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CONCEPTION OF THE ARDUINO PLATFORM AS A BASE FOR THE CONSTRUCTION OF DISTRIBUTED DIAGNOSTIC SYSTEMS

Summary. Systems for distributed parameter measurements are very expensive solutions; however, they offer many possibilities in terms of real-time verification of machine status. Of course, ready, complex and easy-to-use measuring systems can be used, where the cost of such a solution may be prohibitive. In the case of research carried out under the experimental sphere of an object, e.g., using a research measurement system, it is possible to create a project for a system based mainly on the Arduino platform. As an example, the concept of a distributed measurement system will be presented, with the possibility for use on cranes and conveyors, i.e., on the most common machines on industrial plants.
Keywords: measurement, Arduino, diagnostics, distributed system, temperature, acceleration, data transmission

1. INTRODUCTION

In an era of globalization and reduced human resources, as well as associated costs, it is a necessity to eliminate every possible human part of the information chain, which is also the weakest link. The system of distributed measurement is based on a complex system of devices, not only measurement and control equipment, but also data-processing systems and

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their localization both inside and outside of the object or group of objects, e.g., industrial objects. Depending on needs requirements, the necessary data for the machine and its parameters need to be supplied continuously at a high or low frequency (for coarse control). Depending on the amount of data, it is increasingly necessary to fit the appropriate module with the transmission and processing of measured data [1, 4, 5] and any data from the feedback loop of the diagnostic and control system. They can be explosion-proof control systems on conveyor belts transporting coal dust where, e.g., temperature sensors are often used at very large distances and multiple measuring points are important. Other work systems are proposed as an alternative to, e.g., fibre optic sensors used on conveyor belts, to verify the temperature both in an environment of rollers and sets of bearings at the gears (Fig. 1).

(a) (b)

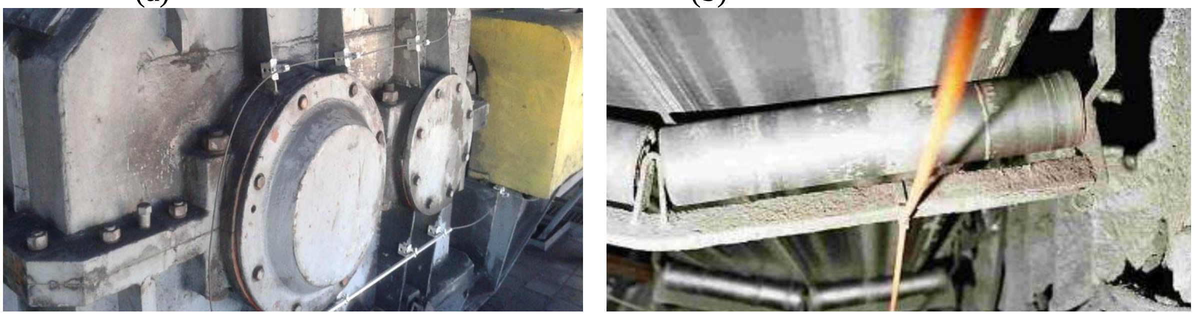

Fig. 1. Fibre optic temperature measurement (a) at the gearbox bearing and (b) along the conveyor [6]

Systems for distributed parameter measurements of objects are expensive solutions; however, they offer many possibilities in terms of real-time verification of operations on the object concerned. Of course, complex and easy-to-use measuring systems can be used, but the cost may be prohibitive. In the case of research involving scientific activities or within the sphere of experiments on a real object, it can be tempting to design a bespoke system based on the Arduino platform. As examples, the concept of a distributed measurement system for use on an overhead crane (Fig. 2) and a system for use on a conveyor belt will be proposed.

The first example will involve an application for measuring the temperature and current, while the other example will measure the acceleration and temperature, together with the verification of skewing and approaches near the edge of the pathway, with the use of ultrasound technology or laser beam scanning.

Fig. 2. Overhead crane [3]

2. SYSTEM CONCEPT

The concept of a distributed measurement system, as presented in Figure 3, is based, among other things, on the Arduino platform and consists of a central diagnostic computer, which supervises locally installed measurement modules, that is, the so-called nodes (Fig. 4).

