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METROLOGICAL RISKS AT DESIGN STAGE FOR MULTIDISCIPLINARY-BASED OBJECTS

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1. INTRODUCTION

A general course for evaluation of measuring uncertainty [1] regarding decision-making in conformity assessment is continuously developed since the topics become complex and multidisciplinary. Attention is focused on the statistical analysis of data recorded by the measurement system. In such a way conclude the acceptability of the applied measurement system through the quantitative expression of its indicators [2]. Such a task has to be solved considering not only the design stage but also the exploitation peculiarities.

2. PURPOSE OF WORK

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

3. SPECIFICITY OF WATER STRIDER’S DESIGN

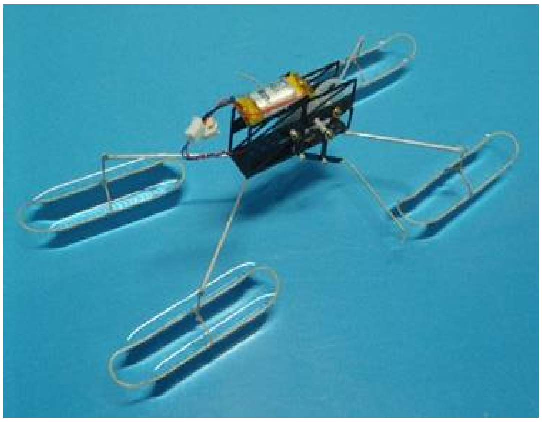
Multi-legged walking devices of the spider type are widespread recently. The development of university educational programs, monitoring of the environment and, first of all, the state of water resources, for the subsequent control of their parameters demand the continuous assessment of the designed robots’ performance as well as their metrological risks at certain stages of design and operation.
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. 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 such mechanisms as a "water strider". The study and research of these insects has already become interesting in China [1] 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.

Table 1. Worldwide universities’ studies of water striders.

Major characteristics

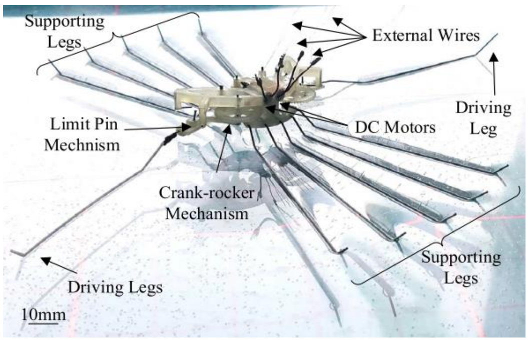
Year	Institution	Movement Form	Ability to carry sensors	Drive method	Quality, g	Linear speed, mm/s.
2003	MIT	Sliding	No	Elastic band	0.35	180
2010	Carnegie			DC Motor	21.75	71.5

	Mellon University	Sliding	No			
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

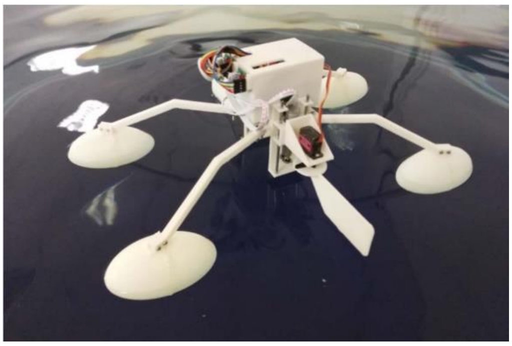


Kogakuin University（Japan）

Carnegie Mellon University



Harbin Institute of Technology



Zhejiang University

Fig. 1. Different designs of water striders

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 some 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's surface. The study [1] 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.

Fig. 2. ESP32 development board

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.

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).

