**Universitatea Naţională de Ştiinţă şi Tehnologie Politehnica Bucureşti**
**Facultatea de Electronică, Telecomunicaţii şi**
**Tehnologia Informaţiei**

# COURSE DESCRIPTION

## 1. Program identification information

| | |
|---|---|
| 1.1 Higher education institution | **National University of Science and Technology Politehnica Bucharest** |
| 1.2 Faculty | **Electronics, Telecommunications and Information Technology** |
| 1.3 Department | **Telecommunications** |
| 1.4 Domain of studies | Electronic Engineering, Telecommunications and Information Technology |
| 1.5 Cycle of studies | Bachelor/Undergraduate |
| 1.6 Programme of studies | Technologies and Telecommunications Systems |

## 2. Date despre disciplină

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 2.1 Course name (ro)<br>(en) | | | | Introducere în prelucrarea imaginilor şi vedere artificială<br>Fundamentals of Image Processing and Computer Vision | | | |
| 2.2 Course Lecturer | | | | Conf. Dr. Radu-Ovidiu Preda | | | |
| 2.3 Instructor for practical activities | | | | Conf. Dr. Radu-Ovidiu Preda | | | |
| 2.4 Year of studies | 4 | 2.5 Semester | I | 2.6. Evaluation type | V | 2.7 Course regime | Op |
| 2.8 Course type | | S | 2.9 Course code | 04.S.07.A.612 | | 2.10 Tipul de notare | Nota |

## 3. Total estimated time (hours per semester for academic activities)

| | | | | | |
|---|---|---|---|---|---|
| 3.1 Number of hours per week | 3.5 | Out of which: 3.2 course | 2.00 | 3.3 seminary/laboratory | 1.5 |
| 3.4 Total hours in the curricula | 49.00 | Out of which: 3.5 course | 28 | 3.6 seminary/laboratory | 21 |
| Distribution of time: | | | | | hours |
| Study according to the manual, course support, bibliography and hand notes<br>Supplemental documentation (library, electronic access resources, in the field, etc)<br>Preparation for practical activities, homework, essays, portfolios, etc. | | | | | 48 |
| Tutoring | | | | | 0 |
| Examinations | | | | | 3 |
| Other activities (if any): | | | | | 0 |

| | |
|---|---|
| 3.7 Total hours of individual study | 51.00 |
| 3.8 Total hours per semester | 100 |
| 3.9 Number of ECTS credit points | 4 |

## 4. Prerequisites (if applicable) (where applicable)

| | |
|---|---|
| 4.1 Curriculum | - Object Oriented Programming,<br>- Digital Signal Processing,<br>- Data structures and algorithms. |
| 4.2 Results of learning | General knowledge regarding one-dimensional and two-dimensional signals, object-oriented programming and working with dedicated libraries |

**5. Necessary conditions for the optimal development of teaching activities** (where applicable)

| | |
|---|---|
| 5.1 Course | The course takes place in a hall owning a videoprojector and a computer. |
| 5.2 Seminary/ Laboratory/Project | The laboratory activities are held in an suitable space having computers, videoprojector and adequate furniture. |

**6. General objective** *(Reffering to the teachers' intentions for students and to what the students will be thought during the course. It offers an idea on the position of course in the scientific domain, as well as the role it has for the study programme. The course topics, the justification of including the course in the currcula of the study programme, etc. will be described in a general manner)*

The current discipline is studied in the domain of „Electronic and telecommunications engineering", speciality „Technologies and telecommunications systems (english)" (TSTen). The aim of it is to familiarize students with the main approches, techniques and theories applied in the field of digital image processing and Computer Vision, methods used to solve practical applications, relevant for the learning process in students.
This discipline advances as specific educational program the basic notions, concepts and principles: introductive notions in image processing and computer vision, basic linear algebra, specific methods for frequency and spatial image analysis, feature detection and content descriptors, feature matching and image registration, basic shape recognition. The students are presented with typical image analysis and enhancement applications, semantic content extraction and spatial segmentation applications. The active learning process passes through simulations and algorithms analysis for arbitrary shapes and face detection.

