Science, Engineering & Education, 7, (1), 2022, 37-49

AUHydroBot2021 – Robot Based on Renewable Energy Source

Aleksandra Aleksandrova Umlenska

HMS "Prof. Emmanuil Ivanov", Kyustendil, Bulgaria

Received 15 June 2022, Accepted 05 September 2022

ABSTRACT

AUHydroBot2021 is a robot that is powered by an environmentally friendly energy source. The project was created according to the characteristics of sustainable economic development in the cities of the future, among which the environmental, social, and regulatory aspects are forming. For its implementation, technological additions are included, which support its personalization and its effective implementation in modern everyday life.

Keywords: hydrogen, solar, robot, sustainable development, energy.

INTRODUCTION

The cities of the future correspond to different narrowly specialized fields combined with each other. They ensure sustainable economic development and high quality of life for their residents, focusing on the economy, the environment, transport, and governance. Sustainable development is characterized by achieving a balance between social, technological, and environmental principles for active economic development. Leading is the integration of technology in society, with robotics and automation becoming key components of modern development, which play a major role in Industry 4.0. The initial implementation of smart systems began in the industrial environment, gradually moving into the service sector and the daily lives of individual users.

The environmental aspect is one of the leading components that work in parallel with the public and technological. Due to the widespread use of fossil fuels, waste materials, the synthesis of environmentally non-friendly substances, and others, there is an irreversible accumulation of damage that the human species causes to their habitat. If environmental issues are systematized, air pollution will play a leading role. The annual mortality rate affected by this factor has reached 11.65 % of the total, which is equivalent to more than 7 million people worldwide in 2021. Air quality affects not only this indicator but also the overall lifestyle. Its deterioration

**Correspondence to: Aleksandra Aleksandrova Umlenska, HMS "Prof. Emmanuil Ivanov", Kyustendil, Bulgaria*
E-mail: aleksandraumlenska@yahoo.com

causes many health problems, among which the leading ones are respiratory and cardiovascular diseases. In addition to humans, air pollution has a far-reaching impact on nature, affecting every environmental sphere [1]. The active replacement of energy sources with renewable ones would have the greatest positive impact on overcoming the problem. This is one of the reasons why the word "decarbonization" has become the word of 2021. Decarbonization is not only an environmental but also a political and economic process, which presents a reduction in the amount of carbon in fossil fuels, which helps reduce carbon emissions and volatile substances. The start of the hydrogen economy is set by industry and energy, gradually integrating into everyday life. Thanks to the flexible use of hydrogen, it is suitable for implementation in all aspects of life, despite some of its challenging characteristics.

Respectfully to the environmental, technological, and economic aspects, the project AUHydroBot2021 was created, which presents a combination of robotics, automation, ecology, and the social factor. In its face can be found a robot powered by renewable energy source with implemented technological solutions - smart relay, HMI [2], microcontroller, and tablet. The original contribution to robots of this type is the use of a project-based environmental and efficient approach to powering the technological device and a comprehensive plan for the implementation of systems of this type in industry and services. The aim of the development is to acquaint the public with the needs of the environment, to innovate in modern energy efficiency, to demonstrate hydrogen as an alternative completely environmentally friendly fuel, which is the biggest challenge for companies developing methods of hydrogen production, and a combination of modern customized technological solutions.

The design of the AUHydroBot2021 robot's body (Fig. 1) is adaptable to the user's preferences. Lightweight and durable materials are used to build the body and chassis.

The possibilities for personalization of the project through technological additions, including smart relay Zelio SR2 B121BD, programmed by functional block diagrams, HMI Magelis, modeled with the program Vijeo Designer [2], BBC Microbit, and tablet, define it as applicable in various fields of industry and services - trade, communication, navigation, and trivial actions.

Two gear motors are used for the powertrain of AUHydroBot2021. The prototype is navigated by a module controlling 4 relay outputs, regulated by the "jumping" code KeeLoq. AUHydroBot2021 provides various control modes - via remote control, computer or phone application, and through to the intelligent monitoring mode of the camera, which is located at the upper of the robot.

A several-step process has been developed for its power supply, which constructively complements the ecological focus of the development. Two of them have a practical application – the use of lithium-ion battery and the hybrid combination between a lithium-ion battery and an autonomous solar system. The third is presented theoretically and tests have

Fig. 1. AUHydroBot2021.

been held. It aims to develop an innovative method of hydrogen production that can be applied to the construction of robots, supporting the decarbonization process. The redox process electrolysis was chosen for the AUHydroBot2021 mechanism [3].

