→ What is multimedia?

"Multimedia" implies simultaneous use of more than one medium
(audio, image, video, text, graphics ...)

Perhaps a better name is

"Integrated media"

→ "Networked multimedia": where communication supports interaction at a distance

→ "Interactive multimedia": manipulations of multimedia "objects" in which the human participants have to assume an active role

ECE462: Multimedia Systems
Winter 2025

Instructor

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Teaching assistant:

Calendar Description

Topics in the engineering area of multimedia systems with particular emphasis on the theory, design features, performance, complexity analysis, optimization and application of multimedia engineering technologies. Topics include sound/audio, image and video characterization, compression, source entropy and hybrid coding, transform coding, wavelet-based coding, motion estimation, JPEG coding, digital video coding, MPEG-1/2 coding, content-based processing, and MPEG-7, New Video Coding Standard H264 and H265.

Learning Objectives

Multimedia systems are an integral part of our modern lives providing unprecedented opportunities to connect, convey and distribute information. Our ubiquitous dependence on such systems have made multimedia technologies, networks, assets and services essential to our society's health, safety, security and economic well-being. The objective of this course is to provide an introduction to signal compression technologies which is the power engine that enables multimedia systems. Topics include image, speech and video compression methodologies and principles.

Lectures

Monday, 10:00-11:00 am, room BA1230
Tuesday, 11:00 -12:00 pm , room BA2185
Thursday, 10:00-11:00 am, room MY360
First class: Monday, January 6, 2025

Office Hours: By appointment

Discussion Board: We will use Piazza for the class discussion board. Please post your course related questions to Piazza. Others may have the same question and will benefit from the response if it is available to everyone. Information on how to use Piazza will be provided soon.

Labs

Labs are scheduled every Tuesday 3:00-5:00 pm in BA3128 starting on Tuesday January 21, 2025.

Midterms

Two midterm exams will be given, 10:00-11:00 pm during class time with tentative dates, Thursdays Feb. 13 and March 20, 2025.

Marking Scheme

Final Exam	50%
Midterms (2)	30%
Lab(s)	20%
Total	100%

Course Outline

Topic	**Chapter(s)**
Introduction to Multimedia (Optional)	1
Graphics/Image Data Types	3.1
Colour in Image and Video	4
Distortion Measures	8.2
Quantization	8.4
Transform Coding (Lossy) - DCT, KLT	8.5
Information Theory/Lossless Coding	7.1-7.4, 7.6
Predictive Coding (Lossless)	6.3
JPEG Standard	9.1
Wavelet Transform	8.6
Wavelet Based Coding (EZW)	8.8-8.9
JPEG2000 Standard	9.2
Video Compression/Motion Estimation	10.1-10.4
MPEG-1/2 Standards	11.1-11.3

MPEG-4/H.264 Standards	12.1-12.2, 12.5
Vocoders (Speech Compression)	13.3
MPEG Audio Compression	14.1-14.2
Special Topics (Time Permitting): -H264,H265 Video standards - Digital Camera Image Processing - MPEG-7 (Content Description)	

References

Textbook (Required)

Fundamendals of Multimedia, Second edition
ZeNian Li, Mark S. Drew, Jiangchuan Liu
Springer, ISBN978-3-319-05289-2, ISBN 978-3-319-05290-8 (ebook), 2014

Additional References (Optional)

Introduction to Data Compression (3rd Edition)
K. Sayood
Morgan Kaufmann, ISBN 978-0-12-620862-7, December 2005

Multimedia Signals and Systems
Mrinal Kr. Mandal
Kluwer Academic Publishers, ISBN 1-4020-7270-8, December 2002

Color Image Processing and Applications
K.N. Plataniotis, A.N. Venetsanopoulos
Springer Verlag, ISBN 3-540-66953-1, August 2000

Digital Video Processing
A. Murat Tekalp
Prentice-Hall, 1995

IEEE Signal Processing Magazine: Transform Coding (Special Issue)
IEEE, September 2001

IEEE Signal Processing Magazine: Immersed in Multimedia (Special Issue)
IEEE, January 1999

Lab details

Lab work is to be done individually. Discussion of problems with your classmates is acceptable, but you must write all your code yourself. Plagiarism will not be tolerated and dealt with as per departmental and university policy. On line lab submissions must be submitted in a single Zip file. The Zip file must contain:

• Working code without errors for the lab task

• Screenshots demonstrating all the results (Without these you will not receive any credit for the lab)

• Explanation of the results in a short note. (Without these you will not receive any credit for the lab) .

• For in person labs, the TA will be available during the lab time to answer any questions you have. In person lab submission will be demonstrated (including, code, procedure and results) to the TA during Lab time.

