INFORMATION AND MEASUREMENT TECHNOLOGIES IN MECHATRONICS AND ROBOTICS

DESIGN OF THE WATER STRIDER-LIKE ROBOT

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Abstract. The development of the human population produces ecosystem changes. Monitoring of them can be considered one of the key prerequisites for ensuring its survival. At the same time, the development of Metrology 4.0 based on the study of land massifs and the control of their characteristics should consider the methods and means for studying the aquatic environment by new types of robots, as platforms for deployment of some sensors, namely multi-legged walking devices, for example, the "water striders".

In the paper, we consider the possibility of solving the quite complex task of designing of light robot designed to slide on the surface of the water without submerging in it and equipped with built-in sensors.

Key words: Light robot, Design of water strider-like robot, Hardware, Software.

1. Introduction

In nature, there are several insects with unusual material characteristics and superior locomotion. Insects, for instance, frequently have extremely hydrophobic surfaces that enable them to glide and jump over water swiftly. Some insects also have delicately folded wings and compound eyes, while others may crawl, burrow, swim, and fly, swim, and burrow. A significant task for scientists is to create new and diversified micro-robots that resemble insects, reveal novel microscopic phenomena and laws, and benefit humans [1].

2. Drawbacks

Different robots are designed to study ground, air, and aquatic environments. Nevertheless, robots for studying the quite interesting boundary between water and air, which can pass the powerful physical, chemical, and biological processes, are not developed yet. It is due to the high weight as well as a row of special demands to their construction.

3. Goal of work

The goal of the issue is the study of designing a light robot (water strider) equipped with smart sensors for possible investigations in aquatic environments, mainly on the water surface.

4. SpecificITy of water strider-like robot

Scientists are thinking about and tackling the problem of how to create microscopic robots with novel and varied tasks that resemble insects, reveal new phenomena and laws at the microscopic scale, and assist humans. More and more academics are conducting theoretical research in this area and developing a variety of water strider-like surface movement robots as a result of the ability of water striders to glide and jump on the water surface with low energy consumption, high efficiency, low damage to the water surface, and low noise [[2].

There are currently two conjugated directions of research into water strider robots: in terms of bionic structures and terms of measurement functions equipped with sensors. Considering that for the design of structures, there is usually a need to take into account the effects of weight, most of the functions that other types of measurement robots can bring are sacrificed to accomplish the degree of fitting of bionic robots.

Multi-legged walking devices of the spider type have become widespread recently. Monitoring of the environment and, first, the state of water resources, for the subsequent control of their parameters demand the continuous assessment of the designed robots' performance.

To reduce the effect of water pollution, by the enhanced methods and means of monitoring the parameters of the water environment, is necessary to develop supporting platforms, especially the small-sized and superlight ones [3]. Since the water is rather an aggressive environment, characterized by corrosiveness, is desirable to minimize the contact with the volume of water.

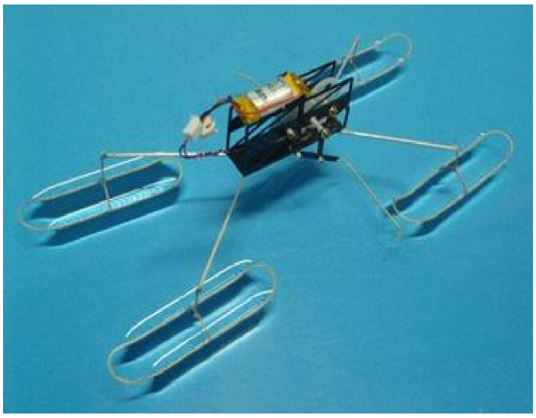
These requirements are met by a such mechanism as a "water strider". The study and research of these insects has already become interesting in China [4] It was shown an 11-gram technical device programmed to perform movements on the water surface. With such a robot, it is enough to simply install and connect sensors for temperature, humidity, insolation, and the presence of certain chemical pollutants in the strider's body.

The researchers provided the computer simulation to study the forces [3-5] that hold water striders on the surface of the water. They concluded that to allow the designed object to move and jump on the surface of the water without the risk of drowning, they need to apply superhydrophobic material or material whose surface is not wetted by water [6]. For example, there was proposed the microporous material based on nickel. Microscopic bubbles of this material, filled with air, practically eliminate contact of the material with water, giving it hydrophobic properties and positive buoyancy. Moreover, the last issue demonstrates studies of artificial muscles and wireless energy transfer to robots aiming at the minimization of their weight [7].

Designs of the mentioned robots can be very diverse (Fig. 1, Table). However, the motion system of the microrobot-water meter involves the presence of a miniature electric motor and a mechanism that allows the robot to move through the water in steps commensurate in length with the size of the robot's body.