Decarbonization is expressed in the reduction of carbon that would be most effectively achieved through the use of hydrogen. Hydrogen is a perspective fuel with specific characteristics, which is undergoing an active process of development and implementation in various systems, including robots, cars, or hybrid combinations [4].

EXPERIMENTAL

For the development of AUHydroBot2021, detailed schemes and sketches were prepared, which describe the elements of the mechanism and the optimal distribution of space provided by the body and chassis of the robot (Fig. 2). The AutoCAD software product was used for their compilation, and for the maximum efficiency of the project, the necessary calculations were made. For the robot wiring, additional simulations of the electrical circuits were performed, using LTSpice.

The body of AUHydroBot2021 is produced with durable and lightweight materials (Fig. 3). Translucent polycarbonate reinforced with aluminum edging is used for the hull. The distribution of the various elements of the mechanism is done on several story structures, depending on their quantity and size, as shown in the sample initial sketch. The aluminum chassis of the robot has a frame composition. The motive and additional wheels for stabilization of the robot are attached to it. For the motive wheels, the gear used is a belt. They can be replaced in view of the search for higher off-road capability or specific characteristics of the terrain on which the robot will be used if it is necessary.

The used remote control module regulates 4 relay outputs, providing 4 operating modes – transfer, hold, trigger, and time (Fig. 4). For its regulation the "jumping" code KeeLoq is used, representing a method by which the code emitted from the transmitter to the receiver is different each time a button is pressed. The module is located on the side of the housing and is closed in an additional box that does not interfere with the transmission of signals between the remote and the device.

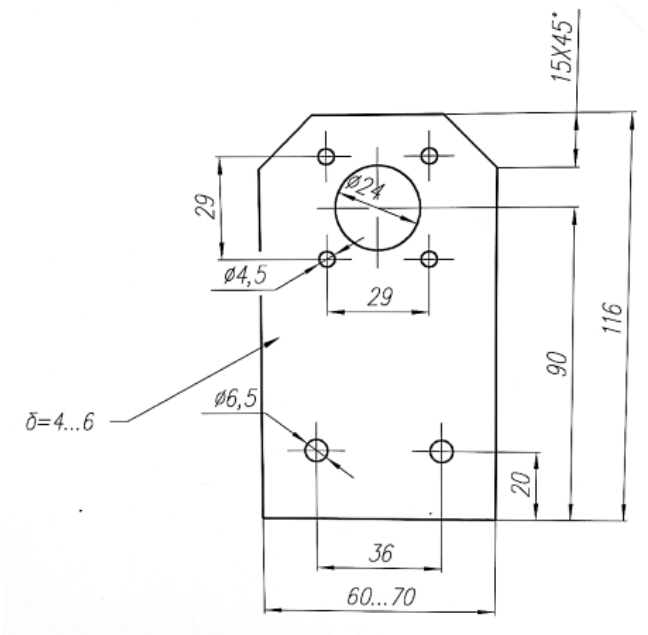

Fig. 2. Carrier scheme.

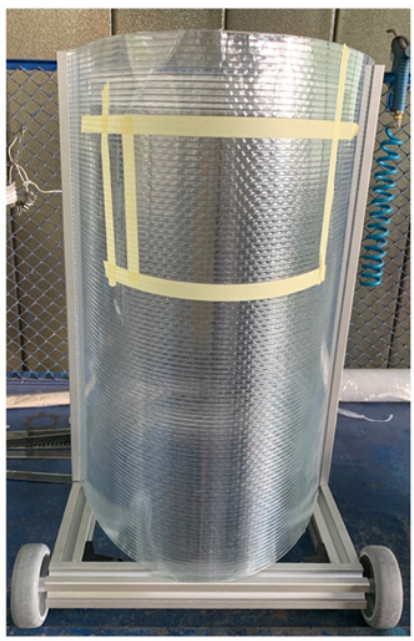

Fig. 3. Body and chassis.

