REVIEW

of the dissertation work of Assist. MSc. Eng. Vasil Georgiev Tsvetkov for acquiring the scientific and educational Doctoral degree, presented for defense at the Institute of Robotics at the Bulgarian Academy of Sciences with title "Enhancing the cognitive abilities of robots through optimization of their sensory system" ; Field of higher education: 5. Technical sciences; Professional field: 5.2 Electrical engineering, electronics and automation; Scientific specialty: "Application of the principles and methods of cybernetics in the field of technical sciences", Scientific supervisor - Assoc. Prof. Dr. Eng. Nina Valchkova

Reviewer: Acad. Chavdar Roumenin – Institute of Robotics at BAS

1. General phenomenology of the dissertation work

The dissertation is developed in a volume of 122 pages and contains a List of abbreviations used, Introduction, Four chapters, List of literature and applications. The main text is presented on 102 pages with 42 figures and 8 tables. The bibliography covers 96 titles, of which 16 in Cyrillic and 80 in Latin. The applications are designed on 17 pages, including 1 table and assembler program code. The material is well illustrated with figures, graphs, tabulograms, etc., and what, in my opinion, is especially important is that the author has not overdone them. The text and the presentation are well structured. The suggestions through the results, conclusions and contributions are highly professional and consistent. The essential data that MSc. Eng. V. Tsvetkov claims are already reflected in his publications and are available to the professional community.

2. Relevance of the dissertation topic, goal, objectives, etc.

I consider the topic of the dissertation to be very relevant. It is enough to mention the key role that robotics, sensors and artificial intelligence are acquiring in all, without exception, human activities. If in the recent past the key goal in robotics was to adapt these systems to specific activities of ours through software algorithms and hardware configurations , recently the agenda of this aggressively penetrating civilization is cognitive sensor-information In improving the sensors and cognitive

capabilities of individual robots expands the functional capabilities of interaction with the surrounding reality and virtual environment. These technological advances open up new possibilities for robots to perceive, " understand " and interact with the world around them in an " intelligent " and human-like way.

Sensor configurations allow to provide information databases about the environment with a high degree of reliability and uniqueness. These conversion elements can be optical cameras, microphones, devices for touch and proximity, for chemical composition and analysis, spatial orientation and navigation, ultrasonic recorders, etc. The sensory "picture" thus obtained is the basis of the cognitive abilities of robots . especially when interpreting data. A key role here is for robotic complexes to be able to make well-defined and informed behavioral decisions. In this context, emphasis should be placed on the development of individual elements of artificial intelligence that can purposefully process sensor data for specific cognitive goals. By integrating different types of sensors, robots can " capture " and select data from different modalities, simulating human senses and expanding their capabilities for machine perception. Sensor systems alone are not enough for robots to truly understand and navigate their environment. This is where cognitive abilities come into play. For example, audiosensory devices allow robots not only to perceive the sound environment, but also to interact with people through speech recognition by processing a corresponding language, as well as to localize sound sources with high accuracy, to initialize their spectrum and the logical information embedded in it. I positively evaluate the doctoral student's conclusion that the continuous development of sensor systems and cognitive abilities will improve the capabilities and usefulness of robots, bringing us closer to the state in which these intelligent machines, together with people, increase the its capacity, improving the quality of life. I would add that the simultaneous receipt of heterogeneous data sets is possible through the new direction in sensorics - multisensor systems. They simultaneously and independently measure with a high degree of accuracy and uniqueness various non-electrical impacts - from the components of the magnetic field to the mechanical vibrations of sound and the gravitational potential. Therefore, as it is centered, I find the dissertation work to be successfully implemented and adequately included in one of the most current areas of sensor micro- and nano-electronics - the level of intelligent sensors and multisensors.

I find the main goal of the dissertation to be logically well-motivated – effective design of a new type of sensor system for robots, aimed at upgrading

cognitive capabilities by improving and increasing the quality of their technical characteristics. The main tasks directly related to the purpose of the study are also logically selected. The tasks are quite sufficient, there are four in total, including the classification of the main sensors and devices; the development of a method for designing and optimizing the characteristics of a sensor system for cognitive robots and experimental verification of a newly proposed methodology for creating the sensor system. For me, of particular importance is the actually implemented robotic mobile platform with an omni-wheel module for testing cognitive robots, the formulation and creation of simulation sensor models and the most important in my opinion – the design and implementation of intelligent multi-sensor modules.

The background of the individual chapters is comprehensive, a clear and in-depth treatment of the issues considered is given. The conclusions to them are sufficiently detailed and convincing. I have not found any fundamental errors, or ignorance of the theoretical apparatus, experimental methods and instrumentation used. To a large extent, this is due to the professionalism and high quality of preparation generated by Eng. V. Tsvetkov, which is undoubtedly noticeable by the reader.