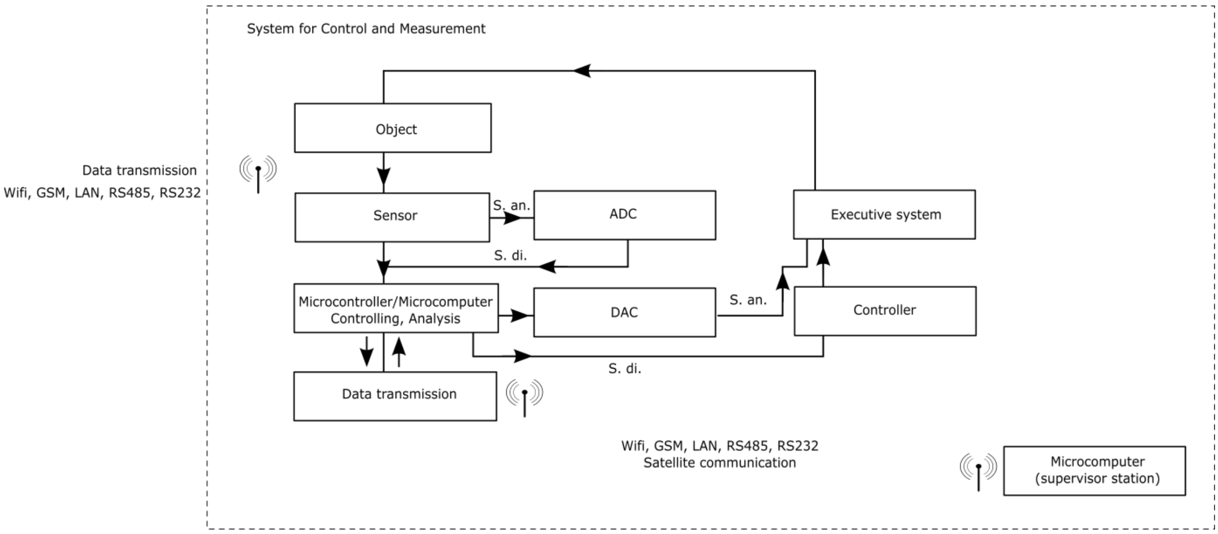

Fig. 3. Structure of distributed measurement system (S.an = analogue signal and S.di = digital signal)

Individual measurement modules are equipped with sets of transducers for measuring currents, temperature and vibrations of monitored elements, and a laser scanner, a distance sensor and wireless systems designed to transmit data to a central diagnostic computer, which supports a two-way data exchange between distributed measurement modules. It uses both standard Wi-Fi and the GSM network, with limitations in terms of both the range and the amount of transmitted data [2].

The bidirectional exchange of data enables, among other things, connecting the right module to the corresponding actuators of the machine (Fig. 3 and Fig. 4). The exchange of data within the system does not necessarily have to take place only wirelessly; it can also involve mixed systems using wired or standard protocols (i.e., RS 485 or RS 232), depending on the needs and resources for the construction of the system.

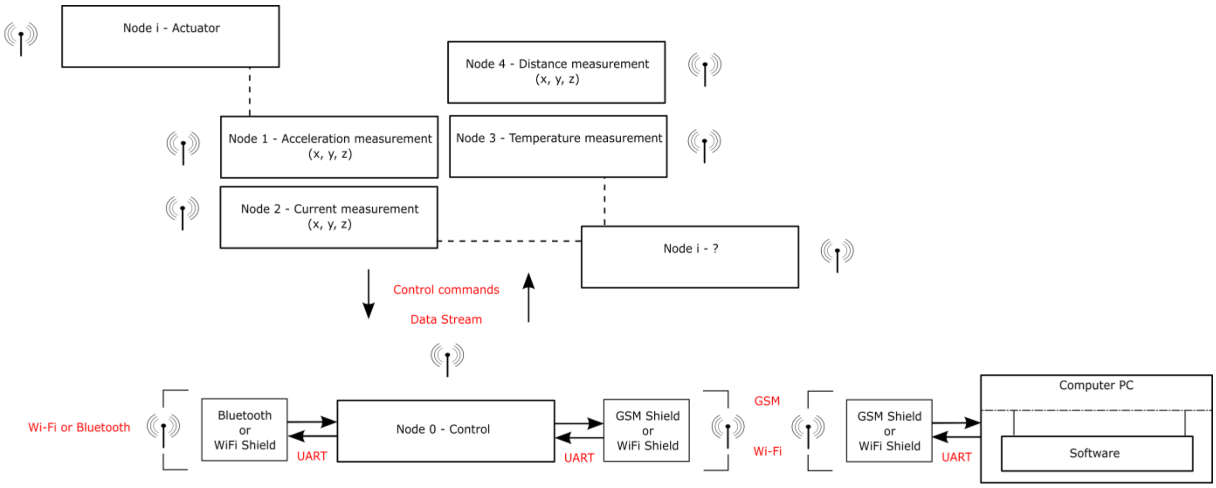

Fig. 4. Structure of nodes conception

Fig. 5. RockBLOCK Mk2 Iridium SatComm Module [7]

