Національний технічний університет України
«КИЇВСЬКИЙ ПОЛІТЕХНІЧНИЙ ІНСТИТУТ
імені ІГОРЯ СІКОРСЬКОГО»

Department of Computer Engineering

Computer Vision Technologies

The work program of the discipline (Syllabus)

Requisites of the Cours

Cycle of Higher Education	***First cycle of higher education (Bachelor's degree)***
Field of Study	*12 Information Technologies*
Speciality	*121 Software engineering*
Education Program	*Computer Systems Software Engineering*
Стату Type of Course с дисципліни	*Optional component of OP, of the professional education cycle*
Mode of Studies	*full-time / part-time*
Year of studies, semester	*1,2 year (2 semester)*
ECTS workload	*4 credits / 120 hours*
Testing and assessment	*Exam / modular control work*
Course Schedule	*http://rozklad.kpi.ua/*
Language of Instruction	*Ukrainian*
Course Instructors	Lecturer: *D.Sc., Seniour Scientist Pysarchuk Oleksii Oleksandrovych, kga46826@gmail.com.* Teacher of practical work: *D.Sc., Seniour Scientist Pysarchuk Oleksii Oleksandrovych, kga46826@gmail.com.*
Access to the course	*https://drive.google.com/drive/folders/ 1qXc3Ami_HNiVaTPlY7jLom0YRwtiGTQr?usp=sharing* *https://classroom.google.com/c/NDIxODIzNTEyNDc2?cjc=mgwrbui*

The program of discipline

1. Description of the discipline, its purpose, subject of study and learning outcomes

The discipline "Computer Vision Technologies" is designed *to provide students with the ability to synthesize, verify mathematical models and algorithms, develop specialized software with the implementation of Computer Vision technologies. This is achieved by studying the theoretical bases of mathematical model synthesis, methodology for choosing methods and algorithms for digital image processing, verification of the results obtained by simulation modeling, as well as the practical implementation of the selected approaches to develop specialized applications using Computer Vision technologies.*

The aim of the course "Computer Vision Technologies" is *to provide students with the ability to synthesize, verify mathematical models and algorithms, develop specialized software with the implementation of Computer Vision technologies.*

The purpose *of the discipline is to provide a thorough theoretical basis and powerful practical skills in the programmatic implementation of methods, mathematical models and algorithms of Computer Vision technologies.*

The course is based on the knowledge gained in the following disciplines: Higher Mathematics; Theory of Probability and Mathematical Statistics; Discrete Mathematics; Programming; Data Structures and Algorithms; Database Organization; Organization of Computing Processes.

The theoretical foundations of Computer Vision are presented through lectures with a mandatory demonstration of the practical implementation of the algorithms as examples of program code.

Practical skills of Computer Vision technologies are developed in laboratory classes, which are based on the system of increasing the complexity of the developed scripts. At the same time, we pay special *attention to software engineering processes.* ***The practical part of the discipline is focused on using Python*** *(high-level programming language) with the study of the features of Graphics, Tkinter, Matplotlib, NumPy (for the "raw" implementation of Computer Vision algorithms) and specialized packages such as PIL/Pillow, OpenGL, OpenCV to create complete practical software modules.*

The discipline explains the stages of processing digital graphic images: image synthesis (spatial transformation) - rasterization (realistic image, digital processing) - vectorization (object identification and targeted image processing).

The acquired skills of Computer Vision can be applied in the implementation of projects related to the following applied fields and technologies:

1. Reconstructing and navigating a 3D scene (Structure-from-Motion, Road Scene Understanding and Autonomous Driving);

2. Segmentation of the scene and plot understanding (Significance maps, video and 3D segmentation, 3D stream, multiple tracking, object detection, activity detection and prediction, group analysis, object detection and recognition);

