National University of Science and Technology
POLITEHNICA Bucharest
Faculty of Mechanical Engineering and Mechatronics
mecanica.upb.ro

DOCTORAL SCHOOL

OF MECHANICAL ENGINEERING AND MECHATRONICS

MODELING, SIMULATION AND EXPERIMENTATION OF MECHATRONIC SYSTEMS

- ABSTRACT -

- HABILITATION THESIS -

Assoc. Prof. PhD. Eng. Bogdan GRĂMESCU

BUCHAREST - ROMÂNIA

2026

ABSTRACT

The developed habilitation thesis entitled "MODELING, SIMULATION AND EXPERIMENTATION OF MECHATRONIC SYSTEMS" briefly presents the author's achievements during 28 years dedicated to educational and research activity in the Faculty of Mechanical Engineering and Mechatronics. Some additional external activities had the role of seeing things from the perspective of the economic environment and did not go beyond the scope of technical training.

The mentioned time interval, of which 21 years after obtaining the doctoral degree, was a dynamic period, with scientific research projects, educational projects, development of new courses, responsibility in the Mechatronics study program, administrative activities... This thesis is an opportunity to remember.

The habilitation thesis is structured in 7 chapters plus own Bibliography, in an attempt to review the activity over the years.

Thus, **Chapter 1** refers to *Academic Activity*. The author's scientific activity is briefly presented, his field of activity starting from the basic training in Fine Mechanics and the doctoral thesis in the field of Mechatronics and Robotics: "*Research on the development and use of autonomous micro-robots*". The themes of the research and development projects, in which the author participated as a responsible person or as a member of the research team, can be classified into 5 areas of interest, of which 4 are associated with the disciplines he teaches. It is worth noting that all of them refer to mechatronic systems or components. These are: Models and simulation environments of mechatronic systems; Actuators and positioning systems; Sensory and data acquisition systems; Mobile and micro robotics; Applications of active and "smart" materials.

The first part then reviews the teaching activity and the development of new courses, as well as the involvement in educational projects. The list of doctoral students for whom the author has been or is part of the supervision committee is presented, as well as the list of those for whom he has been on the doctoral thesis defense committees. The educational initiatives related to collaboration with universities in the country and abroad, collaboration with companies, and with the pre-university environment are presented. Finally, the grants and research-development projects are presented, as well as the scientific recognition of the author's activity.

The second chapter refers to the activity regarding *Models and Simulation Environments*. Modeling and simulation are mandatory stages of the research and development process of complex technical systems that, in general, couple several physical fields (mechanical, electrical, electronic, thermal, hydraulic, etc.). The study on the model has facilitated remarkable developments in the industries of robots, automobiles, aviation, satellites, medical devices and other technical systems, which have also benefited from real-time simulations, of the “hardware in the loop” type. The content of the chapter was based on 13 published scientific works (presented in the own bibliography), of which one book with ISBN and 12 articles (3 WoS, 4 Scopus) and 3 citations. A small observation can also be made, namely that modeling and simulation methods were used by the author in the development of some courses, and part of the research results were introduced as laboratory works (case

studies) in undergraduate and master's courses, obviously depending on the complexity. Thus, a consistent chapter was dedicated to modeling and simulation in the Mechatronic Systems course in the Mechatronics undergraduate program and a separate discipline in the Advanced Mechatronics master's program. All these models were associated with the appropriate simulation environments available at the university: Matlab, Simulink, 20-sim, Scilab, Xcos and Open Modelica.

The third chapter addresses concerns regarding drive elements, namely *Actuators and positioning systems*. This chapter opens the applied engineering research directions of the paper, addressing, mainly, electrical drive and subsidiary, that with fluids. A special mention deserves the electromagnetic drive, also addressed in the modeling chapter. Starting from two research projects on the variable distribution of an internal combustion engine, the constructed biposition actuator, its control and the results of its testing in medium speed regime are presented. Also, regarding electrical drive, among the achievements, the method of theoretical-experimental identification of the functional parameters of DC motors and high-resolution positioning servomechanisms is presented. The chapter was based on 11 published scientific papers, including 2 WoS and scientific reports of the 4 research projects, including a CNCSIS grant.

