UNIVERSITY OF DEBRECEN

PEKÁR IMRE DOCTORAL SCHOOL OF MECHANICAL ENGINEERING SCIENCES

EDUCATIONAL PLAN

Debrecen, 2024

last updated: 14.10.2025

Content

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1. Personal background of the Doctoral School

The core members, supervisors and lecturers of the Doctoral School are primarily staff members of the Faculty of Engineering of the University of Debrecen. Still, colleagues from the Faculty of Natural Sciences and Technology of the University of Debrecen also participate in the supervision and educating tasks of the doctoral school. Based on the many years of cooperation, a professor at the Technical University of Cluj also takes on a teaching role. In the case of certain doctoral topics, we would also like to invite colleagues with degrees working for industrial research institutes as co-supervisors during the operation of the doctoral school.

Head of doctoral school:

Dr Ferenc Kalmár, doctor of the Hungarian Academy of Sciences, professor

The number of founding core members is 8, including

- 6 professors
- 3 Doctors of the Hungarian Academy of Sciences

Core members of the doctoral school:

1. **Dr István Budai** PhD, associate professor (UD)
2. **Dr Géza Husi** PhD, habil., professor (UD)
3. **Dr Ferenc Kalmár**, doctor of the Hungarian Academy of Sciences, professor (UD)
4. **Dr Imre Kocsis** PhD, habil., professor (UD)
5. **Dr Péter Korondi**, doctor of the Hungarian Academy of Sciences, professor (UD)
6. **Dr Ákos Lakatos** PhD, habil., professor (UD)
7. **Dr Tamás Mankovits** PhD, habil. associate professor (UD)
8. **Dr Péter Petrik** doctor of the Hungarian Academy of Sciences, professor (UD)

In addition to the 8 core members, 23 students will participate in the work of the doctoral school to be set up as supervisors and lecturers.

Of the 31 members of the doctoral school

- 10 members are professors;
- 1 member is a scientific advisor;
- 7 members are doctors of the Hungarian Academy of Sciences (DSc)
- 14 members are habilitated.

The secretary of the doctoral school is Dr Ferenc Szodrai.

The professional base for the work of the Doctoral School is created by the educating, research and development work carried out at the departments of the Faculty of Engineering of the University of Debrecen. Nicolae Balc, professor at the Technical University of Cluj-Napoca, is a visiting professor at the Universities of Nottingham and Leicester (De Montfort), as well as at the Technical Universities of Poznan, Maribor, Vienna and Rijeka. His main research areas are Additive Manufacturing, Product Design for Competitive Manufacturing, and Innovative Manufacturing for Rapid Product Development.

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2. The structure and main characteristics of the educational and research program of the Doctoral School

The Doctoral Regulations of the University of Debrecen define the training-education-research ratios for the Pekár Imre Doctoral School of Mechanical Engineering. According to this, doctoral students must obtain most of their performance expressed in study credits through research and publication activities.

2.1. Structure of the research program

At the start of the doctoral school, it announces two programs (two sub-programs within the second program) with the following titles:

I. BUILDING SERVICES ENGINEERING, BUILDING ENERGY PROGRAM

program leader: **Dr Ferenc Kalmár**, doctor of the Hungarian Academy of Sciences, professor

II. INTEGRATED INTELLIGENT MECHANICAL SYSTEMS PROGRAM

program leader: **Dr Péter Korondi**, doctor of the Hungarian Academy of Sciences, professor

II.1. MECHANICAL PROCESS DESIGN, MATERIALS AND MACHINE DIAGNOSTICS SUB-PROGRAM

sub-program leader: Dr Imre Kocsis PhD, habil, professor

II.2. MECHATRONICS, CYBER-PHYSICAL SYSTEMS SUB-PROGRAM

sub-program leader: Dr Géza Husi PhD, habil., professor

The supervisors are primarily instructors of the departments of the Faculty of Engineering with scientific degrees and actively carrying out research activities. Although the programs are also open to receiving research topics announced by external supervisors if they fit into the programs. The Doctoral Council of the Specific Scientific Field approves the announcement of the topic.

Students are expected to do continuous research from the very beginning, and in the period after the complex exam the emphasis is placed on achieving appropriate results, publishing and writing the dissertation. Students conduct research work on the chosen research topic under the guidance of their supervisors, preferably joining the departmental teaching and research work, as well as research and development programs.

The possibility of monitoring their progress is provided by the semester reporting obligation of students. The reports are evaluated by the program leaders based on the recommendations of the supervisors, and the research work is recognized by the Doctoral School with credits. In evaluation, publication performance is increasingly emphasized during training. The pro rata temporis fulfilment of the requirements shall be judged primarily on the basis of the number and quality of scientific publications and the quality of the engineering work related to the research topic.

2.2. Structure of the training program

The aim of the organized training at the Doctoral School is to broaden professional knowledge and horizons, to get acquainted with the methods and tools of technical development and innovation, to acquire research methodological knowledge and independent research practice, to acquire overall proficiency in the topic of the dissertation and to become capable of preparing the dissertation at a high level.

The training organized in the programs of the Pekár Imre Doctoral School of Mechanical Engineering is available in full-time and correspondence form.

The deadline for applications is (as a rule) 15 May and 15 November each year.

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The conditions of application and information on admission can be found on the website of the University of Debrecen, at https://www.unideb.hu/ address (Science → DOCTORAL TRAINING → Downloadable Documents) and on the website of the Doctoral School at engphd.unideb.hu.