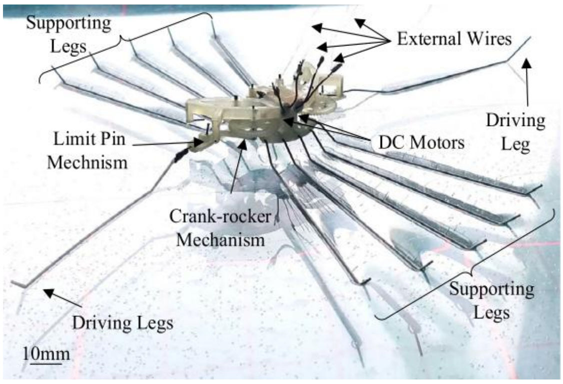
Table. Worldwide universities' design of water striders; major characteristics

Year	Institution	Movement Form	Ability to carry sensors	Drive method	Quality, g	Linear speed, mm/s.
2003	MIT	Sliding	No	Elastic band	0.35	180
2010	Carnegie Mellon University	Sliding	No	DC Motor	21.75	71.5
2011	Minzu University of China	Sliding	Yes	DC Motor	6	200
2015	Harvard University	Jumping	No	Shape-Memory Alloy	0.068	—
2016	Zhejiang University	Sliding	Yes	Steering Gear	439	90
2017	Shanghai Jiao Tong University	Sliding	No	PZT Driver	0.165	151
2017	Kogakuin University	Sliding	No	DC motor	4.39	59.2
2022	Harbin Institute of Technology	Sliding	No	DC motor	4.9	139

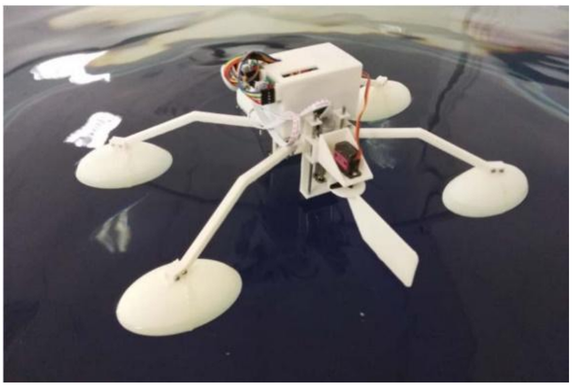


Kogakuin University（Japan）

b) Carnegie Mellon University



Harbin Institute of Technology



Zhejiang University

Fig. 1. Design of different water striders

In addition, in nature, the water meter jumps in height to avoid obstacles when moving. In the overview of constructions (Table 1), we highlight the construction of Harvard University scientists, where such an opportunity is provided. The study [4] of the jumping construction of water striders was based on the legs made from shape-memory alloys. This is the specific design that demands the energy source able to supply power to 6 legs simultaneously aiming to heat them in a few degrees.

Jumping is associated with a large ground reaction force and a short duration of the launch phase [5]. It is observed that animals with extremely different scales can achieve the same magnitude of jump height because they are geometrically similar [6]. The analogy for robots is the same as for animals. The phenomena became a motivation to check how changes in the dimensions of the robotic leg affect the requirements of the joint actuators to perform vertical jumps.

5. Design of water strider's robot

Let's emphasize that the water strider moves on it without submerging, thanks to the effect of the surface tension film. At the same time, it is the multitude of dust-like substances settling on this film that are concentrated there. By installing a radiation sensor on the strider, we can determine of enlargement in several orders of magnitude the radiation power (during the Chornobyl accident, the scattering of contamination led to a 1,000-10,000-fold increase in the content of radioactive particles on the water surface, and then on the coastal sand).

The study of the algorithms of movement and robotic software, which is carried out currently at the level of spiders, is being changed in the direction of the formation of robots for studying the boundary of the water-air, namely the robot-strider. To provide an ecological investigation of human interaction with the environment, the latter has to be equipped with several smart sensors.

We have studied the possibility of the design of the water strider, which is planned to be light to lay on the water surface. The study [4] estimated its weight at 11 g in the presence of 10-12 legs as the floats. On this basis, we chose the next design components. For this water strider robot, we use Espressif Systems company's MCU Esp32 (Fig. 2). It supports communication protocols nearby: IIC, SPI, UART, CAN bus as also Wi-Fi, LoRa, and Bluetooth. Compared to the high-power consuming transmission of Wi-Fi and Bluetooth, LoRa is a new transmission method with low bandwidth, low power consumption, and long distance.

The ESP32 is an integrated 2.4 GHz Wi-Fi and Bluetooth dual-mode single-chip solution using TSMC's low-power 40nm process, offering superior RF performance, stability, versatility, and reliability, as well as ultra-low power consumption to meet different power requirements for a wide range of applications. The ESP32 is the industry's leading integrated Wi-Fi + Bluetooth solution with only 20 external components and integrated antenna switches, RF, power amplifiers, low noise amplifiers, filters, power management modules, and advanced self-calibration circuitry, significantly reducing the printed circuit board (PCB) footprint. The ESP32 also incorporates advanced self-calibration circuitry that enables dynamic auto-tuning to eliminate external circuitry defects and better adapt to changes in the external environment.