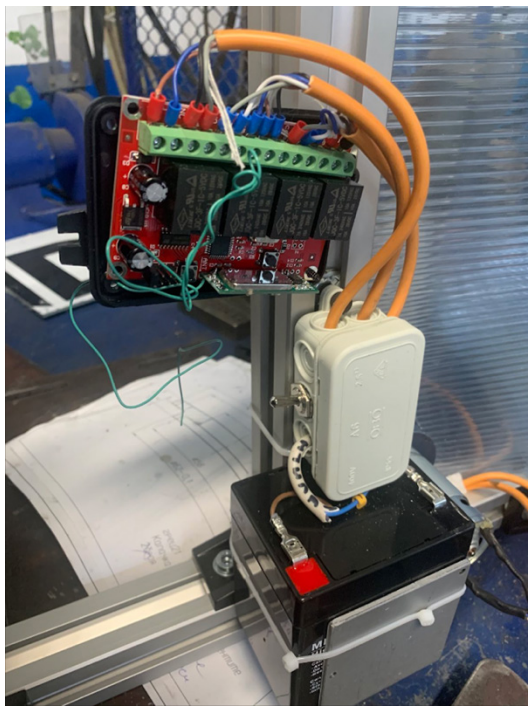

Fig. 4. Remote control module.

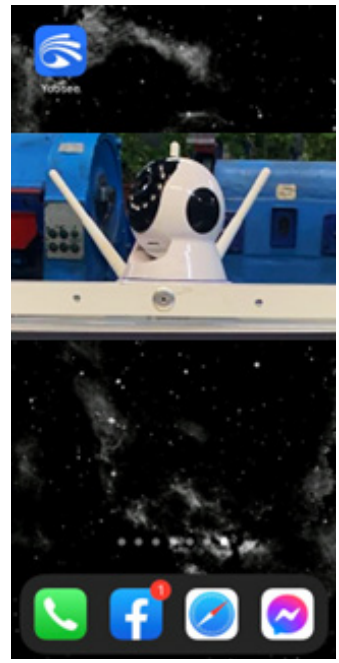

Fig. 5. Camera with intelligent tracking mode.

The camera is an addition whose purpose is to control the management of the robot and information exchange in various forms (Fig. 5). It is characterized by 720p/1080p HD video transmission, recording via manual adjustment or automatic, setting via Wi-Fi or Remote Wizard. It can control the project through a mobile application that provides real-time monitoring, audio exchange, control mode, and others. It provides access to an alarm, communication between users and it can capture separate elements.

The camera provides an intelligent tracking mode, due to which an object is determined for tracing. In combination with relays for reversing the motors, it offers a second mode for remote control by movement relative to the object. The 'Yoosee' camera application provides a mode for manually moving the direction of the tracking range, which gives a third option for navigating the prototype - from a mobile device or computer.

Two gear motors are used for the movement of the drive wheels, providing the option to control four drive wheels with four gear motors in unsuitable terrain for AUHydroBot2021. The representation of the elements is an electric motor with adjustable speed with minimal reduction in efficiency.

The used power supply was optimized in three stages, including two practical and one theoretical-practical. The first stage was aimed at driving the robot and developing its aesthetic appearance. For this purpose, a lithium-ion battery with an operating voltage of 12 V was used. The choice of the battery type is based on its key characteristics, including long life, high durability, fast charging capability, and relatively low operating temperature [5].

The goal of AUHydroBot2021 is to use a renewable energy source for its power supply, which necessitated a transition to the environmental aspect of the development in the second stage. The battery was included in a hybrid combination with an autonomous solar system (Fig. 6). The system provides optimal operating conditions that predispose the use of a non-environmental source (battery) as a backup

Fig. 6. Solar System PNI GreenHouse H01.

in adverse external and internal conditions. The autonomy insured by the device is up to 12 hours. Energy savings reach over 80 %. It is characterized by an operating voltage of 12 V, power of 10 W, and a plug & play system. The solar system has a compact size, and its location is on the back of the robot or on one of its floors.

The third stage of optimization includes a theoretical plan for the extraction and use of hydrogen as a prospective energy source. The work with this type of fuel is precise due to its specific characteristics, which require longer development of the mechanism. Tests were conducted to study the explosive conditions of the system under safe conditions. An electrolysis cell, a water seal [6], and an energy transformation system have been developed for its implementation.

The process of electrolysis was chosen for the extraction of hydrogen, as the goal is to use the hydrogen obtained directly, without storage (Fig. 7). Electrolysis is widely used in industrial processes – purification of gases and metals, electroplating, and chemical analysis, which ensures its future active development and improvement, as well as its implementation in various mechanisms and systems. The process of electrolysis can be influenced by various factors – ion concentration, temperature, type of electrolyte and electrodes, current size, and others. It is characterized as a spontaneous redox process that takes place in solutions or melts of electrolytes under the influence of direct electric current, registering the exchange of electrons, leading to a change in the degree of oxidation [3]. The power source used in the case of AUHydroBot2021 is renewable – the solar system, providing enough energy not only for hydrogen production [7] but also to power electronic components that are additions to the robot.