Obtaining a degree by individual preparation is also possible. In this case the applicant have to prove his/her scientific work and the future supervisor must declare that the doctoral thesis can be completed within two years. The Council of the Doctoral School decides whether the proposed subject is suitable for obtaining a degree.

In some programs of the Doctoral School, students must complete a total of 240 credits (an average of 30 credits per semester) in 8 semesters (48 months).

2.2.1. *Study (training) credit*

During the first 4 semesters of doctoral training, a minimum of 16 academic credits have to obtained by completing the 2-credit courses announced or by having them accepted at the Doctoral School (by reporting on the exam). A minimum of 12 credit points out of the 16 academic credits have to be gained by completing courses opened within the Doctoral School.

A maximum of 4 credits can be gained by completing courses offered at another doctoral school of the university with the prior approval of the supervisor; the head of the doctoral program decides on the eligibility of credits. This maximum of 4 credits can also be obtained at another university or during the doctoral student's study trip abroad – based on the prior proposal of the supervisor. In this case the decision on the credits obtained or the documented performance is made by the Council of the Doctoral School.

The Council of the Doctoral School may also invite an external lecturer to lead special courses.

The educational standards of each program are formulated by the participating instructors and the program leader. Some programs define specific topics in the educational cycle and prescribe compulsory courses for their students. Other programs adapt flexibly to the needs following the constant change of research topics, and new courses may be opened each academic year.

2.2.2. *Education credit*

Credits may be awarded for the doctoral student's teaching activities according to the doctoral regulations, based on the decision of the Council of the Doctoral School.

In full-time studies a maximum of 40 educational credits can be obtained during the 8 semesters of the program by participating in the educational work of the Faculty of Engineering. (1 credit: 12 contact hours/semester or 30 hours of other teaching activities).

2.2.3. *Research credit*

During the 8 semesters of a doctoral training a minimum of 184 research credits must be obtained in full-time and 224 in correspondence studies, of which a maximum of 40 can be replaced by teaching credits.

Based on the proposal of the supervisor, the program leader may recognise research work in units of 6, 10, 20 and 30 credits (1 credit: 30 working hours) in each semester.

Each semester students prepare a written report in which they present their work and achievements during that period. In their report, students have to provide the following data: name of the student, name of the supervisor, number of semesters spent as PhD students, self-assessment of performance taking into account previously formulated plans. The data provided at the application have to be agreed by the supervisor in advance.

Students who have not yet submitted their thesis for preliminary discussion are required to report annually on the completion of the research plan. The report can be made at a PhD workshop organized by the DS or before the leader of the DS program/DS sub-program. The workshop is attended by

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members of the DS Council, supervisors and lecturers, as well as PhD students. There are no extra credits for the report itself. The Doctoral School Council may make comments on the progress of the PhD student and the completion of their research plan. First-year students need to present only their research plan and future vision. The presentations are 20 minutes long. The organization of the workshop is the responsibility of the secretary and the head of the Doctoral School.

The first stage of training ends with the complex exam at the end of the fourth semester.

3. Organisation, study and examination schedule of doctoral programs

The training can be attended according to full-time, correspondence and individual curricula. The quality requirements for daytime, correspondence and individual participation are identical.

In addition to budget-funded places the training is self-funded.

The DS is entitled to provide cost support from its own revenue.

According to our expectations, research topics will attract the interest of students with good qualifications. Thus, highly prepared facility engineers, mechatronics engineers, vehicle engineers and mechanical engineering master's students form the base of the next generation.

There is also a growing interest in doctoral studies among foreign students.

Within the framework of the study phase, the organized training lasts 8 semesters, during which a total of 240 credit points have to be obtained. This is the requirement of obtaining absolutory. During this time, under the guidance of the supervisor, the candidate can prepare his dissertation.

The credit ratios in the training phase are determined by the Doctoral Regulations of the University of Debrecen. The allocation of credits for full-time and correspondence courses is shown in Tables 1 and 2 respectively.

Table 1: Credit system for doctoral programs (full-time and part time)

	Credit units	Altogether
Excams	2	min. 16
Research work	26, 30 (1 / 30 research hour)	184 - 224
Lecturing	1 / 12 lecturing hour	0 - 40
***Total*:**		***240***

In order to facilitate the academic work of doctoral students and to evaluate their performance, recommendations are made in the Recommended Credit Completion document, which can be found on the DS website (https://engphd.unideb.hu/en/evaluation-semester).

The greatest weight is given to research. Credits can normally be obtained according to the guidelines described above, but credits can also be awarded for equivalent performance in other accepted genres based on the decision of the Council of the Doctoral School.

During the training, the candidate reaches the absolutory. In order to obtain the doctoral degree, it is also necessary to pass a complex exam in the main subjects listed in the document. One subjects of the main subjects and another subject of the secondary subjects have to be selected. Furthermore, a dissertation have to be prepared and defended. A successful workplace dispute is a prerequisite for being released for protection.