3. Image recognition, object identification (Convolution networks, Deep learning, Image Retrieval, Object Detection).

As a result of studying the discipline, the student should know:

digital image synthesis methods and algorithms (2D, 3D objects, graphical method, analytical and non-analytical methods);

basic geometric transformations of 2D, 3D objects (scaling, moving, rotation, projection);

methods and algorithms for rasterization and processing of digital raster images: principles of creation, characteristics and processing algorithms for brightness change, filtering, etc;

methods, algorithms and technologies of digital image vectorization, mathematical models, approximation, interpolation and smoothing (MNK, Splines, Bézier curves, etc.);

fractal models of digital images (synergetics, fractals, fractal algorithms, fractal generators);

methods, models, algorithms and technologies for generating realistic images: augmented reality, light and shadow models: 3D pipeline, rendering;

methods, models, algorithms and technologies of digital image processing and applied aspects of Computer Vision: filtering; colour correction; segmentation; vectorization; morphological processing; recognition, artificial neural networks.

As a result of studying the discipline, the student should be able to:

apply methods and algorithms for digital image synthesis (2D, 3D objects, graphic method, analytical and non-analytical methods);

apply basic geometric transformations of 2D and 3D objects (scaling, moving, rotating, projecting);

apply methods and algorithms for rasterization and processing of raster digital images: principles of creation, characteristics and processing algorithms for brightness change, filtering, etc;

apply methods, algorithms and technologies of digital image vectorization, mathematical models, approximation, interpolation and smoothing algorithms (MNC, Splines, Bézier curves, etc.);

apply fractal models of digital images (synergetics, fractals, fractal algorithms, fractal generators);

apply methods, models, algorithms and technologies for creating realistic images: augmented reality, light and shadow models: 3D pipeline, rendering;

apply methods, models, algorithms and technologies of digital image processing and applied aspects of Computer Vision: filtering; colour correction; segmentation; vectorization; morphological processing; recognition, artificial neural networks.

Mastered knowledge, skills and abilities acquired in the discipline "Computer Vision Technologies" required for the position of: *Software Developer with Computer Vision; Embedded developer for Computer Vision systems; Computer Vision Research Engineer мощо.*

The course includes *4 credits (120 hours), 54 hours of classroom learning and 66 hours of individual work.*

2. **Prerequisites and post-requisites of the course (the place of the course in the scheme of studies by curriculum)**

Prerequisites:

Basic knowledge of programming, architecture of computer systems and networks, discrete mathematics, computer logic, software engineering processes.

Post-requisites:

Computer systems, Computer networks

121:

ЗК01 Ability to think abstractly, analyze and synthesize;

ФК07 Knowledge of data information models, ability to create software for data storage, extraction and processing;

ФК14 Ability to think algorithmically and logically;

ПРН05 Know and apply relevant mathematical concepts, methods of domain, system and object-oriented analysis and mathematical modeling for software development.

123:

ЗК 1 Ability to think abstractly, analyze and synthesize.

ФК2 Ability to use modern programming methods and languages for developing algorithmic and program software.

ФК18 Ability to develop, adapt and use software to improve the efficiency of high-performance computer systems

The role of the discipline in the structural and logical scheme of education:

The discipline belongs to the optional component of the OP, the cycle of professional education. The course focuses on applied aspects of design, synthesis and development of mathematical models, algorithms and software of complex distributed information systems with intelligence properties, which is a connection between different disciplines of the educational program.

3. **Content of the course**

MODULE 1. METHODOLOGICAL FOUNDATIONS OF COMPUTER VISION
THEME 1. Create and present digital 2D images.
THEME 2. Coordinates and transformations in 2D and 3D spaces.
THEME 3. Digital raster images.
THEME 4. Digital vector images.
THEME 5. Digital fractal images.
MODULE 2. TECHNOLOGICAL ASPECTS OF COMPUTER VISION.
THEME 6. Realistic representation of digital graphic objects and scenes.
THEME 7. Digital processing of images for Computer Vision tasks.

