

MINISTRY OF SCIENCE AND HIGHER EDUCATION OF THE RUSSIAN FEDERATION
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NORTH CAUCASUS FEDERAL UNIVERSITY

APPROVED BY:

Faculty of Mathematics and Computer
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Full name

Assessment Tools Fund on the Discipline
DIGITAL IMAGE PROCESSING AND MACHINE VISION / ЦИФРОВАЯ
ОБРАБОТКА ИЗОБРАЖЕНИЙ И МАШИННОЕ ЗРЕНИЕ

Discipline (module) title

Training program	02.04.01 Mathematics and Computer Sciences
Directivity (profile)	Training Program for Electronic Information
Year of admission	2026
Mode of study	intramural
Implemented in	2

Developed by

PhD, Head of the Department of
Mathematical Modelling
Lyakhov P.A.

Introduction

1. Purpose: The Assessment Tools Fund (ATF) is intended for the objective assessment of the level of competencies formation in the discipline "Digital Image Processing and Machine Vision / Цифровая обработка изображений и машинное зрение" for students studying in the Master's program 02.04.01 Mathematics and Computer Sciences, profile "Training Program for Electronic Information".

2. Scope: The ATF is an application to the work program for the "Digital Image Processing and Machine Vision / Цифровая обработка изображений и машинное зрение" discipline and provides structured instruments for continuous monitoring of student progress and intermediate certification in Semester 2. Competencies assessed: UC-1.1, OPC-1.1, OPC-2.1, PC-1.2 (as defined in Section 3 of the Work Program).

3. Developer: Lyakhov P.A., Head of the Department of Mathematical Modeling.

4. The ATF assessment was conducted.

Expert group members:

Chairperson:

Poddubnaya N.A., Chairperson of the Teaching and Methodological Complex, Faculty of Mathematics and Computer Science named after Professor N.I. Chervyakov

Commission members:

Gladkov A.V., Member of the Teaching and Methodological Complex, Department of Computational Mathematics and Cybernetics;

Andrukhiv L.V., Member of the Teaching and Methodological Complex, Department of Mathematical Modeling;

Kopytkova L.B., Member of the Teaching and Methodological Complex, Department of Mathematical Analysis, Algebra, and Geometry.

Employer representative: Lapin V.G., Head of the Automated Control Systems Department, Stavropol Regional Clinical Consultative and Diagnostic Center.

Expert opinion: The ATF assessment for the discipline "Digital Image Processing and Machine Vision / Цифровая обработка изображений и машинное зрение" allows for assessing the level of competence development. Recommend for use in the educational process.

«____»_____ 2026 г.

5. The ATF validity period is determined by the implementation period of the educational program.

1. Description of criteria for assessing competencies at various stages of their formation, description of assessment scales

Competency (ies), Indicator (s)	Level of competencies formation			
	Minimum level not reached (Unsatisfactory) 2 grade points	Minimum level (Satisfactory) 3 grade points	Medium level (Good) 4 grade points	High level (excellent) 5 grade points
Competency: UC-1 Able to conduct critical analysis of information, apply a systematic approach to solve research and professional tasks				
Learning outcomes for the course: <i>Indicator:</i> UC-1.1 Applies spatial/frequency representations and geometric vision models to design robust image processing pipelines	Struggles to select appropriate mathematical tools for a given visual analysis task; cannot justify algorithm choice based on problem constraints	With guidance, selects basic spatial or frequency methods; provides limited justification for parameter choices	Independently selects appropriate representations (e.g., Fourier vs. wavelet) for a given task; justifies choices with reference to noise characteristics and computational constraints	Expertly designs hybrid pipelines combining multiple representations ; provides rigorous justification based on signal properties, noise models, and efficiency requirements
Competency: OPC-1 Able to apply fundamental mathematical knowledge and modern programming technologies to solve professional problems in the field of mathematics and computer science				
Learning outcomes for the course: <i>Indicator:</i> OPC-1.1 Implements core image processing algorithms from scratch using Python/NumPy/OpenCV	Code fails on basic test cases; relies entirely on high-level library calls without understanding underlying operations	Core functionality works for clean data; minor reliance on library shortcuts; limited error handling	Implements algorithms correctly with attention to numerical stability; includes basic edge-case handling and documentation	Implements algorithms with optimized numerical routines; demonstrates understanding of complexity trade-offs; includes comprehensive testing and validation
Competency: OPC-2 Able to conduct independent research using modern methods, tools, and information technologies in the chosen professional field				