**7. Competences** *(Proven capacity to use knowledge, aptitudes and personal, social and/or methodological abilities in work or study situations and for personal and proffesional growth. They refflect the empolyers requirements.)*

| | |
|---|---|
| **Specific Competences** | Application, in typical situations, of basic methods of signal acquisition and processing.<br>Signals characterization in time and frequency domains; The usage of simulation environments to analyse and process digital signals; Using specific methods and tools for signals analysis;<br>Application of standard and domain specific methods and tools to assess and evaluate a situation, considering the confirmed issues, and identify solutions.<br>Explanation and interpretation of the main requirements and techniques used typically in the field, using key concepts of the discipline and specific methods.<br>Building scripts in an object-oriented language, starting from specifying the requirements and up to execution, debugging and results interpretation;<br>Oral and written communication in a foreign language (english) – prove the mastery of the vocabulary in that field. |

| | |
|---|---|
| **Transversal (General) Competences** | Team work and efficient communication skills, to coordinate efforts with others to solve typical problems of medium complexity.<br>Autonomy and critical thinking – the ability to think in scientific terms, to search and analyse data independently, confirm and present solutions and conclusions.<br>Analysis and synthesis skills – can present in a concise manner the acquired knowledge.<br>Respect the academic ethic principles – cite and copyright rules.<br>Practice of emotional intelligence to solve various situations of academic / professional nature, proving selfcontained and taking objective decisions in stressful situations.<br>Adaptation to new technologies, professional and personal development, by continuous formation by using books, articles, specialized software and electronic resources in English. |

**8. Learning outcomes** *(Synthetic descriptions for what a student will be capable of doing or showing at the completion of a course. The learning outcomes reflect the student's acomplishments and to a lesser extent the teachers' intentions. The learning outcomes inform the students of what is expected from them with respect to performance and to obtain the desired grades and ECTS points. They are defined in concise terms, using verbs similar to the examples below and indicate what will be required for evaluation. The learning outcomes will be formulated so that the correlation with the competences defined in section 7 is highlighted.)*

| | |
|---|---|
| **Knowledge** | *The result of knowledge aquisition through learning. The knowledge represents the totality of facts, priciples, theories and practices for a given work or study field. They can be theoretical and/or factual.*<br>Enumerate main methods in digital image processing and computer vision.<br>Define basic notions in the field of analysis.<br>Present main modern techniques used in image analysis and enhancement.<br>Developp the ability to extend the knowledge acquired in course for applications of image content extraction and processing.<br>Identify main issues related to digital image processing and semantic content extraction.<br>Acquire basic technical skills to determine the best solutions in practical Computer Vision situations. |
| **Skills** | *The capacity to apply the knowledge and use the know-how for completing tasks and solving problems. The skills are described as being cognitive (requiring the use of logical, intuitive and creative thinking) or practical (implying manual dexterity and the use of methods, materials, tools and intrumentation).*<br>Select and group relevant data in a certain context.<br>Usage based on arguments of specific principles.<br>Able of productive team work.<br>Write a scientific text.<br>Verify in practice the identified solutions.<br>Solve practical applications.<br>Find suitable interpretations for causality relations.<br>Analyze and compare methods to be used in solving a specific problem.<br>Identify solutions and establish solving plans.<br>Designate conclusions for the experiments realized.<br>Scientifically argue the identified solutions |

| | |
|---|---|
| **Responsability and autonomy** | *The student's capacity to autonomously and responsably apply their knowledge and skills.*<br>Select and analyze suitable references<br>Respect principles of ethic in academia by citing the sources used.<br>Prove beeing receptive to new learning contexts.<br>Colaborate with coleagues in teaching activities.<br>Selfcontained and autonomous in organizing the learning process<br>Social responsible and actively involved in student activities<br>Understand the value of its own work in identifying solutions. |

**9. Teaching techniques** *(Student centric techniques will be considered. The means for students to participate in defining their own study path, the identification of eventual fallbacks and the remedial measures that will be adopted in those cases will be described.)*

The teaching process relies on displaying the information using a video projector (covering the communication and argumentation functions); the oral communication methods are the enunciation and the interpretation methods. Course materials include lecture notes and course presentations. Students use the OpenCV library and a Python 3 programming environment to simulate, test and assess independently the image processing methods and the algorithms for semantic content detection / extraction. The teaching materials in laboratory are the laboratory platforms.