4. **Coursebooks and teaching resources**

Basic literature:

1. *Educational and methodical package for the discipline “ Computer Vision technologies” [https://drive.google.com/drive/folders/1qXc3Ami_HNiVaTPlY7jLom0YRwtiGTQr?usp=sharing].*
2. *E-course on the educational platform Sikorsky «Computer Vision technologies», 2022: https://classroom.google.com/c/NDIxODIzNTEyNDc2?cjc=mgwrbui*
3. *«Komp’iuterna hrafika : navchalnyi posibnyk : v 2-kh kn.» [Computer graphics: a textbook: in 2 books.] / Compilers : Totosko O.V., Mykytyshyn A.H., Stukhliak P.D. – Ternopil : Ternopilskyi natsionalnyi tekhnichnyi universytet imeni Ivana Puliuia, 2017 – 304 p.*
4. *Matsenko V.H. «Komp’iuterna hrafika: Navchalnyi posibnyk» [Computer graphics: A manual].– Chernivtsi: Ruta, 2009 – 343 p.*
5. *«Komp’iuterna hrafika: konspekt lektsii» [Computer graphics: lecture notes] / Compiler:*

Skyba O.P. – Ternopil: Ternopilskyi natsionalnyi tekhnichnyi universytet imeni Ivana Puliuia, 2019. – 88p.

Additional literature:

6 Lavrishcheva K.M. «Prohramna inzheneriia» [Software engineering]. – K.: 2018. – 319 p.

7 Hlibko O. A., Maksymova M. O., Hrechka I. P. «Komp'iuterna hrafika. Stvorennia modelei ta stsen u tryvymirnomu seredovyshchi: Navchalnyi posibnyk» [Computer graphics. Creation of models and scenes in a three-dimensional environment. A tutorial]. – Kharkiv.: NTU «KhPI», 2018. – 132p.

8 Peter Comninos.Mathematical and Computer Programming Techniques for Computer Graphics. Springer-Verlag London Limited, 2016. – 556c.

9 Eric LengyelMathematics for 3D Game Programming and Computer Graphics. Course Technology, a part of Cengage Learning, 2017. – 566c.

Educational content

5. Methodology

MODULE 1. METHODOLOGICAL FOUNDATIONS OF COMPUTER VISION.

Theme 1. Create and present digital 2D images.

Lecture 1. Introduction to Computer Vision technologies.

1. Structure and objectives of the discipline.

2. General information about Computer Vision technologies.

3. Computer Vision technologies and Python.

Lecture 2. Modern technologies for applying and implementing Computer Vision methods and algorithms.

1. Programming systems.

2. Basic graphics packages and modules of the Python programming language.

Laboratory work 1. Exploring the basic graphical features of the Python programing language.

Creating graphical primitives using basic Python graphics packages.

Theme 2. Coordinates and transformations in 2D and 3D spaces.

Lecture 3. Coordinates and transformations. Planar (2D) transformations.

1. Basic geometric transformations of graphic objects.

2. Simple and composite two-dimensional (2-D) transformations.

Laboratory work 2. Research of technologies for constructing and transforming coordinates of planar (2D) objects

Generating 2D graphic object and its coordinate transformations.

Lecture 4. Coordinates and transformations. Spatial (3D) transformations.

1. Basic 3-D transformations of graphic objects.

2. High-order 3-D spatial transformations.

3. Technological features of geometric transformations of graphic objects.

Lecture 5. Mathematical models of geometric objects.

1. Mathematical models of geometric objects.

2. Technological features of constructing and converting 3-D graphic objects.

Laboratory work 3. Research of technologies for constructing and transforming coordinates of spatial (3D) objects.

Generating 3-D graphic objects and their coordinate transformations.

Theme 3. Digital raster images.

Lecture 6. Digital raster images. Algorithms for raster images.

1. Concepts of creating raster digital images.

2. Algorithms for generating, processing, and converting raster graphics.

Lecture 7. Basic algorithms for generating and processing raster images.

1. Basic algorithms for generating and processing raster images.

2. Technologies for creating and processing raster images.

Generating a 3D digital image and its coordinate transformations.

Laboratory work 4. Research of algorithms for the generating and processing of digital raster images.

Generating digital raster images from vector forms, working with ccolourmodels of raster images.

Theme 4. Digital vector images.

Lecture 8. Basic information about digital vector images.

1. General characteristics of digital vector images.

2. Mathematical bases of formation and processing of digital vector images.

Lecture 9. Algorithms for generating digital vector images. Removing invisible lines and surfaces.