Learning outcomes for the course: <i>Indicator:</i> OPC-2.1 Designs and validates experimental pipelines for visual information processing	Cannot structure a complete processing workflow; fails to evaluate results against theoretical expectations	Constructs basic pipeline with guidance; performs simple validation against reference outputs	Designs complete workflow with appropriate parameter tuning; conducts comparative analysis against benchmarks	Designs robust, reproducible pipelines with ablation studies; critically evaluates failure modes and proposes principled improvements
Competency: PC-1 Able to develop and apply mathematical models and software systems for processing electronic information and intelligent data analysis				
Learning outcomes for the course: <i>Indicator:</i> PC-1.2 Solves multi-view geometry problems using projective geometry and epipolar constraints	Cannot formulate epipolar constraints; calibration results are numerically unstable or physically implausible	Performs basic calibration with reasonable parameters; limited error analysis	Correctly estimates fundamental/essential matrices; validates reconstruction error; interprets geometric residuals	Performs bundle adjustment with convergence analysis; handles degenerate configurations; integrates RANSAC with statistically sound inlier thresholds

The assessment of the level of development of competence in the discipline is carried out on the basis of the "Regulations on the current monitoring of academic performance and midterm assessment of students in higher education programs - bachelor's programs, specialist programs, master's programs - at the federal state autonomous educational institution of higher education "North Caucasus Federal University" in the current version.

ASSESSMENT TOOLS FOR CHECKING THE LEVEL OF DEVELOPMENT OF COMPETENCIES

Task Number	Correct Answer	Question Content	Competency
		Semester 1	
1.		Derive the frequency response of a Gaussian filter from its spatial representation. Explain the relationship between the kernel width and the passband in the frequency domain	UC-1.1
2.		Justify why wavelet thresholding provides sparse representations for piecewise smooth images. Provide a mathematical argument in terms of the properties of basis functions and signal energy	UC-1.1
3.		For a given noise type (additive Gaussian, impulse, multiplicative), justify the choice between Wiener filtering, variational TV smoothing, and the non-local means method. Compare the computational complexity and theoretical guarantees of structure preservation	UC-1.1, OPC-2.1
4.		Derive the epipolar constraint from the camera's perspective projection model. Show the transition from the projection matrix to the fundamental matrix via internal calibration	PC-1.2
5.		Describe the degeneration conditions of the 8-point algorithm (point collinearity, pure rotation, planar scene). Explain the outlier compensation mechanism in RANSAC and justify the choice of the inlier tolerance threshold.	PC-1.2, OPC-2.1
6.		Compare batch optimization and sequential SfM in terms of computational complexity, reconstruction accuracy, and scalability. Specify the conditions under which each method is preferable.	PC-1.2, OPC-2.1
7.		Compare Fourier and wavelet basis representations for different classes of images. Justify the choice of basis in terms of spatial-frequency localization and information compression.	UC-1.1
8.		Derive the Euler–Lagrange equation for the ROF functional.	UC-1.1, OPC-1.1
9.		Describe Chamball's step-by-step algorithm; analyze convergence conditions and the role of the projection operator.	UC-1.1, OPC-1.1

10.		Compare fundamental and essential matrices: conditions of applicability, calibration requirements, geometric interpretation and noise immunity.	PC-1.2
11.		Formulate convexity conditions in image restoration problems. Explain the role of proximal operators and manifold constraints in iterative optimization.	UC-1.1, OPC-2.1
12.		Formulate a complete computational pipeline for estimating a dense disparity map from a stereo pair with motion blur and uneven illumination. Justify the preprocessing strategy, feature extraction/matching method, disparity refinement algorithm, and validation protocol with metrics and failure mode analysis.	UC-1.1, OPC-1.1, OPC-2.1, PC-1.2

2. Description of the rating scale

Under the rating system, student performance in the course "Digital Image Processing and Machine Vision / Цифровая обработка изображений и машинное зрение" is assessed through ongoing assessments and midterm assessments. The rating system for assessing student knowledge is based on a set of assessment activities (checkpoints) optimally spaced throughout the course. The principles of the rating system for assessing student knowledge are based on the requirements described in the Regulation on the Organization of the Educational Process Based on the Rating System for Assessing Student Knowledge at the North Caucasus Federal University. The discipline uses a 5-point grading scale aligned with university regulations for continuous monitoring and intermediate certification. Final course grade is computed as a weighted combination: Laboratory reports (30%), Mid-term colloquia (20%), End-to-end project (30%), Final exam (20%). A minimum threshold of 3.0 (Satisfactory) in each component is required to pass the discipline.