The electrolysis method used to decompose the water molecule is the oldest model studied, which has the characteristics of the process. After the passage of the electric current, oxygen is released from the anode and hydrogen from the cathode by the following mechanism:

Fig. 7. Galvanizing` by electrolysis.

Fig. 8. Electrolysis cell.

$2H_2O + 2e^- \rightarrow H_2 + 2OH^-$ reduction

$2H_2O \rightarrow O_2 + 4H^+ + 4e^-$ oxidation

$2H_2O \rightarrow 2H_2 + O_2$

$6H_2O \rightarrow 2H_2 + O_2 + 4H^+ + 4OH^-$

The environment for performing electrolysis is called an electrolysis cell (Fig. 8). It consists of two electrodes – anode and cathode, which perform the processes of oxidation and reduction, respectively. For its production, a container and steel plates, cut on a precision laser, located in a specific configuration, were used. By passing a direct electric current, the ions receive a directed movement, which takes place in the direction from the anode to the cathode. Cell sealing is an important factor in overcoming the unfavorable characteristics of hydrogen. For the highest safety, tests were performed with internal, and external sealing and pinching in order to avoid the chances of permeability. Apart from the securing of the electrolysis cell, the securing of the entire system is required, which is guaranteed by the so-called “water jail”. It presents a water seal that prevents the penetration of oxygen from the air and prevents the flow of gas back through the pipe to the system by naturally “capturing” the gaseous mixtures [6].

The quantitative characteristics of hydrogen production are determined according to the

Fig. 9. Smart relay Zelio SR2 B121BD & HMI Magelis [2].

parameters of the electrolysis cell and the magnitude of the current. AUHydroBot2021 uses a cell with 10 anode and 10 cathode plates measuring 6 x 4 cm and negligible thickness, which guarantees a minimum working surface of at least 48 cm^2. The magnitude of the current at which the tests were performed is 5A, which makes the expected average yield of hydrogen 2 liters/minute with a pressure of up to 0.3 bar. The extracted hydrogen is burned, and the heat generated is used to heat a miniature steam generator. The extracted steam rotates a steam turbine, which is a rotating heat machine that converts the kinetics and heat of the steam that is conducted to it by directed flow and converts it into mechanical energy, characterized by high efficiency. The forced rotational movement that takes place produces the electric current needed to power the entire prototype. The principle of operation of the system is innovative and demonstrative, as one type of energy is converted into another, which determines energy loss and reduction of the useable power, even in minimal quantities, which characterizes the efficiency of the system.

Technological additions support the personalized multifunctional use of AUHydroBot2021. Due to the optimal amount of space provided, they can be replaced or supplemented according to the needs and abilities of users, which confirms the robot as flexible in modern living conditions. Some of the innovative elements are the smart relay Zelio SR2 B121BD, HMI Magelis [2], BBC Microb:it, and tablet.

The smart relay is an electronic component with switch functions that changes the output value. The Zelio Soft configuration software, which supports the FBD graphics language, was used for its programming (Fig. 10). Its role is to automate and regulate processes in an industrial environment or to set specific actions to control the elements of the robot [2]. As the AUHydroBot2021 is not area-specific but has a demonstration use, the capabilities of the smart relay used are through a pre-set schedule to perform functions described by the user.

The programmable logic controller is combined with the Magelis human-machine interface, which allows active human-machine communication via a touchscreen (Fig. 11). Its main role is digitization and centralization of data for the user through data visualization, control of parameters, tracking of production processes in the industry, or actions in the field of services and others. It is used to systematize the technological activities that a person performs in his daily life such as input and output of a system, system configuration, change of language, clock, user assignment, and others.