In the case of communication with very distant measurement system nodes, a satellite connection using the Iridium network can be used, where the basic cost of using that network is USD12 per month, which locates it in the low-budget category system. An example of the use of this technology is the simple-to-use Rock BLOCK Mk2 Iridium SatComm Module (Fig. 5), which is capable of receiving and sending short messages from any location on Earth. This module is based on the Iridium 9602 satellite modem. The device operates with a voltage of 5 V and communicates via UART (RX, TX). This allows for direct cooperation with the ATmega microcontrollers, which are the basis for the Arduino platform, offering a satellite modem at a low cost.

Due to the need for a constant control system, which is under a continuous monitoring signal, the system can be equipped with an operating system based on servomotors or cheaper counterparts; for example, they can be servos to regulate the selected systems, such as the control valves of hydraulic and pneumatic systems.

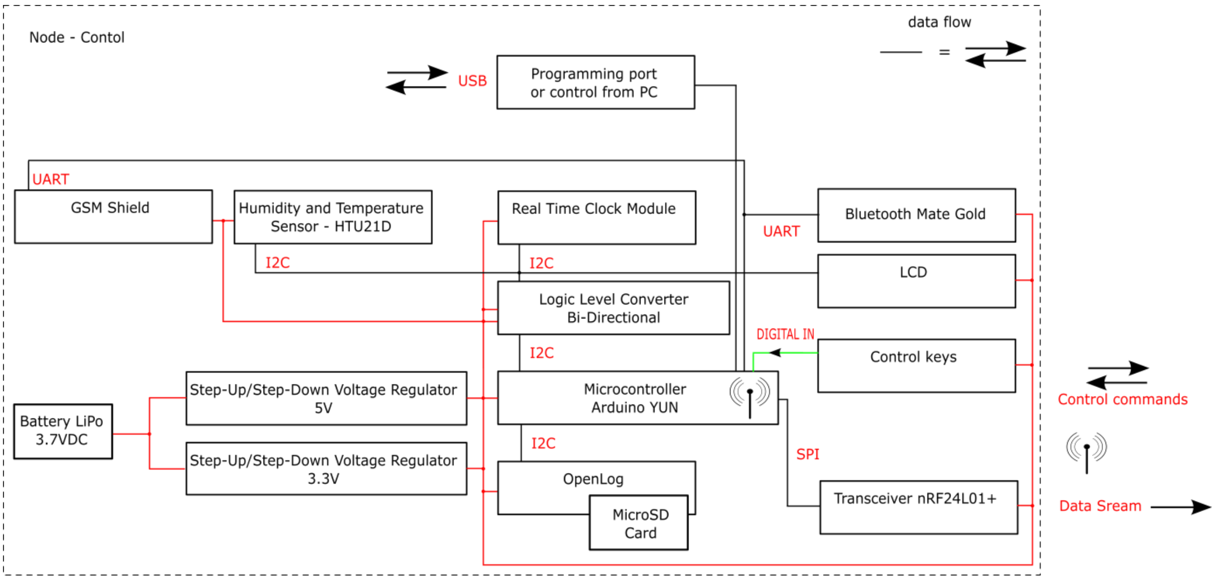

Fig. 6. Example solution: controlling node

The exemplary solution of the control node, as shown in Figure 6, could act as an indirect function between the nodes and the diagnostic computer, which should be characterized by high computing power; for this reason, it is recommended that a standard PC or a compact microcomputer is used in this case, such as a Raspberry Pi. In the case of the simplest solutions, a system control node, based on the Arduino microcontroller YUN, has been proposed. Arduino YUN has integrated Wi-Fi connectivity, which is compatible with the proposed measurement nodes to be discussed later in this article, and uses a separate module for radio transmission, which is responsible for transmitting and receiving only measurement data. For example, the control node is equipped with an RTC and a module for GSM communication, although, depending on the respective needs, any module for communication over long distances will suffice, such as the aforementioned satellite modem.