Working in the field of mechatronics, **the fourth chapter** on *Sensory systems and data acquisition* could not be missing. This part is formally separated from the activity on robotic applications, given the particular achievements, less common in robotics practice and which can constitute independent measuring means. The need to monitor the position of mobile robots led to the development of opto-mechatronic systems, which use triangulation or correlation of stereo images, to detect the position of points located on the visible surfaces of robots. For this purpose, algorithms for calculating coordinates were applied depending on physical parameters and known witness dimensions from the analyzed scene and measurement results. The development of these methods and means benefited from the support of both robotics research projects, but also from 6 other projects mentioned in the own bibliography, resulting in 8 scientific publications, including two WoS (one in IEEE Transactions on Industrial Electronics).

Of course, the best example of a mechatronic system is the Robot, and mechatronics represents the command and control of systems of this type. For this reason, **Chapter Five** presents the concerns regarding *mobile robotics and minirobotics*.

Mobile and/or autonomous robots are a widely addressed topic of scientific research. Unlike traditional robotics, characterized by well-determined and programmed behavior, robotics of autonomous mobile systems address the possibilities of the machine for autonomous evolution, as well as those of adequate reconfiguration to adapt to continuously changing or unknown environments.

The chapter on Mobile Robotics and Micro Robotics presents, perhaps, the most exploited research and development topic, addressed in all the major publications in his own bibliography. Although mobile robotics was a primary concern in the author's scientific activity, the chapter highlights only the major contributions in this field. The ROMAR project, for the conception and realization of a module with mobility comparable to the Japanese M-TRAN (Advanced Industrial Science and Technology) or the American Superbot (University of Southern California), is noteworthy, with which the following were achieved: reconfiguration

of the robot from quadruped to open chain; reconfiguration from open chain to closed chain; movement by crawling in open chain; movement by walking as a quadruped. These actions required hierarchical control, at the module level (microcontroller) and at the robot level (computer), as well as radio communication between the modules and the computer.

A more recent project was a mobile robot for monitoring oil and gas pipelines, capable of moving along the pipeline and overcoming obstacles such as flanges, support brackets and left-right or up-down bends. Additionally, for scanning the circumference of a pipeline, a simple manipulator was designed, capable of positioning, at equidistant points, a camera or other sensor system, oriented in the radial direction, relative to the pipeline.

The research and development activities, related to the field addressed in the chapter, were carried out within projects won through competition or as research themes of the department. The results were disseminated through publications as: two books with ISBN, 16 articles in journals and volumes of international conferences. Of these articles, 4 are WoS quoted/indexed, 7 are Scopus indexed, and 2 EBSCO.

Precision mechanics being in principle the initiation area of mechatronics, and the small dimensions sometimes leading to the need for unconventional drive solutions and not only, it appears necessary to concern itself with *Applications of active and "smart" materials*, presented in **Chapter Six**. Regarding this chapter, the author had the privilege of being part of the team that addressed this research topic, in the Department of Mechatronics and Precision Mechanics of UPB starting with the academic year 1996-1997. After attempts to create piezoelectric motors to equip the Copernicus parallel module, research continued years later by developing piezoelectric structures for drive or with a sensory role, especially for active vibration control. In parallel, drive by wires made of shape memory alloys was investigated.

The seventh chapter tries to synthesize the activity of mentoring young people and teamwork, which in the end may be the reason why someone chooses to work in an university. The scientific research activities and achievements presented are the result of teamwork, led, in many cases, by the author of the thesis. Even if, in the presentation, the research topics are formally divided into different fields of interest, the common element is mechatronic and robotic systems, which the author has studied in depth, becoming one of the promoters of the subject within the Department of Mechatronics and Precision Mechanics of the National University of Science and Technology POLITEHNICA Bucharest. In these circumstances, in addition to achieving research-development objectives, an essential component of the mission was the selection and training of young colleagues, PhD, Master and undergraduate students, in order to obtain the results proposed in the research projects.

The author of the habilitation thesis has a long and rich experience in research, as well as in teamwork, both as a team member and in a coordinating role. He has been involved in both research projects themselves, but also in educational projects with an extremely important role for teaching activity. As a research supervisor, teacher, and leader of student teams, the author has encouraged and promoted young students in the research area, to become doctoral students and university assistants.