In addition to the technological implementation

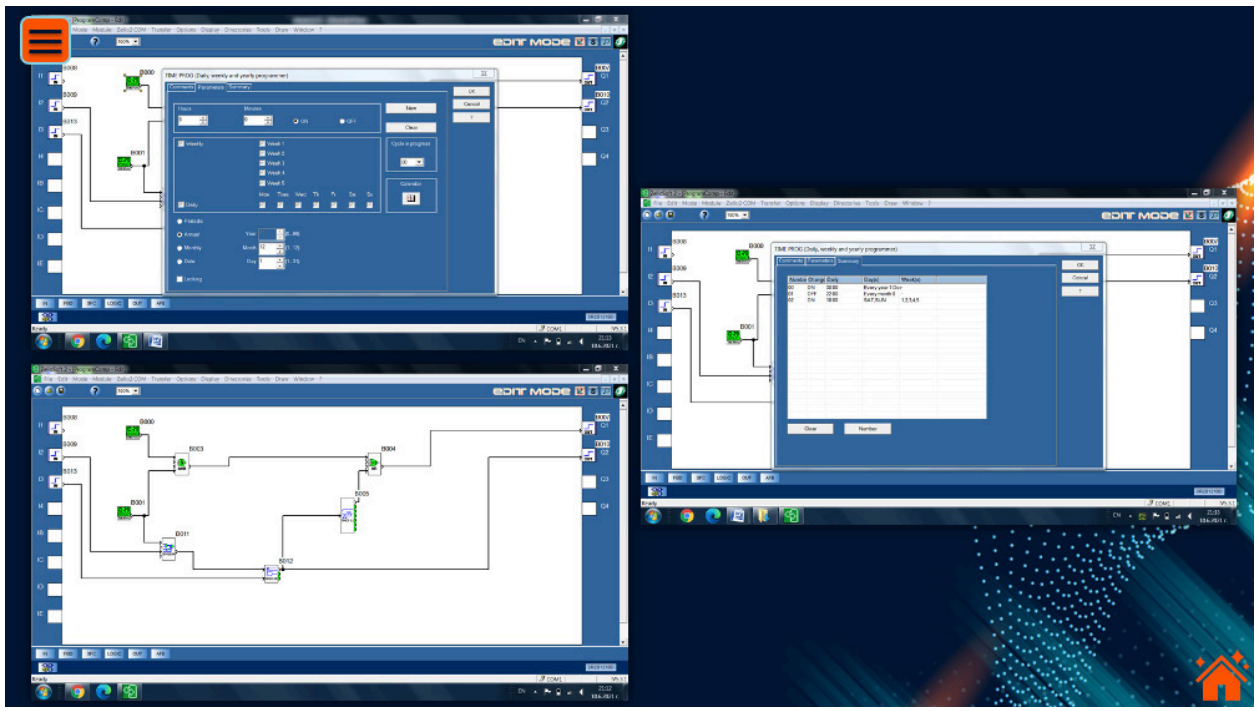

Fig. 10. Process of programming with FBD.