2.1. Measuring node: temperature, current

The system implementing the current measurement and the temperature surrounding the rollers is shown in block diagram form (Fig. 7). This system is based on the ATmega328 microcontroller placed on the board of an Arduino Pro Mini. For the measurement parameters of the system, two sensors are used. The first one is a current sensor working on the basis of the Hall effect, i.e., ACS709 ±75A (Fig. 8a), and the second one is a digital temperature sensor, i.e., TMP102 (Fig. 8b). When measuring the surface temperature of the component is required, a non-contact sensor can be used, based on the infrared sensor TMP007.

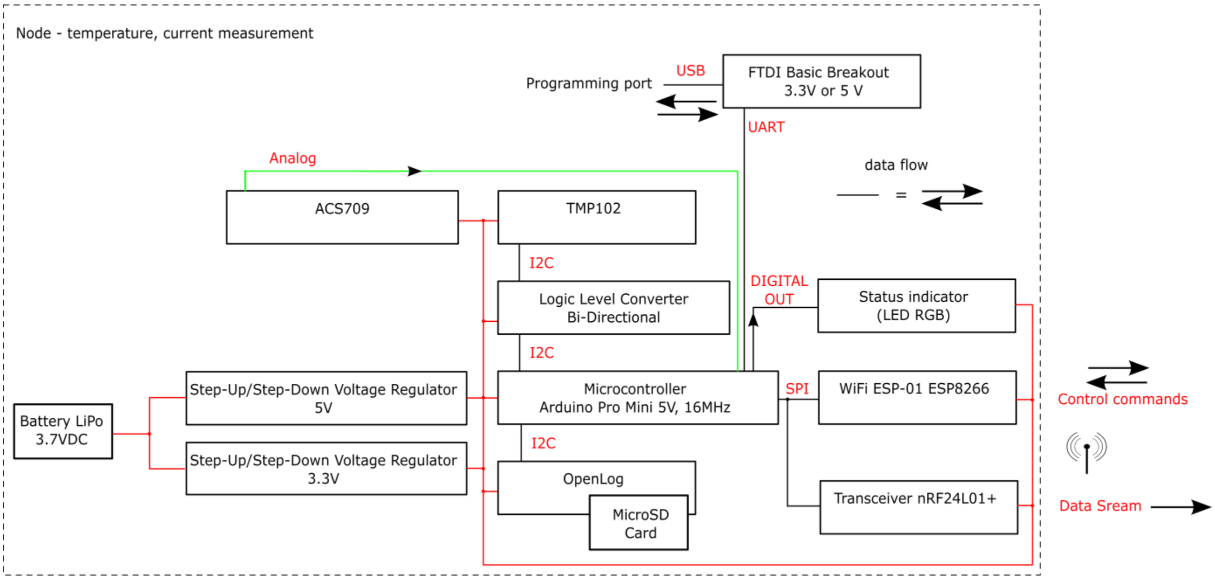

Fig. 7. Measuring node: temperature, current

The power supply circuit is implemented with the use of a lithium polymer battery as a source of energy for step-up and step-down converters. It generates 3.3 and 5 V, for the respective circuits, even when the voltage drops across the battery. The data collected from the sensors are directly saved by the microcontroller to an SD card and sent using the radio module nRF24L01+. In the case of the proposed solution, data transmission was separate from the receipt and transmission of control commands.

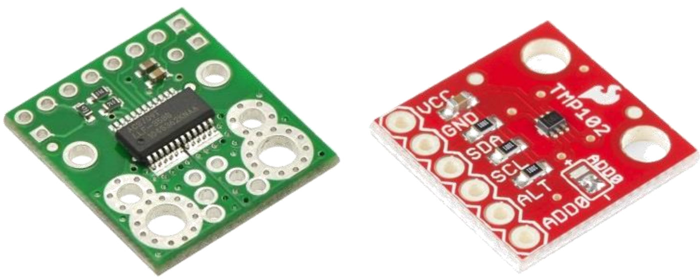

Fig. 8. Sensors for a) current ACS709 ±75A [8] and temperature TMP102 [9]

The nRF24L01+ board system is responsible for data transmission, while the ESP8266 board system is responsible for the transmission of commands to control the Wi-Fi, along with a simple web server with a panel showing basic data about the working node. Control expands the capabilities of the system and provides an opportunity for a quick check of the selected nodes, without needing physical access to the root node.

2.2. Measuring node: acceleration

The system implementing the acceleration measurement is shown in block diagram form (Fig. 9). This system is based on an ATmega328 microcontroller placed on the board of an Arduino Pro Mini. For the measurement of system parameters, an MMA8452Q sensor was used, which is a three-axis accelerometer.

