"FERDINAND I" MILITARY TECHNICAL ACADEMY

DOCTORAL SCHOOL

„ DEFENSE AND SECURITY ENGINEERING”

HABILITATION THESIS

Locomotion systems for mobile robots with military applications

ABSTRACT

Fundamental field: Engineering Sciences

Doctoral field: Mechanical Engineering

Author: CS-I PhD. Eng. GRIGORE Lucian-Ștefăniță

Department: Armament Systems Engineering and Mechatronics
Center of Excellence in Integrated Weapons and Engineering Systems – CESIAG

The habilitation thesis “Locomotion systems for mobile robots with applications in the military field” presents the author's research carried out from 1988 to the present, with a focus on the field of robots with applicability in the military field and emergency interventions. The interval 1995 ÷ 2022 corresponds to the period since I carried out my activity in education and research. The period 2003 ÷ 2022, corresponds to the period after the defense of the doctoral thesis (April 2003) and its confirmation by the Minister of Education and Research (May 2003).

The thesis is structured in three sections.

- first section Scientific Achievements;
- the second section contains the habilitation thesis structured on seven chapters;
- the third section refers to the Plan for the evolution and development of the professional career.

The scientific results are based on the original studies carried out by the author at: “FERDINAND I” Military Technical Academy; “Titu Maiorescu” University, at the University “of South-Eastern Europe LUMINA” and in the Production and Research Bases within the M.Ap.N.

Section I - Scientific Achievements

The evolution of the author is briefly presented, considering that in his development the activities within three universities and some productive units allowed him to be able to develop his abilities to achieve concrete things with direct applicability. Also, the activity during over 25 years in education materialized through the coordination of undergraduate students, dissertations and I was asked to provide support to doctoral students from the Military Technical Academy and the Petroleum-Gas University of Ploiești in their practical and theoretical approaches.

This research was funded from research contracts in the field of mobile robots to combat terrorist acts, as a partner or contract manager (see CV): Program: "Research Excellence" Competition 2, Project category: MODULE 1 , P-CD - ROBTER - Robot for Combating Terrorist Actions, CEEX 20 / 19.10.2006 (€ 497,004,1609), Contracting Authority: Romanian Space Agency, Contractor: Military Technical Academy; Center of Excellence - CE * MOSITEST * ATM, RELANSIN 1723 / 01.09.2003 (€ 429,110.8823); In addition to these projects, the following projects also contributed to the development of hardware and software as well as the evaluation procedures of electric motors: VEMEV - "Vocational Education Platform for Maintenance of Electric Vehicles", Project Number - [2012-1- TR1-LEO05-35189] Funding program: LEONARDO DA VINCI - Lifelong Learning Program, Transfer of Innovation, Multilateral Projects (€ 321,234.00); Mini-UAV / Payload autonomous air system - ROBONET financed by the Sectoral Operational Program "Increasing Economic Competitiveness (SOP CEC) 2007-2013" - co-financed by the European Regional Development Fund - Priority Axis 1 "An innovative and eco-efficient production system" Major field of intervention D1.3 "Sustainable development of entrepreneurship" Operation "Development of business support structures of national and international interest" - SMIS Code 50132 - SC EN-GENIUS SOLUTIONS S.R.L .; Naval Autonomous System + Payload, 02.06.2016 ÷ 18.11.2016, Nr. 157871 SMIS CODE 50130, PAYLOAD; NRMM (NATO Reference Mobility Model) "Implementation of the NRMM in the system of management of logistics resources and maintenance within NATO troops". NATO-funded project worth € 18,000.00 - MTA Bucharest, 2007-2009; “Realization of a remote controlled 4x4 fire extinguisher robot - FFR1”, Beneficiary of Titu Maiorescu University of Bucharest (internal project based on competition) for participation in the PATRIOTFEST 2016-2017 competition.

Also, at the University of Southeast Europe LUMINA "Realization of a remote controlled 6x6 fire extinguisher - RAM-ISU-ICE01",

These projects and results certify the author's ability to coordinate research and development projects and his ability to coordinate young researchers. In parallel with the

research in the field of locomotor system of mobile land robots on wheels and tracks, the author carried out research in the field of mobile air, sea and humanoid mobile robots.

Section II - Habilitation thesis

Chapter 1 presents the Contributions to the Features and Requirements of Mobile Terrestrial Robotic Systems, starting with the State of the Art and ending with the Requirements that a mobile terrestrial robot must meet. Research activities in the field of terrestrial mobile robots have been aimed at: - developing a family of mobile robot systems on wheels and tracks, modular systems adaptable to a multitude of applications by creating a load-bearing platform capable of being equipped with various operational platforms. ; - development of four-wheel drive, six-wheel drive and crawler mobile robots; - development of robots with crawler locomotive structure adaptable for intervention activities in special situations up to those with military specifics.

