REVIEW

of dissertation work
for gaining educational and scientific degree "doctor"

educational area: 5. Technical sciences
professional division: 5.2.Electrical engineering, Electronic and Automation
scientific field: Automated systems for information processing and management
Author: **eng. Stefan Borisov Karastanev**
Topic: **Reengineering of industrial robots**
Supervisor: prof. dr. Dimitar nedelchev Karastoyanov
Jury member: prof. dr eng. Julieta Atanasova Kaleycheva, TU-Sofia
Subject: order № 233/30.9.2019 of the director of IICT-BAS for jury team members and Protocol № 1 for choosing jury leader and members

1. Overall characteristic and actuality of the dissertation

The dissertation is in volume of 258 pages and contains six chapters, contributions to the dissertation, literature, list of publications of the author on the topic of the dissertation.

The main goal of the dissertation is: Reengineering of Industrial Universal Robots (IUR) second-hand through renovation of mechanics, construction of new electronics and software, testing of the robotic system and implementation in new industrial applications.

This goal is achieved by formulating and fulfilling the following tasks: **1**. Review, analysis and systematization of mechatronic robotic systems; **2**. Selection of an IUR type representative for reengineering; **3**. Study of the mechanics, electronics and software of IUR; **4**. Creating methodologies for the study of IUR; **5**. Creating a concept for overall reengineering of the selected IUR; **6**. Construction, testing and verification of the upgraded IUR.

Out of service Industrial Universal Robots (IURs) from a given production after reconstruction and upgrading are fully operational and suitable for use in other industries. The dissertation is up-to-date because it offers modern solutions for the reuse of IUR for new industrial applications. The dissertation contains useful results for the reengineering of KUKA industrial universal robots. An example of this is the applied results of the dissertation work in the probation and testing of a developed prototype of a welding robot with adaptive control and a sample manipulator by the Bulgarian-German company "Spesima" Ltd.

2. Literature overview

There are 87 literary sources in the dissertation, 11 of them in Cyrillic, 65 in Latin and 8 online. Chapter 1 provides an overview, analysis and systematization of robot types and other mechatronic robotic systems. Areas of application of industrial robots and their functional purpose are indicated. Emphasis is placed on the problems of

automated welding and servicing of horizontal injection molding machines, to which the doctoral student is directed in connection with their management. More specifically they are manipulators - casting extractors from horizontal injection molding machines.

The analysis in Chapter 1, is made with great precision and in detail and shows what the current problems in the area are, as well as the potential options for solving them. On this basis, the purpose and tasks that the author sets out in his dissertation are reasonably and precisely formulated.

3. Connection between the research methodology with the stated goal and tasks of the dissertation

The research methodology relates to the mechanical structure and elements, hardware and software management of the selected type of universal industrial robot representative. Includes a sequence of activities which are described in detail in the dissertation. The emphasis of the thesis of the dissertation is on the activities related to the study of the software of the selected robot - determining the characteristics and functionality of the control system. The methodology developed and tested includes a general inspection of the functionality of the software and system assurance, as well as verification of the basic functions for compiling control programs and modes.

The research has identified the need to build a new hardware control system to help the robot to effectively redirect to its new industrial application. This means that the communication, interface, and hardware configuration elements must be tailored to the speed and volume requirements of the information communicated by the controllers, feedback sensors, and actuators.

The steps for configuring the software have been identified, tested and implemented, which is in accordance with the stated purpose and tasks of the dissertation. In addition to basic software, a simulation software package has been developed for designing and pre-testing user programs. The developed package provides tools for building a virtual 3D environment, in which all local, regional and global movements of the robot can be reproduced close to reality.

After the simulation tests of the movements, the user program and the machine logic, tests of the actually functioning prototype of the reengineered robot were carried out, which completely examined the mechanics, drives, servos, sensors and software of the robot.

Afterwards a verification of the robot reengineering methodologies is carried out based on the developed methodologies for testing the mechanical system, hardware and software of the robot, as well as the studies of the upgraded design, hardware and software for controlling the functional laboratory model of the reengineered robot KUKA KR150.

4. Contributions in the dissertation

I accept and evaluate positively the scientific and applied contributions formulated by the student, which reflect in the dissertation and the abstract.

