



COURSE DESCRIPTION CARD - SYLLABUS

Course name

NEXT-GENERATION MULTIMEDIA: VIDEO CODING, AI, AND VR TECHNOLOGIES [S5ITIT>MNG]

Course

Proposed by Discipline

–

Year/Semester

2/3

Level of study

Doctoral School

Course offered in

English

Form of study

full-time

Requirements

elective

Number of hours

Lecture

8

Laboratory classes

0

Other

0

Tutorials

0

Projects/seminars

0

Number of credit points

1,00

Coordinators

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Lecturers

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Prerequisites

Basic knowledge of digital technologies, computer systems, or signal/data processing at a general engineering or scientific level is recommended. No previous knowledge of video coding, machine learning, or virtual reality is required. Students should be able to read scientific and technical literature in English and participate in discussions on interdisciplinary research topics.

Course objective

The aim of the course is to provide doctoral students with a research-oriented overview of emerging technologies in next-generation multimedia systems, with particular emphasis on modern video coding, artificial intelligence, video coding for machines, immersive media, and virtual reality. The course introduces the principles behind these technologies, discusses their current development and standardization trends, and presents selected open research challenges. Particular attention is given to the interaction between conventional signal processing, machine learning, computer vision, and novel representations of visual information. The course also aims to develop the ability to critically analyze recent scientific approaches and identify potential directions for interdisciplinary research.

Course-related learning outcomes

Knowledge:

1. The student knows and understands the state of the art and major development trends in modern video coding, AI-based multimedia processing, video coding for machines, and immersive media technologies. SzD_W01, SzD_W02
2. The student understands the fundamental principles, potential advantages, and limitations of selected next-generation multimedia technologies, including hybrid and learning-based video coding, machine-oriented visual communication, and immersive/VR representations. SzD_W01, SzD_W02

Skills:

1. The student is able to critically analyze and compare research approaches in multimedia technologies, taking into account compression efficiency, computational complexity, quality, interoperability, and application requirements. SzD_U02
2. The student is able to use knowledge from different scientific and engineering disciplines to identify and formulate research problems related to next-generation multimedia systems. SzD_U01

Social competences:

1. The student is prepared to critically assess emerging technological solutions and recognize both their research potential and practical limitations. SzD_K01, SzD_K03

Methods for verifying learning outcomes and assessment criteria

Learning outcomes presented above are verified as follows:

Written and/or oral exam from material presented during lectures. The grade depends on the number of points the student earns relative to the maximum number of required points. Earning more than 50% of the possible points is a prerequisite for passing. The relationship between the grade and the number of points:

<=50%; 2,0
above 50% – 60.0%: 3.0
above 60% – 70.0%: 3.5
above 70% – 80.0%: 4.0
above 80% – 90.0%: 4.5
above 90% – 100%: 5.0

Programme content

Current and emerging research directions in multimedia technologies, including advanced video compression, artificial intelligence for visual data processing and compression, video coding for machines, immersive video, virtual and extended reality, and novel representations of visual information.

The course discusses the transition from conventional video coding towards AI-assisted and machine-oriented communication systems, as well as the evolution from traditional 2D video towards immersive and three-dimensional representations. Selected standardization activities, practical applications, evaluation methodologies, and open research challenges are also presented.

Course topics

Lecture 1 Next-Generation Video Coding

Evolution of video compression from conventional hybrid coding towards next-generation codecs. Main principles of modern video coding, selected technologies used in HEVC, VVC and beyond, computational complexity, coding efficiency, and current research and standardization directions. Introduction to AI-assisted coding tools.

Lecture 2 Artificial Intelligence for Multimedia Compression and Processing

Machine learning and deep neural networks in multimedia systems. Learned image and video compression, neural tools supporting conventional codecs, enhancement and reconstruction methods, complexity–quality trade-offs, and selected challenges related to practical deployment and standardization.

Lecture 3 Video Coding for Machines

Visual communication in systems where the primary consumer of information is a machine rather than a human. Video Coding for Machines, feature and semantic representations, collaborative intelligence, task-oriented compression, human-machine communication scenarios, evaluation methodologies, and current research and standardization trends.

Lecture 4 Immersive Video, VR and Emerging 3D Representations

Technologies enabling immersive and interactive visual experiences, including VR, free-viewpoint and six-degrees-of-freedom video. Principles of immersive video representation, geometry and depth information, view synthesis and MPEG Immersive Video. Emerging representations such as neural rendering and Gaussian splatting, their potential use in multimedia communication, and open research challenges.

Teaching methods

Lectures are conducted in an interactive form and supported by multimedia presentations, diagrams, visual examples, demonstrations, and selected results from recent scientific publications and international standardization activities.

Selected research problems and case studies are discussed during the classes in order to encourage students to critically compare alternative technological approaches and relate the presented topics to their own research disciplines.

Bibliography

Basic

J.-R. Ohm, G. J. Sullivan, High Efficiency Video Coding: Coding Tools and Specification, selected chapters and recent overview papers on modern video coding.

G. J. Sullivan et al., publications describing the Versatile Video Coding (VVC) standard and its coding tools, IEEE Transactions on Circuits and Systems for Video Technology.

Selected overview and research papers on AI-based image and video compression from IEEE TCSVT, IEEE Transactions on Image Processing, IEEE Transactions on Multimedia, and IEEE Transactions on Broadcasting.

Selected publications and technical documents related to MPEG Video Coding for Machines and machine-oriented visual communication.

Selected publications and technical documents related to MPEG Immersive Video and immersive media systems.

Additional

B. Mildenhall et al., "NeRF: Representing Scenes as Neural Radiance Fields for View Synthesis," ECCV, 2020.

B. Kerbl et al., "3D Gaussian Splatting for Real-Time Radiance Field Rendering," ACM Transactions on Graphics, 2023.

Recent MPEG, JVET, and ISO/IEC standardization documents concerning video coding, immersive media, and machine-oriented multimedia communication.

Recent research papers indicated by the lecturers during the course.

Breakdown of average student's workload

	Hours	ECTS
Total workload	50	2,00
Classes requiring direct contact with the teacher	8	0,50
Doctoral student's own work (literature studies, preparation for laboratory classes/tutorials, preparation for tests/exam, project preparation)	42	1,50