transfer the data	(May et al., 2000)
A system with a direct connection of an oscilloscope to a personal computer	A fully automatic measurement system can be implemented	Reducing mobility and increasing the cost of the system	(Benedito et al., 2001)
Measurement system with Data Logger	It can be used independently without the need for a personal computer	Reducing mobility and increasing the cost of the system	(Nowak, 2015)
Self-contained system for obtaining ultrasonic characteristics	All operations on receiving and pre-processing of measurement data should be performed in the sensor module	The cost of the measuring system depends on those of the personal computer and the measuring module	(Simeonov et al., 2009)

Table 2. Factors affecting measurement accuracy with ultrasonic sensors

Factor	**Main influence**	**Source**
Air temperature and humidity	Propagation speed of the ultrasound signal	(May et al., 2000)
Atmospheric pressure and gas composition of air	They can be neglected when measuring the same altitude	(Buckin, 2003)
Measuring distance	Operating frequency of ultrasonic sensors	(Ilarionov et al., 2010)
Measured material	The object of measurement must be located in the far zone of the ultrasonic emitter	(Nowak, 2015)
Reflection angle and distance	Angle of displacement of transducers and their dimensions	(Awad et al., 2012)

Factors affecting the accuracy of measurement can be divided into two main groups - essential, which must be compensated for, and minor, which can be neglected.

The temperature and humidity of the air affect the speed of propagation of the ultrasonic signal. They can be compensated after measuring their values and calculating a compensation equation.

At the same altitude, atmospheric pressure and gas composition of the air can be neglected.

When increasing the working distance to the measured object, it is necessary to choose a lower operating frequency of the ultrasonic sensors. This is also related to another factor – the transmitter's operating frequency.

The object of measurement must be located in the far zone of the ultrasonic emitter, where the wave can be assumed to be flat.

It is necessary that the angle at which the ultrasonic waves are reflected from the material, as well as the distance to it, should be such as to ensure their maximum perception on the working surface of the receiver. The measurement accuracy also depends on the angle of displacement of the transducers and their dimensions.

From the analysis of the factors affecting the accuracy of measurement by ultrasonic sensors, it is clear that humidity and air temperature have the greatest influence. Therefore, it is necessary to measure them periodically in order to make a correction and validation, by means of computational methods.

The measurement distance must also be selected correctly depending on the material to be measured as well as the frequency of the emitter. It is necessary to analyze the influence of these factors when indirectly determining the quality indicators of the studied products using ultrasonic characteristics.

5. Pedagogical approaches

In addition to the technical aspects, when developing laboratory equipment, it is necessary to take into account the pedagogical ones. The development and use of ultrasound devices allows for the use of project-based and problem-based learning. Multimedia learning can be successfully combined with game-based learning.

Table 3 presents the more commonly used pedagogical approaches in training to work with ultrasound devices. Through appropriate hardware and software, video clips, electronic textbooks and courses can be realized. A graphical representation of the ultrasound signal can be recorded for multiple objects. In this way, ultrasound data can be processed remotely, by students who have a computer and an Internet connection. Through online data processing and analysis tools, they can complete part of the exercises without having to be present in the school's laboratory.

6. Proposed laboratory device for ultrasonic measurement

After searching the available literature sources, a laboratory setup was developed for obtaining ultrasonic characteristics. The option with an oscilloscope connected to a personal computer is selected. Despite the many disadvantages and limitations of this configuration, it uses multiple measuring devices, making it suitable for educational activities. The laboratory setup can be used in educational disciplines related to electronics, embedded microprocessor systems, and express analysis of food products.

Figure 1 shows a general view and block diagram of the developed laboratory setup for obtaining ultrasonic characteristics of various products. Position (1) denotes the ultrasound system, which consists of a single-board microcomputer, an ultrasound sensor with receivers, and a transmitter. To compensate for the influence of ambient humidity and temperature, their measurement is carried out with a digital sensor for these environmental parameters. The ultrasound system is connected to an oscilloscope (2), through which the ultrasound signal is received and visualized. The oscilloscope is connected to a personal computer (3). The oscilloscope software visualizes and records the ultrasonic data for the measured samples (4).

A comparative analysis of the developed device was made with other devices described in the available literature.

Nowak (2015), proves that not all signs obtained from the ultrasound signal can be applied in the identification of specific characteristics of the studied objects, due to the lack of significant differences in their average values.