1. Algorithms for removing invisible lines and surfaces.

2. Technologies for removing invisible lines and surfaces.

Lecture 10. Algorithms for generating digital vector images. Algorithms for constructing interpolation and smoothing curves.

1. Algorithms for generating interpolation and smoothing curves.

2. Technologies for generating interpolation and smoothing curves.

Laboratory work 5. Research of algorithms for the formation and processing of digital vector images.

Creation of vector images from raster shapes, removal of invisible lines and surfaces, conversion and animation of 3D vector graphic objects.

Theme 5. Digital fractal images.

Lecture 11. Digital fractal images. Basic algorithms for generating and processing fractal images.

1. Algorithms for generating and processing fractal images.

2. Technologies for forming and processing fractal images.

Laboratory work 6. Study of algorithms for the formation and processing of fractal images.

Formation of digital fractal images and their processing.

МОДУЛЬ 2. TECHNOLOGICAL ASPECTS OF COMPUTER VISION.

Theme 6. Realistic representation of digital graphic objects and scenes.

Lecture 12. Colour models of digital realistic images.

1. Digital realistic image models, light and shadow models.

Lecture 13. Technologies for a realistic representation of digital graphic objects and scenes.

1. Technologies for a realistic representation of digital graphic objects and scenes, 3D pipeline, rendering.

Laboratory work 7. Research of technologies for creating realistic digital images.

Digital realistic image models, light and shadow models, 3D pipeline, rendering.

Theme 7. Digital processing of images for Computer Vision tasks.

Lecture 14. Digital image processing for Computer Vision tasks. Theoretical and technological foundations.

1. Theoretical foundations of digital image processing.

2. Digital image processing technologies.

Lecture 15. Digital image processing for Computer Vision applications. Quality improvement of images (colour correction and filtering).

1. Brightness and contrast conversion.

2. Image filtering.

3. Digital image processing technologies.

Lecture 16. Digital image processing for Computer Vision tasks. Image segmentation and object recognition.

1. Theoretical foundations of digital image segmentation.

2. Image recognition.

3. Technologies for image segmentation and recognition.

Laboratory work 8. Research of digital image processing technologies for Computer Vision tasks.

Digital image formation, quality improvement (ccolour correction, filtering), segmentation, recognition.

Lecture 17. Digital image processing for Computer Vision tasks. Artificial intelligence technologies.

1. Artificial neural networks.

2. Technologies of artificial neural networks.

3. Technologies for object recognition with artificial neural networks.

Lecture 18. Computer Vision technologies. Modernity and prospects.

1. Computer Vision technologies. Modernity.

2. Computer Vision technologies. Prospects

Laboratory work 9. Research of Computer Vision processes using artificial intelligence models.

Digital image formation, quality improvement (colour correction, filtering), segmentation and recognition using artificial neural networks.

6. Self-study

The student's independent work includes preparing for classroom classes, making calculations based on primary data obtained in laboratory classes, solving tasks, and completing module tests. The total amount of time allocated for independent work is 66 hours..

Policy and Assessment

7. Course policy

In the process of studying the discipline is encouraged:

- collegiality of relationships in the implementation of the educational process;

- timely reporting on all forms of control;

- compliance with the standards of academic integrity.

The procedure for processing and submitting reports in all forms and the procedure for evaluating results is regulated by the procedure specified in the tasks: for laboratory work; module control work; methodological materials for conducting the test.

8. Monitoring and grading policy

The grading system is module-rating based on a 100-point scale. The student's rating in the discipline consists of points received for the following:

1. Attendance at classes.

2. Execution and defence of 9 laboratory works.

3. Execution of 1 MCR.

System of rating (weight) points and evaluation criteria

Звітність	Lw1	Lw 2	Lw 3	Lw 4	Lw 5	Lw 6	Lw 7	Lw 8	Lw 9	MCR		Sum	Exam	Grade
High level of	9	9	9	9	9	9	9	9	9	18		100	0	100
Middle level of	7	7	7	7	7	7	7	7	7	18		82	18	100
Exam	18													

1. Performing and defending 9 laboratory works

*The weighting score for one work is a max 9. The maximum number of points for all laboratory works is 9 points * 9 = 81 points.*

1.1. Neat design of the laboratory report - 1 point.

1.2. Timely defence of work - 1 point.

1.3. Performing the work completely - 5 points.

1.4. Theoretical preparation for the laboratory work is assessed by answering one control question - 1 point.

1.5. Practical performance of laboratory work is evaluated by answering one control question - 0.5 points.

1.6. Analysis of the results of the laboratory work is evaluated by answering one control question - 0.5 points.

2. MCR

The maximum number of points for the MCR is 19 points.