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4. Doctoral programs, educational concept

4.1. Building services engineering, building energetics doctoral program

Program Leader	Dr Ferenc Kalmár, doctor of the Hungarian Academy of Sciences, professor
Core members participating in the program	Dr Ferenc Kalmár, doctor of the Hungarian Academy of Sciences, professor Dr Ákos Lakatos PhD, habil., professor

The aims and research areas of the doctoral program

Minimizing the energy consumption of buildings is a primary national objective, considering that in Hungary the amount of energy spent on the operation of buildings accounts for more than a third of the total national energy consumption. The situation is similar on average in EU Member States and globally. According to the mandatory compliance with EU Directives, several domestic regulations aim to increase energy efficiency and use renewable energy sources in all energy-using sectors. The National Energy Strategy prioritises reducing energy consumption in buildings, while the National Building Energy Strategy sets out specific goals in this critical area. The requirement of nearly zero-energy buildings is also reflected in the Building Energy Regulation currently in force. The European Council and Parliament have decided that all new buildings should have zero carbon emissions by 2030 and all existing buildings should meet this requirement by 2050. As part of national renovation plans, Member States will develop a timetable for phasing out fossil fuel boilers by 2040. According to the organization, gas boilers can only be exempted from the ban if they are compatible with hydrogen, i.e. if they can burn hydrogen in the energy system of the future. Modern conventional gas boilers with a mixture of 20% hydrogen can be operated without any special transformation. If we want to use a higher proportion of hydrogen, some changes are needed. In relation to buildings, when reducing energy demand, increasing the efficiency of technical building equipment and integrating renewable energy sources, special attention should also be paid to the comfort needs of building occupants. However, comfort targets and energy saving targets are often at odds with each other. Energy savings should not result in a decrease in comfort levels in buildings, as this reduces the efficiency of work, sports or recreation. Depending on the purpose of the building, therefore, the heat, air quality, illumination and noise level meeting the needs must be continuously ensured. In order to be efficient, the performance of HVAC equipment must be constantly adapted to the needs of the moment, as the people in the building have different comfort needs. It is therefore essential to integrate the solutions offered by digitalisation in technical building systems and buildings, and to continuously collect and process data in order to increase efficiency and comfort.

Based on the above, complex building energy solutions and concepts must be developed and building services engineering equipment must be developed, as a result of which energy demand is minimized and the comfort parameters developing in the building meet the changing needs of the occupants in space and time.

Research areas related to the program: analysis of building services engineering systems, examination and application of innovative thermal insulation materials, intelligent buildings, efficient integration of renewable energy sources into energy supply systems, urban energetics.

Within the framework of the Building Services Engineering and Building Energy program, research topics are announced aimed at reducing the energy demand of buildings, increasing energy efficiency

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and ensuring comfort parameters that meet individual needs by developing intelligent building services engineering systems and equipment.

Our research is carried out in the Quality of Internal Environment laboratory available at the Faculty of Engineering of the University of Debrecen, in the Air Technology Laboratory, in the Building Physics Laboratory and in the Building Energy Demonstration Building. Several measuring instruments are available for measuring and recording internal environmental parameters (TESTO, Netzsch 446, KIMO, Bruel &Kjaer, Comfort Sense, Netzsch Sirius 3500, Venticell, Climacell, Cal 2 Eco, thermal imager, HUKSEFLUX heat flow meter, RETROTEC blower door device). Software supporting dynamic simulation is also available for our research (ANSYS FLUENT, TRNSYS, ENERGY+). Large data sets can be managed by access to the supercomputer available at the University of Debrecen.

The precedent of the program is the Sustainable Energy sub-program established at the Doctoral School of Earth Sciences in 2010, which appeared as a program in the training plan of the Doctoral School in 2020. Within the framework of the program, eight people obtained PhD degrees. Currently, two active PhD students are continuing their studies, and two of them have already obtained their absolutory and are currently preparing their dissertations.

Table 3: The educational concept of the Building Services and Building Energy Program

Subject	full-time training (hours/week)	correspondence training (hours/semester)	Credit	grading	lecturer	PhD
Compulsory subjects						
Mathematics	2	12	2	k	Dr Gát György	Dsc
Optional subjects						
Building Energy	2	12	2	k	Dr Kalmár Ferenc	DSc
Thermal Engineering	2	12	2	k	Dr Lakatos Ákos	PhD, habil.
Solar radiation geometry	2	12	2	k	Dr Csáky Imre	PhD
Modelling of energy processes	2	12	2	k	Dr Ferenc Szodrai	PhD
Air distribution systems in buildings	2	12	2	k	Dr Csáky Imre	PhD
Comfort Theory	2	12	2	k	Dr Ferenc Kalmar Dr Kalmár Tünde	DSc PhD
Exergetic-based analysis of building services systems	2	12	2	k	Dr L. Szabó Gábor	PhD
Reliability, safety, risk	2	12	2	k	Dr Árpád István	PhD
Methodology and tools of machinery diagnostics	2	12	2	k	Dr Kocsis Imre Dr Deák Krisztián	PhD, habil. Phd
Measurement and Signal Processing	2	12	2	k	Dr. Korondi Péter Dr. Kocsis Imre	DSc PhD, habil.
Electronics and electronic energy converters	2	12	2	k	Dr Szemes Péter	PhD
Data analysis	2	12	2	k	Dr T. Kiss Judit	PhD
Problem solving with intelligent computing	2	12	2	k	Dr Kocsis Imre	PhD, habil.

Students participating in the doctoral program must complete 6 credits of the listed compulsory elective subjects in addition to the 2-credit compulsory subject. Further study credits can be obtained in the manner laid down in the Rules of Operation of the Doctoral School. The applied credit values are in line with the practice developed at the doctoral schools of the University of Debrecen.