**10. Contents**

| **COURSE** | | |
|---|---|---|
| **Chapter** | **Content** | **No. hours** |
| 1 | 1. Basic concepts in image processing and computer vision.<br>1.1. Image acquisition and formation, the digital camera.<br>1.2. Image representation, standard formats, color spaces and color transforms.<br>1.2.1 Threshold and quantization segmentations. Color based segmentation.<br>1.2.2 Image histogram. Histogram equalization for contrast enhancement.<br>1.3. Human visual perception of luminance and color.<br>1.4. Image and video quality. | 3 |
| 2 | 2. Basic linear algebra.<br>2.1 Vectors and arrays: definitions, operators and special matrices.<br>2.2 Matrix inverse, matrix rank.<br>2.3 Eigenvalues and eigenvectors.<br>2.4 Singular value decomposition (SVD). | 2 |
| 3 | 3. Image processing in the spatial domain. Image processing in the frequency domain.<br>3.1 2D convolution<br>3.2 Linear image filtering. Mean filters, edge detection filters, sharpening filters.<br>3.3 Non-linear spatial filtering.<br>3.4 Image enhancement through filtering.<br>3.5 Introduction to 2D transforms. | 5 |

| | | |
|---|---|---|
| 4 | 4. Feature detection and content descriptors.<br>4.1 Contour detection. Image gradient. Canny edge detector.<br>4.1.1 Segmentation based on edge detection. Region extraction methods.<br>4.1.2 Morphological operations.<br>4.2 Local invariant features.<br>4.3 Corner detection. Harris, Shi-Tomasi detectors.<br>4.4 Transform-invariant feature extraxtion. Basic description of Laplacian of Gaussian (LoG), Difference of Gaussians (DoG), Harris-Laplacian. General presentation of MOPS and SIFT descriptors.<br>4.5 The Hough transform in arbitrary shape detection. Line detection.<br>4.6 Sliding windows detection. Histogram of oriented gradients (HOG).<br>4.7 Dictionary based global content descriptors. General presentation of Bag of words (BOW), Vector of Locally Aggregated Descriptors (VLAD), Fisher vectors. | 10 |
| 5 | 5. Feature matching and image alignment.<br>5.1 Feature matching using content descriptors.<br>5.2 Image transforms. Transform matrices. Scaling, rotation, translation. Homogeneous systems.<br>5.3 Affine transforms. Homographic transforms.<br>5.4 RANSAC. Image alignment. | 6 |
| 6 | 6. Fundamentals of shape recognition:<br>6.1 Introduction to object recognition.<br>6.2 Difficulties and challenges in shape recognition.<br>6.3 Example of a simple binary classifier. | 2 |
| | **Total:** | 28 |

**Bibliography:**

Preda R.O., Oprea C.C., ”Introducere în prelucrarea imaginilor şi vedere artificială”, suport de curselectronic, https://curs.upb.ro/2021/course/view.php?id=9724
C. C. Oprea, R. O. Preda, Fundamentals of Image Processing and Computer Vision – Theory andApplications, Politehnica Press, ISBN 978-606-9608-03-6, Bucharest, 2022.
R. Szeliski, Computer Vision: Algorithms and Applications. 2nd Edition, ISBN 978-3030343712,Springer, 2022.
R. Knette, Concise Computer Vision: An Introduction into Theory and Algorithms, ISBN 978-1-4471-6320-6, Springer, 2014.
S. J.D. Prince, Computer Vision: Models, Learning, and Inference, Cambridge University Press, ISBN-13:978-1107011793, 2012
R. O. Preda, N. Vizireanu, Securitatea conţinutului multimedia, Politehnica Press, ISBN 978-606-515-465-0, Bucureşti, 2013