Table 3. Pedagogical approaches in teaching to work with ultrasonic apparatus and equipment

Approach	Description	Source
Project-based training	Project work is an interactive strategy for realizing the connection between students' theoretical knowledge and practical activity, for connecting learning with their real life and cognitive experience, for realizing full socialization and for orientation in the existing information environment as necessary competencies.	(Diawati et al., 2018)
Problem-based training	It offers opportunities for multiple interactions between the participants in the learning process, which in turn leads to the formation of skills for successfully dealing with life situations of different origins.	
Training through play	Appropriately introduced game method develops greater independence and activity in students, mediates the contact of	(Tee et al., 2019)

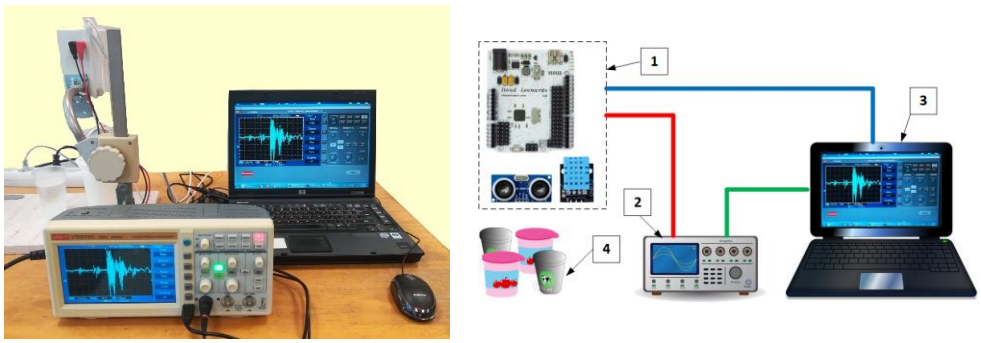
	Students with material culture, the acquisition of socially significant experience and provides a comprehensive approach to development.	
Multimedia-based training	Modern information technologies are used to ensure the learning process and innovative research. These are computer-based teaching, testing and assessment tools.	
Computer-simulation based training	Simulation training is associated with professional fields where there is zero tolerance for deviation from established standards. It helps to reduce errors and maintain a culture of safety in professions directly related to the development and protection of human life.	
Systematized approach	It represents a hierarchical approach, which is expressed in the mutual subordination of some elements to others. Structuring is manifested in the combination of components in subgroups, between which certain relationships are established.	(Shen et al., 2013)
A directed survey experiment	It represents conducting a scientific experiment in education. Revealing to students the methods of reaching knowledge, which are research and explanation.	(Kvittingen et al., 2016)
Method experiment	This is a special organization of the pedagogical activity of teachers and students with the aim of checking and substantiating previously developed theoretical assumptions or hypotheses.	
Method demonstration	Demonstration as a teaching method means showing objects or didactic materials, accompanied by descriptions and explanations, through which students receive information about the studied phenomena.	
Method – Workshop	The workshop allows students to work together and assess the work of other students or on tasks set by the teacher. There are multiple options for rating by different criteria.	(Bonjour et al., 2014)

This thesis was confirmed by Daskalov et al. (2019). According to the authors, representing the ultrasound characteristics by signs is a better option than using their raw data directly.

The presented schematic solution, algorithm, and test of the proposed non-contact ultrasonic measuring device overcome the shortcomings of the one proposed by Simeonov et al. (2009), from the point of view of its application for laboratory training, because the experimental set-up consists of several measuring

devices – an oscilloscope, an ultrasound system, and a personal computer. For this reason, it can be used in more than one academic discipline.

What has been said so far is a prerequisite for the implementation of future research related to improving the performance of the proposed ultrasonic device, from the point of view of accurately determining the values of the characteristics of the investigated objects, in laboratory conditions and directly on the production line, as well as evaluating the possibility of predicting these parameters with ultrasound techniques.



a) General view b) Block-diagram

Figure 1. Laboratory set-up for ultrasonic measurements

7. Conclusion

In the present study, a comparative analysis of ultrasonic devices is made from the point of view of their principle of operation, the factors influencing the measurement with such technical means, as well as the pedagogical aspects related to their application as educational and technical means.

Using the methods of comparative analysis and those for the development of educational and technical means, a model of a device for obtaining ultrasonic characteristics is proposed.

The comparative analysis showed that ultrasound measurement systems can be divided into three main groups: using an oscilloscope, using a Data Logger, and stand-alone measurement systems.

It has been found that the factors that influence the accuracy of measurement with ultrasonic devices can be divided into two main groups - essential, which must be compensated for, and minor, which can be neglected.

Pedagogical aspects in the development and use of ultrasound devices are reviewed. It has been found that they can be successfully used in project-based and problem-based learning. Multimedia learning can be successfully combined with game-based learning.

As a result of the studies, a laboratory setup was proposed, in which, in addition to the ultrasound system, an oscilloscope is used. Despite the

shortcomings of this configuration, it has the potential to be used in more than one academic discipline.

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