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4.2. Integrated, Intelligent Mechanical Systems doctoral program

Program Manager	Dr Péter Korondi doctor of the Hungarian Academy of Sciences, professor
Core members participating in the program	*Mechanical process design, material and machine diagnostics subprogram* Dr István Budai PhD, associate professor Dr Imre Kocsis PhD, habil., professor Dr Tamás Mankovits PhD, associate professor Dr Péter Petrik doctor of the Hungarian Academy of Sciences, professor *Mechatronics, cyber-physical systems subprogram* Dr Péter Korondi doctor of the Hungarian Academy of Sciences, professor Dr Géza Husi PhD, habil., professor

The doctoral program aims at research areas

The program adopts basic and applied research topics, the results of which can contribute to increasing the quality, reliability, availability and productivity of building services engineering, mechatronics and production systems by adapting and further developing the new results of the relevant research areas and formulating new research directions.

In topics close to classical mechanical engineering, investigations cover all stages of the product lifecycle, from design through production to use and recycling; The aim is to optimize processes in terms of cost, material and energy consumption, environmental protection, protection of human health, and create value for users of products and services.

In the field of analysis and optimization of engineering structures, the aim is to model and investigate engineering structures with material and/or geometric nonlinearity, to examine structural integrity based on special material testing methods, finite element modelling, using intelligent calculation methods, and to support product development by connecting design, finite element and optimization tools and simulation.

In the field of analysis and optimization of production processes, the aim is to design complex shaped surfaces, design custom machining tools, technological modelling using computerized technology design and modelling software and finite element software. Technological examination and optimization of cutting machining, comparative analysis of results obtained by modelling and measurement during production.

In the field of powertrain testing, the aim is dynamic modelling and simulation, determining the optimal technical characteristics for a given driving dynamics objective, development of measurement systems and measurement procedures.

The approach developed in the field of technical diagnostics and condition monitoring (operation and maintenance management based on real, up-to-date data, information sharing, efficient coordination of activities) and the tools and systems created as a result of intensive developments that have been ongoing continuously since the 1970s significantly contribute to the development of the ideas and tools of Industry 4.0, to the digitalization of production systems and other technical systems, which today is technical It is an important area of development. The aim of the development of widespread computer-aided maintenance management systems (CMMS) was to efficiently manage and control maintenance

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and repair work, optimize and document their implementation, thereby significantly increasing maintenance efficiency and system availability, productivity and ultimately production profitability.

Today, there is an increasing level of integration of technical diagnostic tools (measuring systems, analysis methods), and diagnostic data collection is part of data collection and data-based real-time control, which form the basis of integrated, intelligent systems. The accuracy and speed (high sampling rate) of measuring systems, as well as data transfer capacity and computing speed, now make it possible for "diagnostic" data to serve not only classical condition monitoring, but increasingly process monitoring as well. For example, condition monitoring systems based on vibration analysis can be used to detect deviations that do not indicate deterioration of machine elements, but changes in technological parameters (e.g. pressure changes, changes in the quality of process material, problems with component connection). The sampling time can be reduced to milliseconds or even fractions thereof, so process monitoring (in some cases control) based on vibration measurement can be implemented.

The state of development of metrology and related computer infrastructure makes it possible to obtain high-precision measurement results on a massive scale. Thus, the efficiency and effectiveness of condition and process monitoring mostly depends on the method of data processing. This is where new results are most likely to be achieved in the field of technical diagnostics. The general principles and methods of data analysis are clarified, according to the current related literature and publications, a significant part of technical diagnostic tests aim to provide specific answers to specific questions. Some of the typical issues are related to the operation of machines and systems (failure, wear and tear), while others are related to production processes (condition of production machines, quality of workpieces). The aim is to answer the special questions arising in industrial production and the operation of mechanical engineering systems in general by applying new analytical methods, and to open new research directions to solve new kinds of questions arising in the world of Industry 4.0 and 5.0 systems. One of the results of the interaction of the research carried out at the Doctoral School may be that by understanding the problems of processes taking place in modern technical systems (arising at harder and software level), we can ask new research questions.

Machine learning-based data processing is increasingly part of the technical diagnostics toolset. The integration of diagnostic systems into cyber-physical systems creates new challenges and opportunities for analysing and using data collected for diagnostic purposes, including the use of intelligent computing methods. Modern online systems (such as SPM's Intellinova system, available in the Diagnostic Laboratory of the Faculty of Engineering of the University of Debrecen) are "Industry 4.0 compatible". Experience with such systems can be of considerable help in studies related to the integration of diagnostic devices. Condition monitoring of autonomous machines requires a new approach, as high levels of automation and high speed and performance associated with high productivity levels create new risks and challenges. In addition to higher requirements, digitalization in smart factories offers a wide range of opportunities for predictive sustainable maintenance. In modern systems, diagnostics must be compatible with the communication between machines and systems. Creating appropriate interfaces should enable widespread access to data, a task that redefines and emphasizes cooperation between corporate IT and maintenance. In real-time process monitoring based on industrial cyber-physical systems, individual equipment is identified as part of a global production environment. In these systems, several sensor systems are typically used to support optimal parameterization, self-diagnosis and automatic reconfiguration. It is possible to compare multiple pieces of data about a system with data from different parts of the production line, which increases the reliability of decisions. By applying

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modern approaches to process monitoring, significant resource savings are possible, which is one of the most important elements for increasing competitiveness.

Developments aimed at integrating diagnostic systems into cyber-physical systems are related to the sub-program "Mechatronics, cyber-physical systems". The diagnostics and condition monitoring of machines used in technical building systems are related to the research carried out in the "Building Services and Building Energetics" program, which raises questions of cost-effectiveness, energy efficiency, reliability or service life related to operation. Building Information Modelling (BIM) enables more efficient planning, construction, operation and maintenance by digitizing building-related processes throughout the entire life cycle.