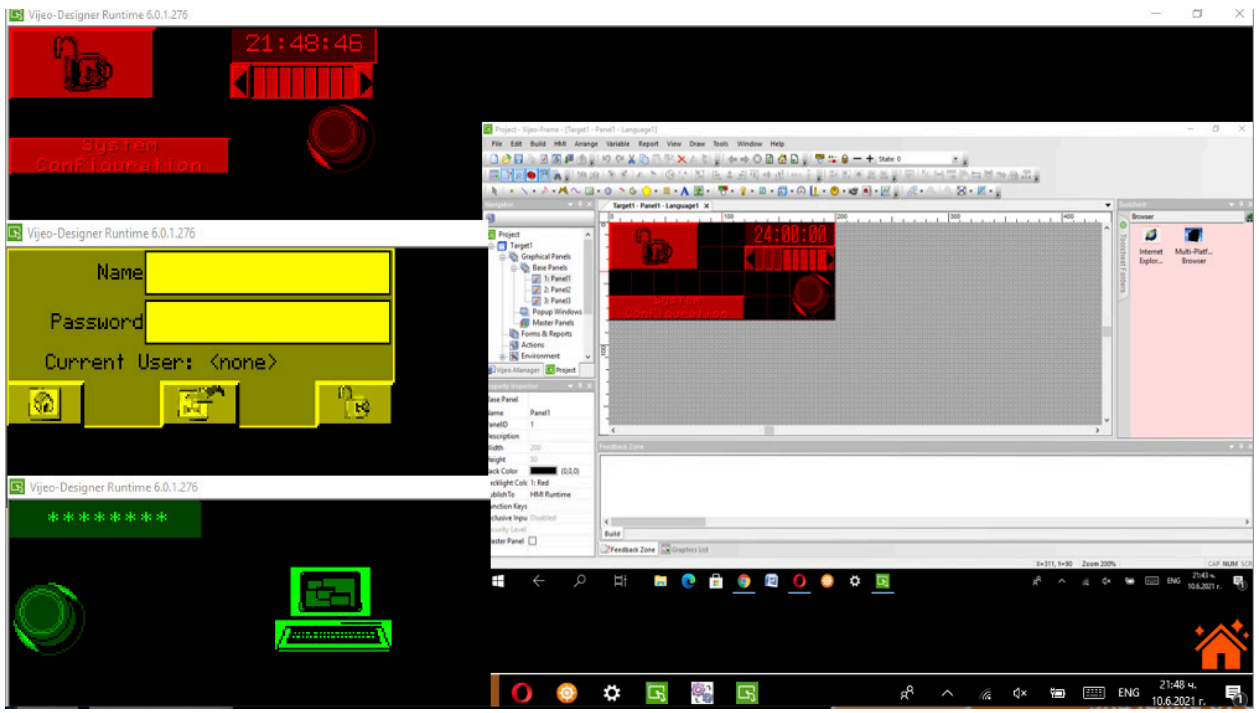

Fig. 11. Process of working with Vijeo Designer.

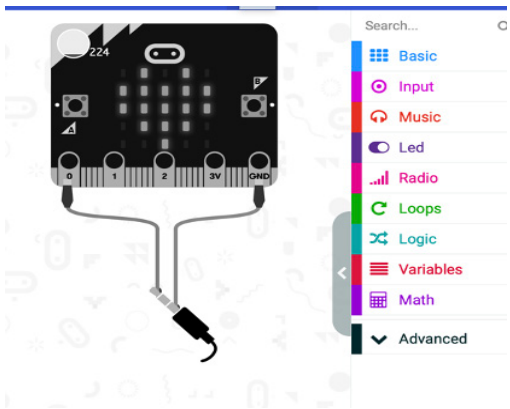

Fig. 12. BBC Micro:bit.

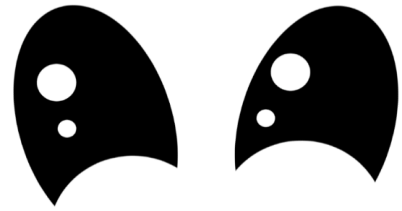

Fig. 13. The logo of AUHydroBot2021.

of AUHydroBot2021, the aspect of the robot's integration into society is considered. Part of the innovative additions responsible for this action is the BBC Micro:bit: bit open-source hardware device. It consists of an ARM Cortex-M0 processor, and sensors for quantifying environmental parameters – magnetometer, accelerometer, and others. Its implementation in a system of devices, their combination, and collaboration are carried out via Bluetooth and/or USB connection. The BBC Micro:bit: bit display consists of 25 red LEDs and two programmable buttons (Fig. 12). It is powered directly by the autonomous solar system. The ARM-based system allows it to be programmed via Micro Python, Microsoft MakeCode, or Scratch. In addition to its main role - the humanization of the robot through a beating heart, which makes it easily receptive to adolescents and friendly to all age groups, can be programmed to control the technological components according to the preferences of the user.

The second component, which ensures the easy integration into society, is the tablet, which visualizes eyes that have the ability to blink or through additional animation express feelings corresponding to the pressing of specific buttons by the user. When the robot is in operation mode, the tablet becomes a device that provides constant access to social networks, notes, Internet browser, camera, and other features typical to this type of device.

RESULTS AND DISCUSSION

AUHydroBot2021 (Fig. 13) has a demonstrative and experimental focus. Due to its customization capabilities, it can be realized in the field of social services or industry. Its main goal is to be integrated into everyday life, meeting the criteria for sustainable development. The environmental aspect of the project is key to the prototype and its subsequent development. The process of hydrogen production is a prerequisite for research due to the specific characteristics of the gas. The economic aspect supports the environmental one, as the type of fuel is perspective. Due to the technological additions and the humane look, the project responds to the public criterion.

Its personalization in a specific field and the optimization of the energy system lead to a variety of opportunities for precision security, testing, software development, etc. The technological additions to the AUHydroBot2021 are flexible, offering work individually or in a synergistic combination. Additional space is provided, which can be optimized with technological elements and sensors such as gyroscope, obstacle detection, parameter reader, etc.

The development of a system based on hydrogen as a source of fuel requires the optimal choice for its yield - according to the use, the required amount, storage capacity, and other characteristics. The methods used for the

common extraction of large amounts of hydrogen in the industry are thermochemical processes based on the thermo-catalytic conversion of hydrocarbons, among which the main are the different types of reforming - liquid reforming based on biomass, reforming of natural gas, etc. Thermochemical methods include biomass gasification, solar thermochemical hydrogen production, and cracking. Most of these processes involve the release of a significant amount of non-environmentally friendly substances, which leaves the decarbonization cycle open [8]. Electrochemical processes, on the other hand, are more environmentally friendly. An electric current is passed through an aqueous solution of electrolyte until hydrogen is released, as it is the case with the electrolysis of water [3]. An innovative method is the direct separation of water with the help of energy obtained from the sun. Photolytic processes, including photobiological ones, which use the photosynthetic activity of bacteria and green algae that synthesize hydrogen and photoelectrochemicals, are in the process of pilot tests to study their effectiveness and feasibility. The test projects also include biologically based processes that are related to the conversion of microbial biomass or can be attributed to photobiological, as different combinations are observed between different groups of processes [9].