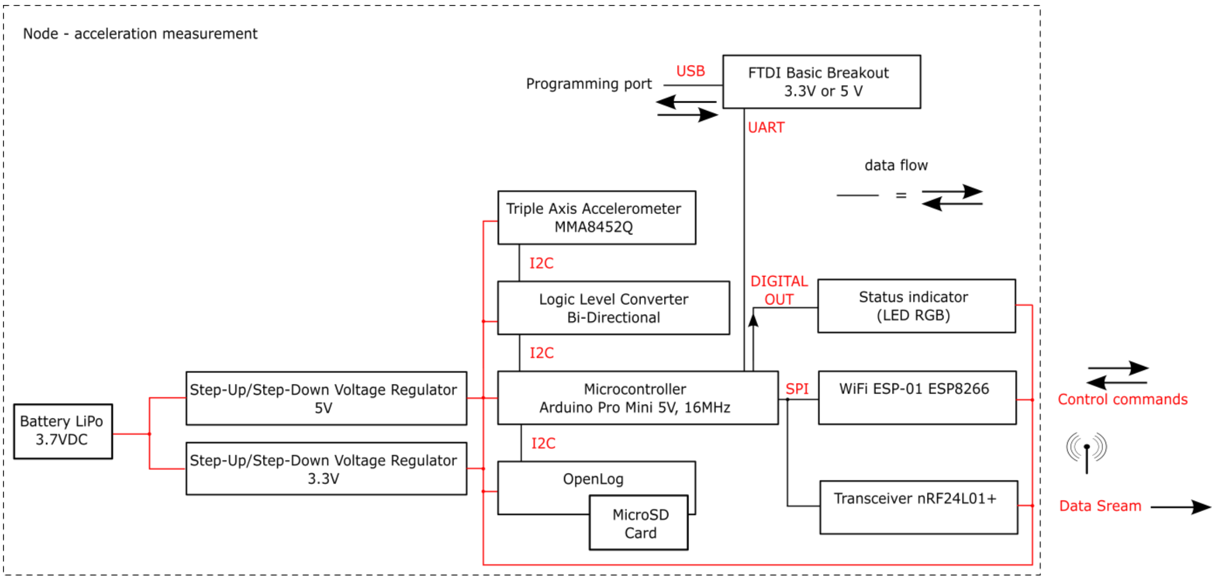

Fig. 9. Measuring node: acceleration

The power supply circuit is implemented in the same way as for the node responsible for current and temperature measurements, i.e., using a lithium polymer battery as a source of energy for step-up and step-down converters, which generate 3.3 and 5 V, respectively.

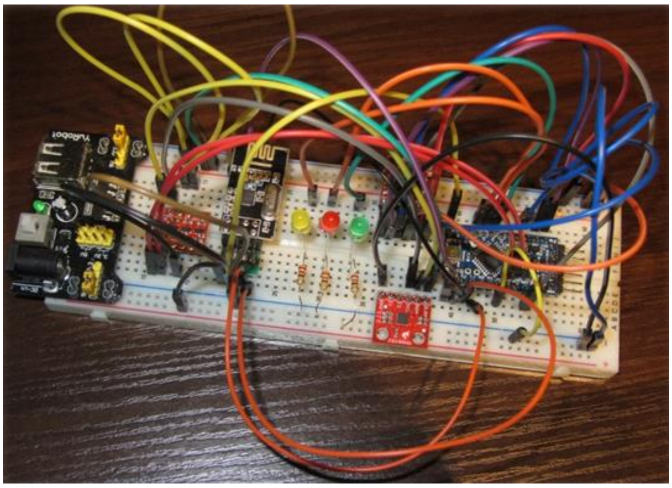

Fig. 10. Prototype of the measurement node responsible for the measurement of accelerations

The nRF24L01+ board is responsible for the data transmission system, while a Wi-Fi ESP8266 board is responsible for the transmission of commands to control the system, as in the case of the node responsible for the measurements of temperature and current. An exemplary implementation of the circuit is shown in Figure 10.

2.3. Measuring node: distance, obstacles

The system implementing the distance measurement and examination of the obstacles in the pathway is shown in block diagram form (Fig. 11). This system is based on an ATmega328 microcontroller placed on the board of an Arduino Pro Mini. For the measurement of parameters, a LIDAR-Lite precise laser distance sensor is used, operating in a range of 0 to 40 m with an accuracy of 0.025 m, and a precise two-dimensional laser scanner is used for detecting obstacles, operating in the area of 360°C in a range of 6 m. The laser scanner is characterized by a refresh rate of 2,000 samples per second.