Research of a technical diagnostic nature is primarily based on the equipment system of the Diagnostic Laboratory of the Faculty of Engineering of the University of Debrecen, but during certain special examinations it may be necessary to involve the tools of industrial partners or cooperating research institutes.

The existing experience and tools in the field of technical diagnostics primarily provide the basis for the following main research topics regarding the machines, tools and processes examined: detection of bearing defects arising during bearing production; detection of bearing defects arising during the use of bearings, prediction of fault development; tool wear monitoring, residual tool life estimation, machine tool monitoring; condition monitoring of building services engineering, mechanical engineering and mechatronic systems; detection of certain malfunctions of internal combustion engines; motor current analysis. The main test methods are: special purpose test benches and test environment; application and development of data analysis based on machine learning, intelligent computational methods; combined application of transformations and optimization algorithms, development of unique signal processing methods, analysis of error detection efficiency; Development of diagnostic systems based on HFRT (High Frequency Resonance Technique), ANFIS (Adaptive neuro fuzzy inference system); development and integration of intelligent diagnostic systems in Industry 4.0 environment; development of diagnostic systems for remote monitoring; development of diagnostic methods based on thermographic measurements and image processing; particle analysis (olya test), the use of tribological tests for diagnostic purposes. The system of topics of the Doctoral School creates opportunities for researches where these test methods are combined with special material testing tools, such as surface testing tools related to thin-film technology.

Data collection and data processing take place partly in MATLAB and LabVIEW environments, partly in software for special measurement systems. We take advantage of the possibilities of interconnecting systems, for example, the high-precision measurement data provided by the SPM system can be processed in MATLAB using any method.

The fields of application of diagnostic and measurement techniques used in thin-film technology and microelectronics have been expanding rapidly in recent years. They seem to becoming suitable not only for the inspection of coatings or sensor layers, but also increasingly for surfaces applied in mechanical engineering. These methods are able to determine the surface material structure on a nano- and micrometer scale, from bonds through crystal structure to layer thickness or surface roughness. Currently, the methods are suitable for examining homogeneous and extremely low surfaces with roughness well below microns. The expansion of application areas (e.g. lateral resolution) is the subject of further research.

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Under the guidance of Péter Petrik, who has thirty years of international experience in the field of material analysis applications of ellipsometry, new research questions are formulated, this method may be suitable for the process-tracking measurement of changes on surfaces on a nanometer depth scale, while increasing lateral resolution poses significant challenges in the medium and long term.

The specific needs related to the elements of mechanical engineering and mechatronic systems require the use of ellipsometry, X-ray photoelectron spectroscopy, scanning probe methods, mass spectroscopy, Raman spectroscopy, optical spectroscopy, X-ray diffraction studies.

The aim of ethorobotics research is to implement complex behavioural models in service robots, enabling the optimization of their behaviour based on the behaviour of people interacting with them, environmental and internal stimuli, or the robot's relationship with a given human. In the study of human-robot interactions, we use the models and methods developed in the research of human and animal behaviour. We don't expect the robot to behave or look like a human, instead the robot's behaviour should be adapted to the robot's functions. To achieve this, we use behavioural models based on the behaviour of social animals, especially dogs, which acquired social skills through domestication, which facilitated their integration into human society.

We develop and implement an emotional model, which is complemented by the development of the robot's multimodal emotional expression by creating a new, specialized actuator; by recognizing persons; and artificial intelligence methods by recognizing simple human emotions. We will also implement an attachment model, which has been developed in previous researches based on human-dog bonding, and we will adapt it to an autonomous service robot and a robot operating in an iSpace environment, and we will investigate its effect in several experiments. Development activities related to smart spaces will certainly identify research tasks in which each program/sub-program will be involved.

Robots will soon become part of our daily lives in households, offices, hospitals and restaurants, but it is not yet clear how robots should communicate with humans. A lot of research aims to develop human-like robots, but this raises problems. We are developing non-human-like robots that behave and communicate in an easy-to-understand way, and considering robots as a new species, we are adapting their appearance and behaviour to the role of robots. Our goal is to equip service robots with complex social skills that make them easier to understand and like. Our plan is to apply an emotional model with which the robot will be able to recognize human emotions and react to them and the robot's environment with behaviour. Our further goal is to investigate the effect of attachment behaviour, which is based on ethological observation of the behaviour of dogs and their owners. The application of the model will help social robots to show attachment to people, such as their owners or elderly carers, whom they help to care.

The ethorobotics concept, which has Hungarian roots, assumes that the behaviour and capabilities of the robot must fit the specific function of the robot, and during their development it is worth considering robots as a new, separate species. During our long-term research cooperation with the Department of Ethology of ELTE, we had the opportunity to conduct human-robot interaction experiments within the framework of ethorobotics, in increasingly realistic situations. It is important that people who do not have technical background knowledge can easily communicate with the robots helping them. Robots must be able to react appropriately in different social situations in order that humans accept them and interact with them willingly.

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Autonomous service robots are tested both in controlled laboratory environments and 'outdoors', in real restaurants or cafés. The complex behaviours we intend to implement and investigate can be applied into other robots in service as well, not only as waiters but also as assisting robots operating in hospitals, where the demand for social robots has greatly increased. The software and hardware improvements we plan to achieve in the areas of person and emotion recognition and emotion expression can also be used in other artificial agents and communication systems.