Fig. 2. ESP32 development board

The core circuitry of the ESP32 series requires only about 20 resistors, capacitors, inductors, a passive crystal, and an SPI flash. The ESP32 series core circuit diagram is designed with 10 parts: power supply, power-on timing and reset, Flash (mandatory) and SRAM (optional), clock source, Radio Frequency (RF), external resistive capacitor, ADC, UART, SDIO, touch sensor (Fig. 3).

Motor drive part (Fig. 4): In general, the output voltage of the ESP32's GPIO pins is insufficient to drive the motor and complete the task of the water strider robot walking on water. To finish this operation, we must connect a motor-driven module to the MCU so that the motor can function normally.

The ULN2003 composite transistor array is a high-voltage, high-current array of seven silicon NPN composite transistors. The ULN2003 is a high-current driving array (Fig. 5) that is commonly used in control circuits like microcontrollers, smart meters, PLCs, digital output cards, and so on. It is capable of directly driving loads such as relays. The input is 5V TTL, and the output is 500mA/50V. Simply put, the ULN2003 is used to boost current and increase driving capability. For example, the output pins of a microcontroller typically output only a few mA, which is insufficient to drive a motor, relay, or solenoid valve. To turn a DC motor, for example, 500mA is required, and after amplification with ULN2003, you can control these devices directly through the output pins of a microcontroller.

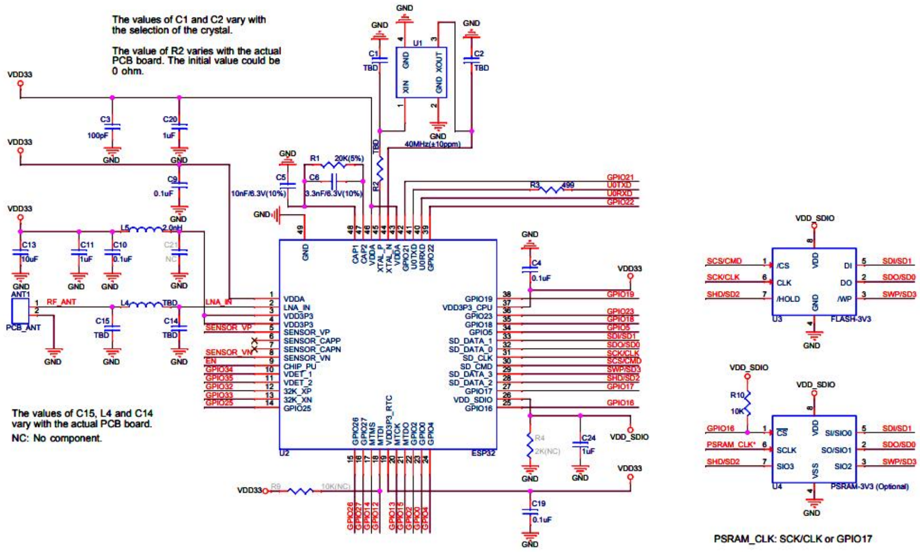


Fig. 3. ESP32 series chip reference schematic design

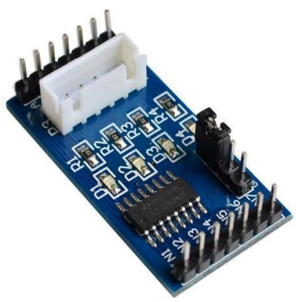


Fig. 4. ULN2003 Motor Driver

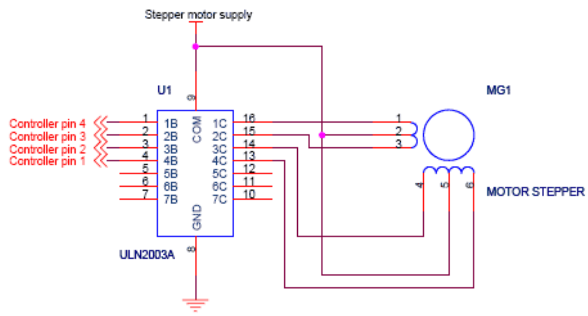


Fig. 5. ULN2003 Motor Driver schematic design

6. Conclusions

The challenge in the small and light (up to 10 g) robots' design, especially water strider-like robots, consists of searching and selecting: a) the functional electronic components, as light as possible to implement the scheme; b) hydrophobic materials, which ensure that the robot floats on a water surface; c) as well as formatting a weight reserve for some necessary sensors' deployment.

7. Gratitude

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8. Mutual claims of authors

The authors have no claims against each other.

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