The hydrogen extraction system of the AUHydroBot2021 project is the optimal possible in the field of robotics, as the devices need relatively small amounts of hydrogen to be used directly for their power supply. As robots are used in the field of social services and industry, it is necessary to respond to the criteria of sustainability and safety, which requires that they have passed a significant period of testing, as in the case of electrochemical processes and direct separation of water by means of solar energy. The aim is to minimize the carbon environment in order to complete the decarbonization process [10], which defines thermochemical processes as insufficiently efficient in robotics when small amounts of hydrogen are needed if they are not in a hybrid combination.

The choice of hydrogen as an energy resource combined with solar energy is supported by its positive qualities. It is safe, efficient, and financially advantageous if it is extracted by electrolysis [3].

The value of AUHydroBot2021 offers flexible regulation according to user preferences. The prototype is estimated at BGN 1,690, although the improvement process predisposes to an increase in the budget before its full implementation because it will have minimal values. Materials, size, technological additions, and others are also significant factors in determining the budget for the robot. The investment in AUHydroBot2021 is one-time, as the materials are durable, the electronic components are high quality and have a long warranty, and the drive mechanism only needs maintenance when using the electrolysis process for energy production [7].

Hydrogen is increasingly being implemented in robot power systems. Their introduction starts from the industrial sphere. The most active in the work on different types of vehicles, as the fuel cells are combined with another type of power supply to optimize the performance of the battery.

On the other hand, automated guided vehicles abbreviated AGV, which are used in the production process, offer a maximum reduction of harmful emissions (Fig. 14). Plug's GenDrive fuel cells are one of the most efficient. They are characterized by the ability to operate at low temperatures, minimal loss of speed of the device when diluting the remaining energy, and increased productivity. Battery charging time is less than three minutes, and carbon and waste emissions are minimal, due to the elimination of the battery charging process in most cases. Fuel cells offer a high level of safety, as they do not contain toxic substances, plumbum, acids, and other components typical for common batteries [11].

Although the effectiveness of this type of

Fig. 14. AGV SSI Schaefer [12].

system in the industry is still being tested, they have begun to be implemented through hybrid combinations in humanoid robots. The most innovative technology in the use of fuel cells is the displacement of hydrogen from microbial processes, which is going to make the system self-sustaining.

The development of the use of hydrogen is also extremely active in agriculture. One of the example systems has closely specialized and innovative GPS tracking, such as support and triangulation techniques. Hybrid autonomous robots are used in precision agriculture in order to reduce fuel consumption and pollution, which would require the implementation of technological systems [13].

Solar energy is already widely used to power devices in the industry - from humanoids to industrial robots and has confirmed its properties over time. It offers flexible, tested, and safe use. Solar cells are most commonly used, which convert solar energy directly into electricity through a photovoltaic effect. The criteria which were the most important in the selection of the cell type are efficiency, surface area, durability, and financial value. Optimal are the systems that are included in a hybrid combination, which ensures the possibility of using the device even in adverse conditions.

Robots that are powered by solar energy can most easily be implemented in agriculture, as they work in outdoor conditions. Examples are Franklin Robotics' Tertill robot, which is a weeding system with an intelligent on-board computer that monitors the charge level using intelligent control and energy-saving mode [14]. Another bigger robot in the same field is AG BOT II (Fig. 15). In commercial agriculture, the prototype Ladybird has a leading role, which is an autonomous robot for data collection - collects information about the whole process and the nature of cultivated crops, providing information to its users. This is one of the most effective methods for detecting pests or diseases in plants. The development of robots based on solar energy is also in ecology. Among them is SAMMI (Seqwater's Autonomous Motorized Monitoring Instrument) system. It monitors the water quality in the various water reservoirs [7]. Harvard University is working in the field of microrobotics, and one of its successful

Fig. 15. AG BOT II [7].

Fig. 16. Bee robot by Harvard University [15].

Fig. 17. SIF Robot - Reception bot [12].