Robotics and mechatronics have been playing a decisive role in industrial automation resulting a significant increase in production efficiency. However, more detailed research is required on the human safety implications of robot-human cooperation. Sensor, actuator and motion control technologies can help us a lot, and we are waiting for breakthroughs in these areas that will allow machines to communicate with humans in intelligent, flexible and satisfying ways.

Promising approaches to future development include new transmission mechanisms, actuator flexibility and optimal energy conversion in terms of motion control. In addition, the focus on sensor modules, combined with the development of modern microelectromechanical systems and nanotechnology, quickly allows a high level of integration with readout circuits. This, in turn, leads to improved sensor functionality and reduced dimensions and costs, thereby improving the overall performance and robustness of systems with ever-increasing functionality.

The industrial sector also needs to adapt to the Internet of Things, and the integration of data transmission technology is essential in this area. Network control systems have undergone a major configuration transformation from a decentralized to a distributed framework resulting huge benefits in information sharing, scalability, and flexibility. On the other hand, there was also a need to develop tools to protect systems from cyberattacks. Another important issue related to reliability, security and real-time response is the efficient use of computing and communication resources and the integration of fault diagnosis and fault-tolerant control systems. Despite the increase in design complexity, this ensures an improvement in overall control performance through the introduction of advanced and intelligent subsystems that analyse the effects of possible changes due to component aging, failure, hardware replacement and the like. Accordingly, future trends will move towards distributed plug-and-play process monitoring and the development of control architectures for large-scale industrial processes in order to deal with high uncertainties and disruptions. For this reason, motion controllers also need to be designed in a particularly robust way.

Due to the widespread spread of robots and drone technology military technology knowledge is expected to be applied in the economy. The most important challenge of signal processing is to ensure the signal-noise-disturbance relationship required for decision-making, to detect and route tracked targets, to maintain and identify the route. Describing targets, activities and human-machine-command behaviours and processing collected data based on decision theory are the priority tasks. The efficient use of the definitions, key principles and mathematical descriptions of related signal and data processing models supported by networked cyber-physical cognitive capabilities awaits the development of safe and reliable solutions from a system operation perspective.

Application-oriented engineering solutions would take advantage of the full electromagnetic wave range, but there seems to be a lack of knowledge of the use of certain spectrum ranges. The electromagnetic interference, electrical smog and other natural and artificial interference caused by various devices and equipment can be controlled applying the EMC (electromagnetic compatibility) regulations, standards and related measurement procedures to reduce interference signals arises during the use of the electromagnetic spectrum. The tasks are complemented by life-cycle technical

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support for the relevant devices and equipment, which means maintaining continuous EMC measurement capabilities. In production processes it is generally expected to increase measurement accuracy and dynamics, the degree of measurement freedom and the ‘measurement performance’. In order to fulfil these requirements system approach methods need to be developed that can also be applied to performance tests of mechatronic sensing and actuator equipment in "deaf rooms" and in-situ environments.

The principles and methods of measurement and sensor application, which are widely used today, need to be further developed. Today large data streams can be processed with rational, speed-oriented structuring of available computing capacities and computer human-machine interaction with cognitive capabilities.

We must also pay attention to the rapid spread of interferometric measurement principles and procedures. It occurs as interferometric measurement methods and holography represent cutting-edge technologies in both 3D visualization and metrology.

Applying modern mathematical methods the mechanical, electrical and computer control parts of mechatronic equipment can be modelled uniformly with scientific demand, and then put into practice. The first task is to evaluate the data coming from the sensors according to their distribution in space, time, frequency range and according to signal-specific attributes such as polarization. At the same time, the most common applications already predefine variables filtering and excluding confounding factors from signal and data processing.

The result of sensor output signals and signal processing is a decision relative to a "threshold" which in mathematically simpler cases functions as a "Boolen" status indicator, but nowadays it is calculated on the basis of nonparametric statistical methods. In order to improve the signal-noise-disturbance (e.g. interference) relationship, the incoming data is analysed and summarized. The central boundary distribution theorem, the application of multidimensional covariance and correlation coefficient matrices can be applied with satisfactory accuracy for this task. This can be used to identify the source of failure or to further narrow down possible causes of failure by using another distribution function.

Regarding spatially distributed systems complex event processing (CEP), event sequence processing (ESP) and abnormal event detection (SED) are methods whose application has proven to be a fundamental need in state-of-the-art real-time systems. The optimal amount of data from different sensors should be determined depending on the target task, taking into account, for example, energy requirements and elimination of redundancy / missing data. Control stream processing (IFP) is an inherent task of IoT systems. Event-driven architecture (EDA) is a special variant of service-based architecture (SOA) in which the occurrence of an event can trigger the start of one or more services. From this perspective, the CEP can be seen as a service that receives and identifies low-level events and generates high-level events. CEP includes rules that perform aggregation, filtering, identification of low-level events in order to create new, high-level events.

The efficiency of time-sensitive measurement and control chains based on different communication network technologies continues to be the subject of scientific analysis. In addition to data, audio and video, classic and currently improved transmission solutions must also transmit signals from sensors and actuators with a time guarantee as a fourth component. The transmission of short state data from sensors to the processor and the timely delivery of commands addressed to actuators require further special M2M QoS tuning not only in the wired network, but also in the wireless sensor network. To achieve this, virtualization procedures of sensor network transmission techniques in application or

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under development must be analysed and, if necessary, new methods developed to seamlessly integrate with new networks. The management of quality guarantees that span the communication layers vertically implies the precise definition of the functions of the adaptation layer, which provides flexible connections to applications. Their QoS side based automatic management is current, required and eliminates scientific challenges, which are crucial not only for IT, but also for data-driven and artificial intelligence-based areas.