3. Contributions to the dissertation

In the dissertation work, a total of 3 scientific-applied and 5 applied contributions have been formulated and proven by the doctoral student. I could debate to what extent the difference is between scientific-applied and applied contributions, but in this case this is a peripheral issue and is of no particular importance. I can present the more significant results as follows:

SCIENTIFIC- APPLIED CONTRIBUTIONS

1. An overview classification of the main part of the most commonly encountered sensors (microsensors) has been made , and their parameters and applicability in robotic complexes have been critically analyzed.
2. A method for designing an optimal sensor system intended for cognitive robots has been proposed, developed and analyzed .
3. Experimental results were obtained and verified when studying the designed sensor modules, including multisensors.

Among *the scientific-applied contributions,* I highly appreciate Tsvetkov's achievement related to the basic method for designing an optimal sensor system intended for cognitive robots, as well as its experimental verification. I accept as correct the concept that a dominant part of the measuring devices, apparatuses and instrumentation can be used through state variables, a set of mutually complementary components, etc. Such an approach guarantees increased accuracy in metrology in robots.

APPLIED CONTRIBUTIONS

1. Designed, constructed and implemented, suitable through its kinematic and geometric parameters as a universal technical tool for testing the functional capabilities and technical characteristics of the developed and optimized sensor modules. and systems .
2. Sensor configurations have been implemented for: temperature measurement; light intensity in the visible part of the spectrum; sound analyzer, etc.
3. Reasonable and functionally presented are multiple modules that perform: initialization of the selected optimal PIC microcontroller; module controlling the communication between the microcontroller and the multisensor unit; device for visualization of a 7-segment display; a software algorithm has been formulated for converting data packets into a form suitable for processing in cognitive robots.
4. A mobile application for Android has been implemented as a human-machine interface for controlling the mobile platform designed for cognitive robots.
5. Experimental studies have been conducted to evaluate the characteristics and states of sensors and multisensors, which is part of the process of designing an optimal sensor system for cognitive robots.

In the applied contributions, the author has successfully built specific databases, platforms, high-performance virtual devices, etc. These developments include theoretical models developed by V. Tsvetkov, which are the basis for original results achieved in his dissertation work. *Since recently, software solutions and models have dominated dissertation topics, I highly appreciate the experimental verification of theoretical models carried out by the doctoral student.* In this context, the dissertation work is an event in the Institute of Robotics and in the scientific field of ICT.

In general, I define the contributions of the dissertation as the formulation and justification of a new scientific concept in the field of robotics and the creation of

original methods and constructions for the purposes of cognitive systems with elements of artificial intelligence.

4. Critical notes, author abstract

In several places in the dissertation I encountered confusion of sentences, including spelling errors. The description of the different types of software platforms needs to be refined from the point of view of the role of the principles of functioning of their physical analogues, if any. I would like to recommend that for future research by Eng. V. Tsvetkov, he pay special attention to the sensor zone in the human-machine interface. Most often, ready-made commercially available modules are used for this purpose. No attention is paid to the accuracy of converting externally incoming information into digital for processing in microprocessors, etc. The contributions could be summarized without this leading to a loss of quality. I believe that the results achieved, the contributions and everything claimed in the dissertation are the personal work of the doctoral student. This conclusion is categorical for me and I have no evidence of his incorrect behavior with regard to intellectual property. I also declare that I have no joint works with Eng. V. Tsvetkov or financial relationships for a possible conflict of interest or influence peddling. As a professional inventor, I believe that the developed robotic wheeled platform contains original modules, elements and connections, even a design, and could be submitted for patenting as an invention. This is my insistent proposal, mainly to Assoc. Prof. Dr. N. Valchkova.

The author abstract is entirely based on the dissertation work, with no texts containing information, suggestions or data that have not been treated in one form or another, or discussed in the dissertation. The contributions and conclusions in the abstract are the same as those in the main material. The results are presented in 3 scientific publications, of which one is abroad and two are in our country and are directly related to the dissertation research.

FINAL CONCLUSION

The proven synergy of the achieved scientific-applied and applied contributions and results, which I confidently define as original, innovative approaches and ideas, and the architectonics of the dissertation work **give me the conviction to recommend to the esteemed Scientific Jury to positively evaluate the dissertation work and to award the scientific and educational degree "Doctor" (Technical Sciences) to Assist. MSc. Eng. Vasil Georgiev Tsvetkov** in

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Sofia

Chavdar Roumenin