**LABORATORY**

| Crt. no. | Content | No. hours |
|---|---|---|
| 1 | Introduction to image processing using Python 3 and OpenCV. Color spaces and image resolution. Image histograms2 | 3 |
| 2 | Morphological operations in image processing and threshold comparison. Connected components analysis. | 3 |
| 3 | Image filtering and enhancement. Contour detection. Concepts related to spatial frequency and 2D transforms. | 3 |

| | | |
|---|---|---|
| 4 | Local feature / descriptor extraction. SIFT. | 3 |
| 5 | Feature matching and descriptors used to build panoramic images. RANSAC. | 3 |
| 6 | Shape detection using sliding windows. Pedestrian detection using histograms of oriented gradients (HOG). | 3 |
| 7 | Laboratory colloquium | 3 |
| | **Total:** | 21 |

**Bibliography:**

Preda R.O., Oprea C.C., ”Introducere în prelucrarea imaginilor şi vedere artificială”, suport de curselectronic, https://curs.upb.ro/2021/course/view.php?id=9724
C. C. Oprea, R. O. Preda, Fundamentals of Image Processing and Computer Vision – Theory andApplications, Politehnica Press, ISBN 978-606-9608-03-6, Bucharest, 2022.
R. Szeliski, Computer Vision: Algorithms and Applications. 2nd Edition, ISBN 978-3030343712,Springer, 2022.
R. Knette, Concise Computer Vision: An Introduction into Theory and Algorithms, ISBN 978-1-4471-6320-6, Springer, 2014.
S. J.D. Prince, Computer Vision: Models, Learning, and Inference, Cambridge University Press, ISBN-13:978-1107011793, 2012
R. O. Preda, N. Vizireanu, Securitatea conţinutului multimedia, Politehnica Press, ISBN 978-606-515-465-0, Bucureşti, 2013

**11. Evaluation**

| Activity type | 11.1 Evaluation criteria | 11.2 Evaluation methods | 11.3 Percentage of final grade |
|---|---|---|---|
| 11.4 Course | - knowledge of basic theoretical notions.<br>- the ability to apply theoretical concepts into real specific situations;<br>- comparative analysis of theoretical techniques and methods. | Written exam in the regular session at the end of the semester; the subjects cover the entire curricula through a synthesis between multiple theoretical issues and applications. | 30% |

| | | | |
|---|---|---|---|
| 11.5<br>Seminary/laboratory/project | - knowledge of Python programming and main OpenCV library functionalities;<br>- basic insight into usual image processing methods;<br>- ability to extract local features and descriptors;<br>- expertise in realization of shape detection systems. | Laboratory assignments given as individual projects allow the assessment of the theoretical knowledge and the ability to implement and test a practical problem. Theoretical and practical knowledge are also evaluated at the end of the semester through a final laboratory test / colloquium | 70% |
| 11.6 Passing conditions | | | |
| Achieve 50% from the total number of points.<br>Achieve 50% from the number of points designated for activities during the semester. | | | |

**12. Corroborate the content of the course with the expectations of representatives of employers and representative professional associations in the field of the program, as well as with the current state of knowledge in the scientific field approached and practices in higher education institutions in the European Higher Education Area (EHEA)**

This subject is presenting the students with deep theoretical knowledge and a significant collection of algorithms and image processing techniques (filtering, enhancement, feature and descriptor extraction, shape recognition, segmentation, classifiers, etc.), and also with practical implementations needed in experimentation.
*The graduates are provided with solid skills for the current-market necessary competences and with a scientific and technical training reaching modern quality standards, allowing them to rapidly find an employment after graduation. The subject is well fitted in the general politics of the Politehnica University of Bucharest, considering the course content and structure, and also considering the wide international outset offered to the students. The potential employers stretch from the academic environment up to industrial research and design departments. This subject is engaging the future graduates in the* Reseach & Development territory by triggering the fundamental research skills and also through a product functional development orientation.

| Date | Course lecturer | Instructor(s) for practical activities |
|---|---|---|
| 21.09.2025 | Conf. Dr. Radu-Ovidiu Preda | Conf. Dr. Radu-Ovidiu Preda |

Conf. Dr. Claudia-Cristina Oprea

**Universitatea Naţională de Ştiinţă şi Tehnologie Politehnica Bucureşti**
**Facultatea de Electronică, Telecomunicaţii şi**
**Tehnologia Informaţiei**

Date of department approval Head of department

Date of approval in the Faculty Council Dean