Table 4: Educational concept of the sub-program Mechanical Process Design, Materials and Machine Diagnostics

Subject	full-time training (hours/week)	correspondence training (hours/semester)	Credit	grading	lecturer	PhD
Compulsory subject						
Mathematics	2	12	2	k	Dr Gát György	Dsc
Optional subjects						
Numerical mechanics	2	12	2	k	Dr Mankovits Tamás	PhD
Structural integrity	2	12	2	k	Dr Mankovits Tamás Dr Árpád István	PhD PhD
Dynamics	2	12	2	k	Dr Hajdu Sándor	PhD
Mechanical systems engineering and modelling	2	12	2	k	Dr Hajdu Sándor	PhD
Optical inspection of metal surfaces and thin films	2	12	2	k	Dr Petrik Péter	DSc
Tracing with radioactive isotopes	2	12	2	k	Dr Ditrói Ferenc	DSc
Non-destructive material testing	2	12	2	k	Dr Cserháti Csaba	DSc
Destructive material testing	2	12	2	k	Dr Szilvia Barkóczy Dr Gyöngyösi	PhD
Composites	2	12	2	k	Dr Budai Istvan	PhD
Modelling of Manufacturing Technologies	2	12	2	k	Dr Bodzás Sándor	PhD
Additive manufacturing	2	12	2	k	Dr Bodzás Sándor	PhD
Applied biomechanics	2	12	2	k	Dr Manó Sándor	PhD
Methodology and tools of machinery diagnostics	2	12	2	k	Dr Kocsis Imre Dr Deák Krisztián	PhD, habil. Phd
Application of fuzzy systems	2	12	2	k	Dr Menyhárt József	PhD
Reliability, safety, risk	2	12	2	k	Dr Árpád István	PhD
Measurement and Signal Processing	2	12	2	k	Dr. Korondi Péter Dr. Kocsis Imre	DSc PhD, habil.
Modern Robotics	2	12	2	k	Dr Husi Géza	PhD, habil.
Data analysis	2	12	2	k	Dr T. Kiss Judit	PhD
Problem solving with intelligent computing	2	12	2	k	Dr Kocsis Imre	PhD, habil.

Students participating in the doctoral program have to complete 6 credits of the listed compulsory elective subjects in addition to the 2-credit compulsory subject. Further study credits can be obtained in the manner

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laid down in the Rules of Operation of the Doctoral School. The applied credit values are in line with the practice developed at the doctoral schools of the University of Debrecen.

Table 5: Educational concept of the Mechatronics, Cyber-Physical Systems sub-program

Subject	full-time training (hours/week)	correspondence training (hours/semester)	Credit	grading	lecturer	PhD
Compulsory subject						
Mathematics	2	12	2	k	Dr Gát György	DSc
Optional subjects						
Mechatronics	2	12	2	k	Dr Husi Géza	PhD, habil.
Modern Robotics	2	12	2	k	Dr Husi Géza	PhD, habil.
The scientific approach to the transition between Industry 4.0 and Industry 5.0	2	12	2	k	Dr Husi Géza	PhD, habil.
Systems and control theory	2	12	2	k	Dr Korondi Péter	DSc
Cognitive Control of Cyber-Physical Systems	2	12	2	k	Dr Korondi Péter	DSc
Electricity	2	12	2	k	Dr Battistig Gábor	DSc
Physics and Technology of MEMS Devices	2	12	2	k	Dr Battistig Gábor	DSc
Measurement and Signal Processing	2	12	2	k	Dr. Korondi Péter Dr. Kocsis Imre	DSc PhD, habil.
Parallel data processing	2	12	2	k	Dr Gál Zoltán	PhD, habil.
Autonomous Driving and Interactive Systems	2	12	2	k	Dr Husam A. Almusawi	PhD
Robotics in Rehabilitation and Assistance	2	12	2	k	Dr Husam A. Almusawi	PhD
Modelling and experimental study of electric drives	2	12	2	k	Dr Gusztáv Áron Sziki	PhD
Thermal Engineering	2	12	2	k	Dr Lakatos Ákos	PhD, habil.
Dynamics	2	12	2	k	Dr Hajdu Sándor	PhD
Numerical mechanics	2	12	2	k	Dr Mankovits Tamás	PhD
Mechanical systems engineering and modelling	2	12	2	k	Dr Hajdu Sándor	PhD
Data analysis	2	12	2	k	Dr T. Kiss Judit	PhD
Problem solving with intelligent computing	2	12	2	k	Dr Kocsis Imre	PhD, habil.

Students participating in the doctoral program have to complete 6 credits of the listed compulsory elective subjects in addition to the 2-credit compulsory subject. Further study credits can be obtained in the manner laid down in the Rules of Operation of the Doctoral School. The applied credit values are in line with the practice developed at the doctoral schools of the University of Debrecen.