Table 1. Applications of service type of robots.

Industry	Types	Robot	Applications
Commerce	Low-cost	Mitra	Voice greeting and touch screen menu
Airports	Low-cost	KEMPA	Responds to inquiries for flights at Kempegowda International Airport
Airports	Low-cost	RADA	Helps boarding passengers
Banks	Low-cost	IRA	Through voice navigation instructs on banking products
Healthcare	Low-cost	Prithvi	Interaction with patients in COVID-19 wards
Commerce	Low-cost	RoboDiCaprio	Present an advertisements board
Banks/ Commerce	Low-cost	Manav	Uses face recognition technology to identify visitors, age, gender, emotional levels and others
Airports	Professional	FRAnny and SEMMI	Concierge robots – welcome passengers at the airport
Hotels	Professional	Greeter	Receptionist – welcomes guests
Events	Professional	ARI – PAL Robotics	Navigates people to the lobby before an event
Commerce	Professional	ARI – PAL Robotics	Attracts people to a stand
Museums	Professional	ARI – PAL Robotics	Offers a map of the museum/ navigates people

developments is a bee powered by solar energy (Fig. 16), which has the size of a real insect [15]. Robots that are part of the service sector use hybrid combinations of energy production (Table 1). Their roles are receptionists, assistants, and guidance systems, and with the development of technology, they reach interact with patients (Fig. 17).

The opportunities for personalization of the project determine its possibility to be used both in homes and in public places or to acquire a fully scientific and educational focus.

Fig. 18. AUHydroBot2021.

AUHydroBot2021 offers various combinations in which it can be closely specialized. Robots used in the field of services are most often used to interact with people in different conditions.

CONCLUSIONS

AUHydroBot2021 presents a robot based on a renewable energy source (Fig. 18). For its effective integration into everyday life, innovative technological solutions have been added - smart relay, HMI, [15] microcontroller, tablet, and others. The robot is controlled by various combinations based on the elements used, including a remote control module, a camera with intelligent monitoring mode, two gear motors, wiring simulated on LTSpice, and others. The body of AUHydroBot2021 is made of durable and lightweight materials. The power supply is hybrid - through a lithium-ion battery and an autonomous solar system. The project is under development. The last stage of development is theoretically and practically oriented - the use of hydrogen obtained through the process of electrolysis. The aim of the robot is to acquaint society with the needs of the environment and to create a new efficient way of feeding through ecologically clean fuel, which is applicable in modern everyday life.

REFERENCES

1. Hannah Ritchie, Max Roser, Air pollution, 2021, https://ourworldindata.org
2. Smart relay & HMI characteristics, www.se.com
3. L. Velichkova, G. Robova, Electrolysis, Chemical Processes. Chemistry of elements and their compounds, Abagar, 2008, (in Bulgarian).
4. Jeremy Rifkin, Hydrogen economy, Zahari Stoyanov, 2004, (in Bulgraian).
5. www.engineering-review.bg
6. Water seal, www.waterpoint.pl
7. Hydrogen production process, https://www.energy.gov/
8. Daniel Hristov, Vilian Radoslavov Yanakiev, eng. Raino Popov, Reforming natural gas and its utilization in the fuel cell, (in Bulgarian).
9. Huyen Dinh, Genevieve Saur, Kevin Harrison, Judy Netter, John Turner, ToddDeutsch, Ricard French, Pin-Ching Maness, Maria Ghirardi, Hydrogen Production and Delivery, https://www.nrel.gov/hydrogen/hydrogen-production-delivery.html
10. Portilo Germanski, Decarbonizaton, https://www.renovablesverdes.com/
11. Fuel Cell Products for the Material Handling Industry. Plug's GenDrive fuel cell products can power anything from a forklift and pallet jack to AGVs and tuggers, https://www.plugpower.com/
12. Stephen Edgar, A Guide to the Fuel Cells Used to Power Humanoid Robots, 2020, https://www.azorobotics.com/
13. Mariano Gonzalez-de-Soto, Luis Emmi, Pablo Gonzalez-de-Santos, Hybrid-Powered Autonomous Robots for Reducing Both Fuel Consumption and Pollution in Precision Agriculture Tasks, 2018, https://www.intechopen.com/
14. Jeff Kart, Tertill Is A Gardening And Weeding Robot From The Inventors Of Roomba, 2012, https://www.forbes.com/
15. Wyss Institute at Harvard University, RoboBees: Autonomous Flying Microrobots, 2019, https://harvard.edu/magazine