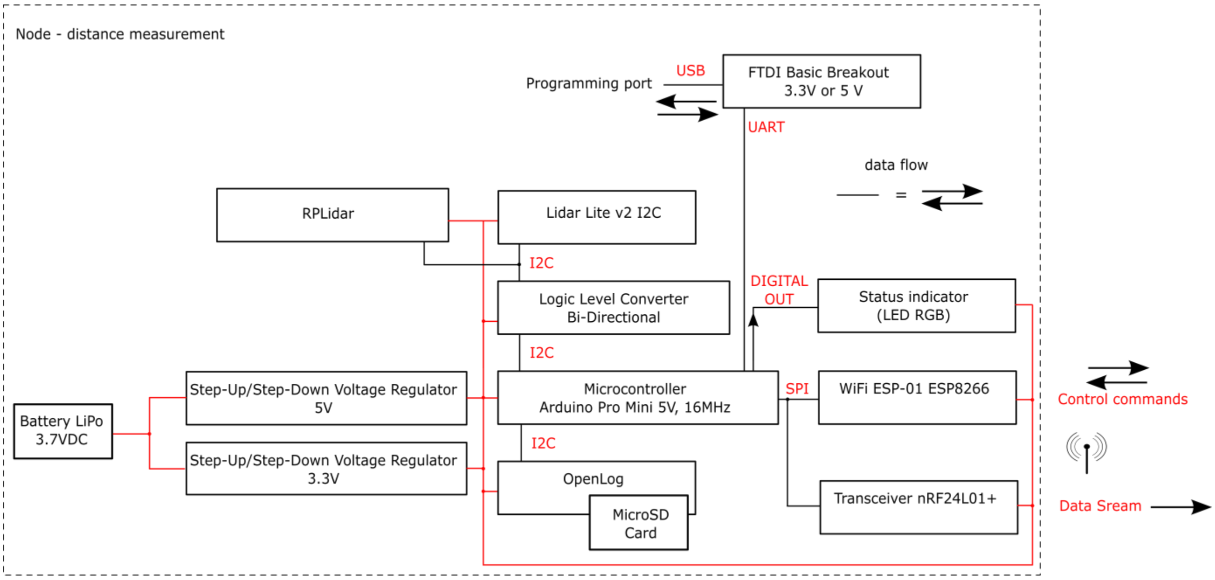

Fig. 11. Measuring node: distance, obstacles

The power supply circuit is implemented in the same way as a node responsible for current and temperature measurements, i.e., using a lithium polymer battery as a source of energy for step-up and step-down converters, which generate 3.3 and 5 V, respectively.

a) b)

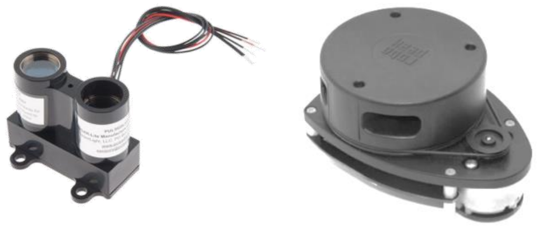

Fig. 12. a) Distance measurement: LIDAR-Lite [10] and b) environment scanner: RPLIDAR [11]

The nRF24L01+ board is responsible for the data transmission system, while the ESP8266 board system is responsible for the transmission of commands to control the Wi-Fi, as in the case of the node responsible for the measurements of temperature and current.

3. CONCLUSION

The article presents the concept of a distributed measurement system to be used on a selected research object, with a specific focus on cranes and conveyors. The proposed system is based on the measurement nodes, characterized by extremely low cost and sufficient accuracy for experimental systems and objects. The author does not specify parameters and costs due to the possibility of using various types of sensors and microcontrollers, which directly impact on the cost, among other things. An example application of the proposed system could be based on the continuous examination of machine status, e.g., overhead cranes in their full-duty cycle.

The measurement system is applicable in terms of the verification of the maximum acceleration values inside the girder in the process of lifting the load, as well as the direct adjustment of the speed and the state of rope tension. As a consequence, it is necessary to reduce the danger to people and the structure dynamic surpluses, along with verifying the skewing process for cranes with a large bridge span with the use of sensors based on laser environment scanning.

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