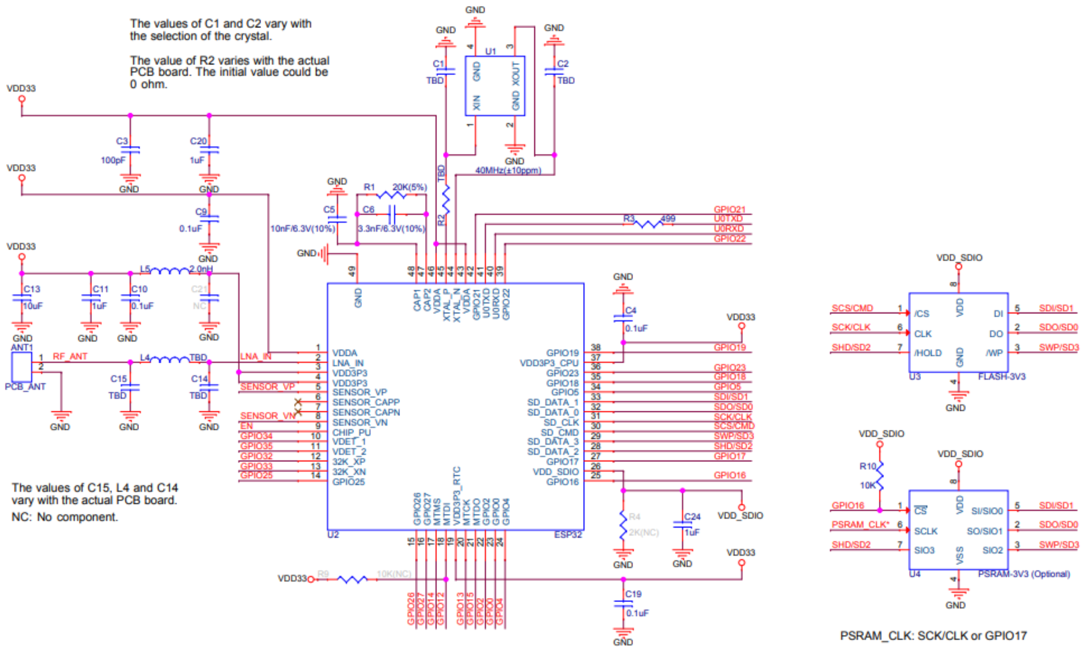


Fig. 3. ESP32 series chip reference schematic design

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.

Fig. 4. ULN2003 Motor Driver

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.

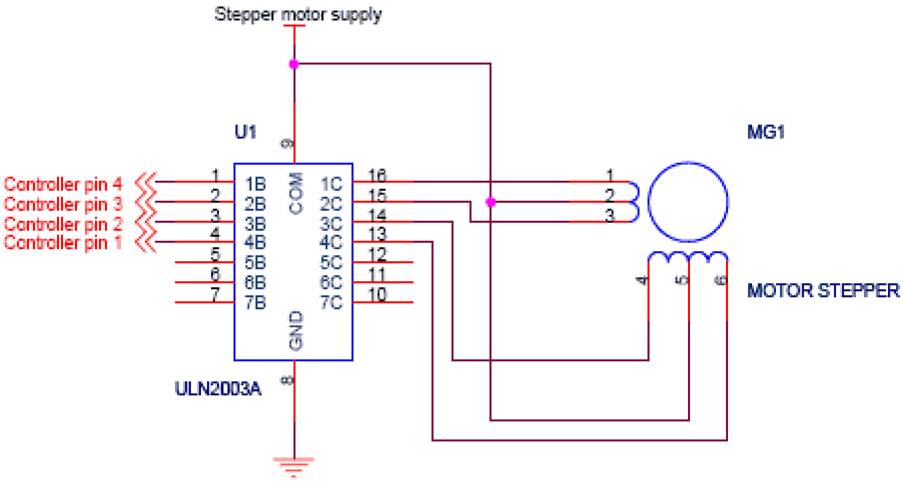


Fig. 5. ULN2003 Motor Driver schematic design

Analysis shows that if you need to carry an MCU that can adapt to the weight of the sensor, you can't perform the same structure as Harvard University. The last research was the jumping construction of water striders based on legs made from shape-memory alloys.