3. 4. Competencies assessment criteria*

The grade “**excellent**” is given to a student if he/she:

skilfully identifies a problem situation, carries out its analysis and diagnostics based on a systematic approach; confidently searches, selects and systematizes information to determine alternative options for strategic solutions in a problem situation; perfectly determines and evaluates the risks of possible solutions to a problem situation, chooses the best option for solving it; confidently chooses ways of constructive interaction with people, taking into account their socio-cultural characteristics in order to successfully complete professional tasks and strengthen social integration; confidently demonstrates a respectful attitude to the historical heritage and socio-cultural traditions of various social groups, based on knowledge of the stages of Russia's historical development (including major events, major historical figures) in the context of world history and a number of cultural traditions of the world (depending on the environment and objectives of education), including world religions, philosophical and ethical teachings; has excellent skills in analyzing various socio-cultural trends, facts and phenomena based on a holistic view of the foundations of the universe and the prospects for its development, understanding the relationship between the diversity of worldviews and the course of history development, science, human ideas about nature, society, knowledge and oneself. Competencies UC-1.1, OPC-1.1, OPC-2.1, PC-1.2 have been mastered to the maximum level.

The grade “**good**” is given to a student if he/she:

correctly identifies a problem situation, carries out its analysis and diagnostics based on a systematic approach; searches, selects and systematizes information to determine alternative options for strategic solutions in a problem situation; correctly determines and evaluates the risks of possible solutions to a problem situation, chooses the best option for solving it; chooses ways of constructive interaction with people, taking into account their socio-cultural characteristics in order to successfully complete professional tasks and strengthen social integration; demonstrates a respectful attitude to the historical heritage and socio-cultural traditions of various social groups, based on knowledge of the stages of Russia's historical development (including major events, major historical figures) in the context of world history and a number of cultural traditions of the world (depending on the environment and objectives of education), including world religions, philosophical and ethical teachings; skilfully analyzes various socio-cultural trends, facts and phenomena based on a holistic view of the foundations of the universe and the prospects for its development; understands the relationship between the diversity of worldviews and the course of development of history, science, human ideas about nature, society, knowledge and oneself. Competencies UC-1.1, OPC-1.1, OPC-2.1, PC-1.2 have been mastered at an intermediate level.

The grade “**satisfactory**” is given to a student if he/she:

with some errors identifies a problem situation, carries out its analysis and diagnostics based on a systematic approach; partly searches, selects and systematizes information to determine alternative options for strategic solutions in a problem situation; determines and evaluates the risks of possible solutions to a problem situation, chooses the best option for solving it; hesitantly chooses ways of constructive interaction with people, taking into account their socio-cultural characteristics in order to successfully complete professional tasks and strengthen social integration; partly demonstrates a respectful attitude to the historical heritage and socio-cultural traditions of various social groups, based on knowledge of the stages of Russia's historical development (including major events, major historical figures) in the context of world history and a number of cultural traditions of the world (depending on the environment and objectives of education), including world religions, philosophical and ethical teachings; analyzes various socio-cultural trends, facts and phenomena based on a holistic view of the foundations of the universe and the prospects for its development; understands the relationship between the diversity of worldviews and the course of development of history, science, human ideas about nature, society, knowledge and oneself. Competencies UC-1.1, OPC-1.1, OPC-2.1, PC-1.2 have been mastered at a minimum level.

The grade “**unsatisfactory**” is given to a student if he/she:

finds it difficult to identify a problem situation, carries out its analysis and diagnostics based on a systematic approach; hesitantly searches, selects and systematizes information to determine alternative options for strategic solutions in a problem situation; with gross errors determines and evaluates the risks of possible solutions to a problem situation, chooses the best option for solving it; finds it difficult to choose ways of constructive interaction with people, taking into account their socio-cultural characteristics in order to successfully complete professional tasks and strengthen social integration; finds it difficult to demonstrate a respectful attitude to the historical heritage and socio-cultural traditions of various social groups, based on knowledge of the stages of Russia's historical development (including major events, major historical figures) in the context of world history and a number of cultural traditions of the world (depending on the environment and objectives of education), including world religions, philosophical and ethical teachings; hesitantly analyzes various socio-cultural trends, facts and phenomena based on a holistic view of the foundations of the universe and the prospects for its development; understands the relationship between the diversity of worldviews and the course of development of history, science, human ideas about nature, society, knowledge and oneself. Competencies UC-1.1, OPC-1.1, OPC-2.1, PC-1.2 have not been mastered at the minimum level.