University Politehnica Timişoara

Mechanical Engineering Faculty

Mechatronics Department

Corina-Mihaela Gruescu

Contributions to development of optical design in mechatronic applications

Habilitation thesis

2019

Abstract

The present habilitation thesis is structured in five sections: (I) Introduction, (II) Scientific achievements, (III) Academic and professional achievements, (IV) Career evolution and development plans and (V) References.

The scientific, academic and professional achievements cover the period 2008 - 2018.

Section (I) provides an overview on the thesis content and highlights the papers published by the author in ISI indexed Journals (3), ISI indexed Conferences (2), and Scopus indexed Conferences (5).

Section (II) describes several scientific achievements within the author´s research directions and is organized in four chapters. Each chapter has a unitary structure including *Statement of the problem*, *Theoretical and/or experimental contributions* to the stated problem and *Conclusions and contributions* of the author.

The first chapter, *Basic optical design. Glass choice*, offers a solution to the problem of choosing the suitable sorts of glass by means of stating mathematical criteria implemented in software application. The practical solutions provided by the application lead to high image quality for apertures twice larger than the traditional ones. Aspheric surfaces can also bring substantial improvement in image quality for systems, which are mainly affected by spherical residual aberration. The proper generating noncircular curve is hard to find without specialized soft and needs appropriate skills of he human operator.

The second chapter refers to *Optical engineering applied in laser machining*. The first paragraph develops *Optics optimization in laser spot radius minimization*. The research starts from the observation that progress in precision and efficiency in laser machining is strongly connected to the quality of the optical system, which ensures the travel of the beam emitted by the source and then the focusing of radiant energy to the machining point. Furthermore, infrared optics needs specific algorithms, which take into account the small number of available materials, the monochromatic radiation and its high power density. The present work provided original solutions for the expander and focusing objective in two variants (spherical and aspheric objective). Both solutions are diffraction limited and may be regarded as very good from optical

point of view. In addition, they take minimal costs of manufacturing as only singlet lenses are used.

The second paragraph is dedicated to *Experimental optimization of process parameters in laser cutting of polycarbonate gears*. Fractional factorial experiments plans stated by Taguchi method and a specialized software – Qualitek – proved to be quick, economic (only 40 samples needed effective machining for optimizing six parameters in two levels and one interaction organized in 8 combinations) and very efficient. For the pieces machined in optimal conditions S/N ratio is better than the predicted one and the mean value is very close to the nominal target, which significantly improves the quality of the lot of pieces. The machining became very precise, considering the optimization criterion (nominal value). As well, the process itself became desirable instead of traditional technology. Auxiliary devices such as molds were totally eliminated and the machining duration decreased considerably (3…4 minutes/piece in function of number of teeth).

The third chapter develops some aspects regarding the *Document digitization*. Two paragraphs are dedicated to *Digitization Equipment and Techniques in Retrieval of Mechanism and Machine Science Resources* and *Interactive animation production by means of advanced image processing*.

Digitization techniques are used on the purpose of retrieving the history of mechanism science and of creating a coherent description of its development since early ages until present days. Digitization of analogue documents requires special resources regarding equipment and software. The team from the University Politehnica Timisoara, as partner in the thinkMOTION project, developed a workstation specialized in digitization of all-type documents. Design and assembling of the scanning equipment as well as the capturing, stocking and managing raw image files software were developed as original contributions of the team. The scanning equipment is a complex mechatronic system, involving optoelectronics, mechanics and software integration. The resulting working station is different from the all-purpose products on the market and gathers selected characteristics, imposed by the specific application. Thousands of high quality pages are now available online for a large range of users (academic staff, students, Ph.D. students, engineers, historians etc.) at www.dmg-lib.org. Beside documents, the library also displays physical demonstration models and mechanism descriptions.

The physical working models of the mechanisms are digitally recorded as a sequence of images, usually covering a full rotation of the input (driving) element. With further handling steps, these image sequences are composed to interactive animations, which can be started

inside the DMG-Lib internet portal with a special player or can be downloaded as video files for local use.

The fourth chapter develops several applications, which implement *Optical engineering in medical investigation*. The first paragraph describes the *Modeling of human spinal column and evaluation of spinal deformities.* A large number of numerical parameters were suggested for the description of the column's shape. A special software – INBIRE – was developed to work with the all purpose imaging system InSpeck. The program provides an interactive database and the facility to export data to the modeling program 3Dmax. Using anthropometrical data, the individual vertebrae and finally the entire column was modeled as a standard. The coordinates provided by INBIRE allow modeling of personalized spinal columns, which can be stored and used by physicians to monitor the evolution of the deformities.

The achievements of the research project contribute to development of local or national healthcare programs, bringing in numerical precision and efficiency in screening and monitoring spinal deformities, which are wide-spread, hard and costly to treat in advanced stages.

The second paragraph covers the subject *Experimental method for evaluation of spinal column deformation*, based on data acquired with a system of accelerometers and advanced image processing. The paper proposes a new investigation method, based on data provided by a set of eight accelerometers, which are stuck on the body of the vertebrae during the whole therapy exercises. The goal of the study is to develop a method to record the Cobb angles variation, which should provide in the future an evaluation of the therapy exercises. The acquired angular data is used to compute an eighth degree polynomial as a model of the spine. Appropriate mathematical algorithm is developed in order to compute the co-ordinates, the coefficients of the polynomial and the Cobb angles. The polynomial approximation was validated by comparing its results with reference data provided by a sure method. The reference is considered the image taken during acquiring data with the accelerometers.

Section III of the habilitation thesis presents the main achievements of the candidate within the past 20 years, since defending the PhD thesis, on May 15th 1998, at the University Politehnica Timişoara.

The teaching activities at University Politehnica Timişoara comprised courses, seminars, laboratory activities or project activities on *Descriptive geometry and engineering design, Technical optics, Optical apparatuses, Photometers and spectrophotometers, Medical optics,*

Reliability in mechatronics, Optical sensors and *Illumination ergonomics*. A number of 12 books were published in printed or electronic format to support these topics.

The research activities were developed in areas similar to the teaching activities, within 8 projects funded at national and European level.

The results of the research work were published in 7 papers indexed in ISI Journals, 12 papers indexed in ISI Proceedings, 19 papers indexed in SCOPUS and over 100 papers indexed in other databases.

The publishing activities were completed with reviewing activities on main Journals and Conferences (ASME - Measurement Journal, Optical Engineering, ASME - Journal of Mechanisms and Robotics, 14th IFToMM World Congress - Taipei 2015, MTM&Robotics 2016 - Aachen, Germany, Scientific Bulletin of the Politehnica University of Timisoara, SYROM 2017 - Brasov, RO, MESROB 2018 – Cassino, It, MEDER 2018 – Udine, It and others).

The candidate is member of an international professional association, IFToMM (International Federation of Mechanism and Machine Science) since 2014 as observer member of the Technical Committee Linkages and Mechanical Controls. The candidate contributed as member of the organizing committee to preparing and developing of 2 international conferences and one summer school supported by IFToMM and was co-editor to one volume of proceedings published by Springer.

Section V renders the references used in the previous sections.