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5. Course list

Table 6: Course list

	Subject	full-time training (hours/week)	correspondence training (hours/semester)	Credit	grading	lecturer	PhD
1.	Mathematics	2	12	2	k	Dr Gát György	DSc
2.	Building Energy	2	12	2	k	Dr Kalmár Ferenc	DSc
3.	Thermal Engineering	2	12	2	k	Dr Lakatos Ákos	PhD, habil.
4.	Solar radiation geometry	2	12	2	k	Dr Csáky Imre	PhD
5.	Modelling of energy processes	2	12	2	k	Dr Ferenc Szodrai	PhD
6.	Air distribution systems in buildings	2	12	2	k	Dr Csáky Imre	PhD
7.	Comfort Theory	2	12	2	k	Dr Ferenc Kalmar Dr Kalmár Tünde	DSc PhD
8.	Exergetic-based analysis of building services systems	2	12	2	k	Dr L. Szabó Gábor	PhD
9.	Numerical mechanics	2	12	2	k	Dr Mankovits Tamás	PhD
10.	Structural integrity	2	12	2	k	Dr Mankovits Tamás Dr Árpád István	PhD PhD
11.	Dynamics	2	12	2	k	Dr Hajdu Sándor	PhD
12.	Mechanical systems engineering and modelling	2	12	2	k	Dr Hajdu Sándor	PhD
13.	Optical inspection of metal surfaces and thin films	2	12	2	k	Dr Petrik Péter	DSc
14.	Tracing with radioactive isotopes	2	12	2	k	Dr Ditrói Ferenc	DSc
15.	Non-destructive material testing	2	12	2	k	Dr Cserháti Csaba	DSc
16.	Destructive material testing	2	12	2	k	Dr Szilvia Barkóczy Dr Gyöngyösi	PhD
17.	Composites	2	12	2	k	Dr Budai Istvan	PhD
18.	Modelling of Manufacturing Technologies	2	12	2	k	Dr Bodzás Sándor	PhD
19.	Additive manufacturing	2	12	2	k	Dr Bodzás Sándor	PhD
20.	Applied biomechanics	2	12	2	k	Dr Manó Sándor	PhD
21.	Methodology and tools of machinery diagnostics	2	12	2	k	Dr Kocsis Imre Dr Deák Krisztián	PhD, habil. Phd
22.	Application of fuzzy systems	2	12	2	k	Dr Menyhárt József	PhD
23.	Reliability, safety, risk	2	12	2	k	Dr Árpád István	PhD
24.	Modern Robotics	2	12	2	k	Dr Husi Géza	PhD, habil.
25.	Mechatronics	2	12	2	k	Dr Husi Géza	PhD, habil.
26.	The scientific approach to the transition between Industry 4.0 and Industry 5.0	2	12	2	k	Dr Husi Géza	PhD, habil.
27.	Systems and control theory	2	12	2	k	Dr Korondi Péter	DSc
28.	Cognitive Control of Cyber-Physical Systems	2	12	2	k	Dr Korondi Péter	DSc
29..	Power electronics	2	12	2	k	Dr Korondi Péter	DSc
30.	Electronics and electronic energy converters	2	12	2	k	Dr Szemes Péter	PhD

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31.	Electricity	2	12	2	k	Dr Battistig Gábor	DSc
32.	Physics and Technology of MEMS Devices	2	12	2	k	Dr Battistig Gábor	DSc
33.	Measurement and Signal Processing	2	12	2	k	Dr. Korondi Péter Dr. Kocsis Imre	DSc PhD, habil.
34.	Parallel data processing	2	12	2	k	Dr Gál Zoltán	PhD, habil.
35.	Autonomous Driving and Interactive Systems	2	12	2	k	Dr Husam A. Almusawi	PhD
36.	Robotics in Rehabilitation and Assistance	2	12	2	k	Dr Husam A. Almusawi	PhD
37.	Modelling and experimental study of electric drives	2	12	2	k	Dr Gusztáv Áron Sziki	PhD
38.	Data analysis	2	12	2	k	Dr T. Kiss Judit	PhD
39.	Problem solving with intelligent computing	2	12	2	k	Dr Kocsis Imre	PhD, habil.

k- exam (the Complex Examination and General Research Skills are independent of the Doctoral School, but are compulsory subjects)

During the studies, the subjects **Teaching I - Teaching VIII** and **Semester Research Report I - Semester Research Report VIII** were added for the purpose of administering research and teaching activities, for which credits can be awarded based on the student's semester performance and the rules of operation. In addition, one of **Annual Research Report I - Annual Research Report IV** must be completed each spring.

6. Regulation of the operation of the Doctoral School

The operation of the Pekár Imre Doctoral School of Sciences is based on the Doctoral Regulations of the University of Debrecen (https://doktori.hu/index.php?menuid=190&lang=HU&i_ID=4).

The Doctoral School has its own regulations, and the relevant regulations of the university and the Doctoral Council of the field of science provide guidance on general issues. The operating rules applicable to the Pekár Imre Doctoral School of Mechanical Engineering (PIDSME) are contained in the Rules of Operation.

In matters not regulated therein, decisions are made by the Council of the Doctoral School as well as in case of any other decisions required to its continuous operation and high-quality training.

The members of the Council of the Doctoral School are core members and secretary of the DS and, by election, a PhD student of the DS. The chosen PhD student participates in the work of the Council of the Doctoral School with consultative rights. Occasionally, the school's senior lecturers are also involved in preparing decisions. The head of the school is obliged to convene the Council of the Doctoral School at least once every six months and report on the most important events and decisions that have taken place since the last meeting.

A secretary assists the Council of the Doctoral School in performing administrative tasks, preparing and maintaining records and preparing decisions.

The website of the Doctoral School (www.engphd.unideb.hu) serves the preparation, then operation and administration of the accreditation of the Doctoral School. The Doctoral School provides authentic and public information about the doctoral trainings and events concerning the doctoral school as well as the annual admission requirements on its website updated at least monthly. This latter information is also published in the usual manner of the higher education institution.

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