In summary, they can be presented as follows:

- A detailed review, analysis and systematization of mechatronic robotic systems, engineering study of the mechanical, hardware and software system of the selected

IUR type representative - KUKA KR150 robot, analysis of kinematic and dynamic models of the studied robot and of the basic parameters of the hardware configuration and software;
- Techniques for inspection of mechanical design, hardware configuration and software have been developed;
- The mathematical algorithm for solving the rights and the inverse problem of kinematics for the researched representative of the IUR is presented, the dynamic model of the selected robot is investigated;
- The mechanical design, hardware and software of the functionally functioning laboratory model of the reengineered IUR, as well as of the developed hardware and software for the new field of use, were investigated;
- Research and verification of the results of the reengineering has been carried out;
- Optimization of procedures for simulation and offline programming of re-engineered robots ;
- An innovative solution for a wireless control panel protected by a recognized patent application has been proposed. The board integrates the best features and features of such limited-use controls;
- A concept for product commercialization resulting from reengineering activities is proposed.

5. Practical use of dissertation's results

The experimentally obtained results are based on the in-depth knowledge of the doctoral student on the current problems of re-engineering that is extremely important for the economy of the Republic of Bulgaria and last but not least on his theoretical knowledge and its application for creation of innovative software and hardware products, one of which is undoubtedly is the wireless control panel. The student has made a large amount of work, characterized by its scope, depth and competence. The work describes well the innovative approaches and methodologies, computer techniques, digitalisation and automation of industrial robotic reengineering processes. So far, the focus of its development is focused on the re-engineering robot KR 150 of the German company KUKA, as the robot meets the set requirements for functionality; anthropomorphic structure; degrees of mobility; spatial movements; mechanical and propulsion system parameters; load capacity; elements of the control system; type of control; positioning accuracy and repeatability.

The author's works have considerable scientific and applied value, with the possibility of their multiplication in various fields of industrial production, for reengineering of functionally suitable technical devices, in particular of universal industrial robots.

6. Publications and citations of dissertation publications

The author has published the results of the dissertation in 7 papers. Publication # 1 is noted in the WoS and Scopus databases (SJR: 0.298), and publications # 2 and # 3 - in the Scopus database. Publications No. 4-6 are from scientific conferences in Bulgaria, and Publication No. 7 is a recognized patent application.

Publications relate to the dissertation topic. No citations for publications are known. I think that their quantity is sufficient for the degree of Doctor and it largely represents the results obtained.

7. Authorship of the results obtained

Out of the 7 publications on the topic of the dissertation, 5 are made and 2 in co-authorship with the scientific supervisor and other scientists. The dissertant's personal contribution to the submitted publications is indisputable.

I believe that the dissertation work and its contributions are the personal work of the doctoral student, achieved under the extremely expert guidance of his scientific advisor Prof. D. Karastoyanov and his team and with the support of the Bulgarian-German company "Spesima" Ltd.

8. Autoreferat

The autoreferat is 30 pages in volume. Each of the 6 chapters is briefly described, followed by contributions and a list of scientific publications on the topic of the dissertation. The content of the dissertation is presented correctly, accurately and clearly. Illustrations in the abstract are also contributing to the good perception and understanding of the work. A list of seven scientific publications of the doctoral student on the topic of the dissertation is presented. In general, the abstract gives a sufficiently complete and clear idea of the content of the work and the contributions of the dissertation.

9. Opinions, recommendations and notes on the dissertation

The dissertation of eng. S. Karastanov is a completed research work. The results achieved by the author fully correspond to the set goal and tasks, using innovative methods, techniques and technologies. The author has received original scientific and applied results for the re-engineering of industrial robots.

I have no significant comments on the dissertation work of Eng. S. Karastanov. I could point out some gaps like:

- the abstract lacks a summary in English;
- publication # 2 in the author's list of publications on the topic of the dissertation is incorrectly referred (the same publication was noted in Scopus by a different sequence of authors' names);
- there are gaps in the layout of the dissertation and inaccuracies in the numbering of figures (for example, in Fig. 6, Fig. 267 and Fig. 268 are replaced instead of Fig. 277 and Fig. 278).

In order to the future habilitation of the PhD student, it is necessary for him to prepare his innovative works as publications, which he should direct for printing in foreign refereed editions.

These gaps do not impair the quality of the development. The dissertation makes a very good impression with thoroughness, precision and striving for systematic use of the interdisciplinary problem posed, as well as with a large number of illustrations. The dissertation has made a thorough study of the problem, analyzed the results of the research and proposed a comprehensive solution in a new and promising area.

Conclusion

I think that the present dissertation **corresponds** to the requirements of ЗРАСРБ and the manual for its application and the specific requirements for gaining a scientific degree in IICT-BAS. The achieved results give me basic to **suggest** an educational and scientific title "doctor" to be awarded to **eng. Stefan Borisov Karastanev** in educational area - 5 technical sciences, profesional division - 5.2. Electrical engineering, Electronic and Automation, Scientific discipline:: „Automated systems for information processing and management", Educational area

22.10.2019
Sofia

Jury member: prof. dr Julieta kaleycheva