Chapter 2 presents the contributions on the kinematics of the propulsion systems of mobile land robots on wheels and tracks. The contributions consist in the description / development of simple algorithms used in the software part necessary for the command and control over the kinematics of the locomotor of the terrestrial mobile robots. The algorithms are defined in modular form, so that, by introducing or removing modules, the software is adapted to the different requirements required by the missions in which the robots must participate. The studied propulsion systems are equipped with electric motors, and for the propulsion systems on wheels but also on the tracks the turning is performed by changing the speed / direction of rotation of the drive wheels.

Chapter 3 presents the contributions on the dynamics of the propulsion systems of mobile land robots on wheels. The contributions consist in the description / development of simple algorithms for 4x4 and 6x6 robots. The author developing locomotive systems with both four-wheel drive and six-wheel drive. Robots designed and developed at the level of prototype / technology demonstrator were used especially for interventions in emergency situations such as: firefighting, identification and monitoring of radioactive sites.

Chapter 4 presents the contributions on the dynamics of the propulsion systems of mobile terrestrial robots on tracks. The contributions consist in the description / development of simple algorithms for crawler robots. The author developing track locomotion systems. The robots designed and made at the level of prototype / technological demonstrator / experimental model were used especially for the intervention to take over or eliminate the explosive artisanal devices used for the purposes of terrorist attacks. Robots developed at the experimental model level were also used for the development of applications for road planning and image identification. The movement of robots using video cameras as sensors requires an extremely fast and quiet response from the locomotor system. Any vibration introduced into the system disrupting the video signal.

Chapter 5 is a natural continuation of Chapter 4, which presents contributions on simulating the crossing of obstacles by crawler robots. The author considered it appropriate to describe the simulations of crawler robot dynamics, as the identified priority requirements require crawler propulsion systems. Also the contributions consist in the numerical validation of the algorithms regarding the dynamics of this type of locomotor system. It can be appreciated that in the conditions of asymmetric risks that military specialists have to face, crawler robots are one of the most reliable solutions.

Chapter 6 presents the contributions regarding the homogeneous terrain crossing starting from the configuration mode of the propeller and finalizing by implementing some methods of simulating the behavior of the terrain at the contact with the track. Since each element of the track, respectively the skates, encounters a different terrain, the normal and shearing demands of the ground generating a different state of the ground on which the skates from the composition of the track will tread. The most eloquent example is the turn / turn

around the center of gravity. In this case the side of the track behaving like the blade of a bulldozer.

Chapter 7 presents the contributions on inhomogeneous terrain crossing, this time using the NRMM (NATO Reference Mobility Model). Chapter 7 presents the behavior of inhomogeneous soil in contact with the caterpillar. The specific thing is that in the case of inhomogeneous lands, situations may occur in which the caterpillar is no longer in permanent contact with the ground. These numerical simulations can highlight the inhomogeneous nature of the slip and forward resistance coefficients, which define the dynamics of a crawler ground robot.

In section III Plans for the evolution and development of the professional, scientific and academic career. The main professional achievements from the beginning of the university career until today, respectively 1995-2021 are presented. During this period I published: 89 articles of which 7 articles listed and indexed ISI WOS + SCOPUS (5 as first author, 2 as co-author), 12 articles in international databases (BDI SCOPUS), 70 articles published in volumes recognized international scientific events in the country and abroad, 6 books in CNCSIS recognized publishing houses, 11 textbooks / electronic course support, 23 laboratory stands, 38 laboratory guidance, 40 educational computer applications, 27 innovative products, technologies, platforms and services . I participated in 51 research projects, coordinated as a director or partner manager 23 research projects (projects won through internal competition), participated as a researcher in the team of 28 national research projects.

The research activities carried out will continue the topic studied so far and new research directions will be approached. In this sense, the author proposes new developments in the field of modular locomotion systems for terrestrial, marine, aquatic and underwater, aerial mobile robots; development of new payload systems for identification, recognition and action for the same types of mobile robots.

In conclusion, considering the activity carried out so far at national and international level and the development plan to be implemented, the author considers that the results can be significantly improved by expanding the research team with PhD students, coordinated as a result of the qualification in Engineering Mechanics, obtained on the basis of this thesis.

In the current year he participated as a reviewer in 4 articles in the journals MDPI Applied Sciences (3) and Sensors (1).