4. ANALYSIS OF VARIOUS MEASUREMENT CAPABILITIES AT THE DESIGN STAGE

The goal of the analysis of various measurement capabilities is to establish the total RMS deviations, known as the measurement uncertainty [3]. Data on processes are mostly obtained with the help of measuring devices, and the devices themselves contain their uncertainties. Accurate and reliable analysis of the measurement system not only ensures the accuracy of the controlled process but also contributes to scientific and industrial development. The quality of the measurement system and the quality of products are interrelated.

Research of controlled objects compliances with a pre-established specification which must be established based on the received results). It is not always possible to avoid type I errors (an acceptable product is considered defective) and type II errors (a defective product is considered acceptable). These two types of incorrectly made decisions mean, respectively: the manufacturer's risk (deviation of product characteristics from optimal values) and the customer's risk (acceptance of the wrong product).

Let's focus on Type II errors. Then the risk passes directly to the customers, causing them complaints and costs due to quality degradation. Increasing variability (RMS deviations) worsens the value of the index and the quality of products, reducing the possibility of monitoring statistical schemes of process control. If the measurement system is not accurate enough, the true value of the monitored characteristic is distorted. This becomes an impetus to improve the measurement system.

it is possible to determine deviations caused by both measuring devices and the activities of service personnel. However, ISO/TS 16949 [4] placed instrument calibration and MSA specification in clause 7.6, and the primary targets for MSA are instruments. Therefore, it is not quite correct to equate MSA with calibration, considering that MSA means calibration plus the statistics of the obtained measurement results.

ISO 17025 [5] on calibration and testing laboratories revised in 2017 adopted the decision rule, considering the level of risk (e.g., false acceptance and false rejection) and applying the rule in the context of decision-making about the conformity of this object. In addition, EURAMET funded the EMPIR 17SIP05 “CASoft” project (2018–2020) to make the

statistical methodology available to decision-making organizations (calibration and testing laboratories, industrialists, and regulatory bodies) in conformity assessment. This project helps them with software for calculating associated risks, which is designed to cover common cases, such as considering distributions, with or without prior information, as well as some situations that occur in life (other probability distributions, bivariate cases, etc.). Standards [3-5] make it even more important to address the problem of conformity assessment in connection with uncertainty; it opens the possibility for the subjects involved in the problem of conformity assessment to agree before the measurement on the decision-making rules applied to the test or calibration.
The problem arises in various industries immediately after the measurement. Then the measured value is compared to the tolerance interval of the desired value: it should be decided whether the product (product, tool, material, etc.) can be considered as conforming to the specification. At the same time, measurement uncertainty contributes to making the wrong decision, that is, accepting an inappropriate product or rejecting a suitable product. Such risks (incorrect decisions) are computed. These include: - Specific risk, which is defined as the probability of making the wrong decision for a specific product; - Global risk, which is defined as the probability of a wrong decision based on the future measurement result. The scope is that the decision is made based on the measurement of a single interest amount (%). That's, such percentage values, which form the "region of uncertainty", are not considered. The only possible decisions are to accept or reject the product, two combined risks are studied, namely the risk of a particular consumer which is the probability that the studied product does not meet the requirements, and the risk of a specific manufacturer, which is the probability that the rejected product meets the set requirements. Here it seems interesting step-by-step development of laser interferometers of SIOS production [6-7]. Starting from interferometers with a low manufacturer's risk and high consumer risk, they have increased their own risk by introducing the additional measurement measures and lowered the consumer risk, f. e. in LM 20/50 model [8].
An example of the water strider design is shown following. Since the robot's weight exceeds the maximum needed to assure buoyancy, the designers eliminate the heavy power supply by optics or/and biomechanics by increasing the designer risk to try to lower the consumer risk.

5. OUTLOOK AND CONCLUSIONS

To minimize the metrological risks of designed objects, it should be considered the whole complex: product + metrology instruments + data processing. The dispersion of the measurement results enables the formation of an attitude toward the object (product, tool, material, etc.) and establishes whether it meets/doesn't meet a predetermined specification. A performance alteration over time, for example, of a water strider robot indicates the presence of impacts.

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