Students who have scored the required number of points and agree to it may be released from the *exam with certification according to the current rating.*

The final performance score RS is adopted by university grading system as follows:

Score	Grade
100-95	Excellent
94-85	Very good
84-75	Good
74-65	Satisfactory
64-60	Sufficient
Below 60	Fail
Course requirements are not met	Not Graded

9. Additional information about the course

A list of questions for semester control

1. *What is Computer Vision? Areas of application.*
2. *Characteristics of the basic graphical modules of Python.*
3. *Geometric transformations. What are the types of geometric transformations?*
4. *Types of geometric transformations of 2D and 3D objects.*
5. *The essence of the graphical method for 2D and 3D objects.*
6. *Properties of matrix structures for 3D transformations.*
7. *The essence of projective transformations of 3D graphic objects and their classes.*
8. *Raster. Types of rasters. Characteristics of raster images.*
9. *The essence of image rasterization algorithms.*
10. *Interpolation and smoothing algorithms for vector images.*
11. *Classification of fractals, their brief description.*
12. *RGB, CMY/CMYK, HSB (HSV) colour model - reveal the essence.*
13. *3D pipeline: the meaning and stages.*
14. *Image rendering: the meaning and stages.*
15. *The essence of synthesizing a realistic image using a 3D pipeline and rendering.*
16. *Purpose and capabilities of the OpenGL library.*
17. *Components of the OpenGL lighting model.*
18. *Basic concepts of digital image processing.*
19. *Stages of digital image processing.*
20. *Algorithms for improving digital image, types and essence.*
21. *Basic algorithms for filtering digital images.*
22. *Image brightness diagram. Essence, properties.*
23. *Method of stretching the brightness chart. The concept and implementation.*
24. *The method of linearization of the brightness diagram. The meaning and implementation.*
25. *Method of normalization of the brightness diagram. Essence and implementation.*
26. *Mathematical formulation of the problem of image filtering. Image model.*
27. *Principles of digital image filtering.*
28. *Purpose and main features of the OpenCV package.*
29. *Methods of colour correction in OpenCV.*
30. *Methods of filtering digital images in OpenCV.*

List of practical questions

1. *To synthesize the mathematical model, develop a block diagram of the algorithm and a python program that implements the following operations: move - rotate - scale a 2D graphic object - triangle. Perform the last operation cyclically with a change in the colour of the internal colour.*
2. *To synthesize a mathematical model, develop a block diagram of the algorithm and a python program that cyclically implements the movement of a 3D graphic object in axonometric projection - a pyramid with a quadrilateral base. The operation is performed with a change in the colour of the contour.*

3. *Using Python's graphic image modeling and processing tools with OpenGL library, develop a script that implements a realistic visualization of a graphic scene in the composition: light source - observer - pyramid with a triangular base - cylinder. Choose the object models by yourself. The objects are static in axonometric projection, taking into account changes in illumination.*
4. *Using the Python digital image processing tools and the OpenCV library, develop a script that implements the formation of grayscale images from colour images and filtering the image using the selected method. Choose the image by yourself.*
5. *Using the Python digital image processing tools and the OpenCV library, develop a script that implements a tuple of operations to select the contour of two objects in a digital image. Colour image - choose by yourself.*

The work program of the discipline (syllabus):

Designed by the teacher of the Department of Computer Science, D. Sc. Pysarchuk Oleksii Oleksandrovych

Adopted by Department of Computing Engineering (protocol № 18, 25.05.2021)

Approved by the Faculty of Informatics and Computer Science Methodological Commission (protocol № 10, 14.06.2021)