- There will be 4 quizes in total during lab time. Lab quizzes will emphasize a fundamental understanding of the lab material (not programming). There is one quiz for each lab, held during the last 30 minutes of week 2 for each lab. Each quiz will count 20/100 of the corresponding lab mark.

Lab Topics

Lab 0: Prelab 1 preparation

Lab 1: Colour Image Processing

Lab 2: DCT Transform and Coding

Lab 3: Wavelet Transform and Coding

Lab 4: Motion Estimation and Video Coding

Schedule: Tuesdays, 3:00 to 5:00 pm , BA3128

		PRA01
Lab 0		Jan. 21
Lab 1	**Week 1**	Jan. 28
	Week 2	Feb. 4
Lab 2	**Week 1**	Feb. 11
	Week 2	Feb. 25
Lab 3	**Week 1**	March 4
	Week 2	March 11
Lab 4	**Week 1**	March 18
	Week 2	March 25

Other Course Policies

- All tests and examinations for this course are closed-book. Everyone taking the course is expected to attend all lab sessions. The lab period will be devoted to discussing concepts and implementation issues. Students are expected to attend lab sessions prepared, and to answer related questions.
- Usage of the course webpage will be limited to people taking the course. This means that in order for students to download relevant labs and course material from the course website, they MUST register.
- Remarking Policy: remarking requests may be made up to **one week** after an item is returned. Only under special circumstances will remarking be considered after this time limit.

Notice of video recording and sharing (Download permissible re-use prohibited)

At times during this course, some interactions including your participation, may be recorded on video and will be available to students in the course for viewing remotely and after each session. Course videos and materials belong to the instructors, the University, and/or other source depending on the specific facts of each situation and are protected by copyright. In this course, you are permitted to download session videos and materials for your own academic use, but you should not copy, share, or use them for any other purpose without the explicit permission of the instructor. For questions about recording and use of videos in which you appear please contact your instructor.

Academic Integrity policies

http://www.academicintegrity.utoronto.ca/https://governingcouncil.utoronto.ca/secretariat/policies/code-behaviour-academic-matters-july-1-2019

Land Acknowledgement

I (we) wish to acknowledge this land on which the University of Toronto operates. For thousands of years it has been the traditional land of the Huron-Wendat, the Seneca, and most recently, the Mississaugas of the Credit River. Today, this meeting place is still the home to many Indigenous people from across Turtle Island and we are grateful to have the opportunity to work on this land.

Statements

- **Syllabus Statements on Inclusivity, Accommodations & Mental Health Support**
- Inclusivity Statement:
- All students and faculty at the University of Toronto have a right to learn, work and create in a welcoming, respectful, inclusive and safe environment. In this class we are all responsible for our language, action and interactions. Discriminatory comments or actions of any kind will not be permitted. This includes but is not limited to acts of racism, sexism, Islamophobia, anti-Semitism, homophobia, transphobia, and ableism. As a class we will work together to create an inclusive learning environment and support each other's learning.
- If you experience or witness any form of discrimination, please reach out to the Engineering Equity Diversity & Inclusion Action Group online, an academic advisor, a U of T Equity Office, or any U of T Engineering faculty or staff member that you feel comfortable approaching.
- Accommodations:
- If you have a learning need requiring an accommodation the University of Toronto recommends that students immediately register at Accessibility Services at www.studentlife.utoronto.ca/as.

- Location: 4th floor of 455 Spadina Avenue, Suite 400
- Voice: 416-978-8060
- Fax: 416-978-5729
- Email: accessibility.services@utoronto.ca
- The University of Toronto supports accommodations of students with special learning needs, which may be associated with learning disabilities, mobility impairments, functional/fine motor disabilities, acquired brain injuries, blindness and low vision, chronic health conditions, addictions, deafness and hearing loss, psychiatric disabilities, communication disorders and/or temporary disabilities, such as fractures and severe sprains, recovery from an operation, serious infections or pregnancy complications.
- Mental Health:
- As a university student, you may experience a range of health and/or mental health issues that may result in significant barriers to achieving your personal and academic goals. The University of Toronto offers a wide range of free and confidential services and programs that may be able to assist you. We encourage you to seek out these resources early and often.
- Health & Wellness Resources: undergrad.engineering.utoronto.ca/advising-and-wellness/health-wellness/
- U of T Health & Wellness Website: studentlife.utoronto.ca/hwc
- If, at some point during the year, you find yourself feeling distressed and in need of more immediate support, visit the **Feeling Distressed Webpage**: www.studentlife.utoronto.ca/feeling-distressed, for more campus resources.
- Off campus, immediate help is available 24/7 through **Good2Talk**, a post-secondary student helpline at 1-866-925-5454.
- All students in the Faculty of Engineering have an Academic Advisor who can advise on academic and personal matters. You can find your department's Academic Advisor here: uoft.me/engadvising

• Absence Declaration

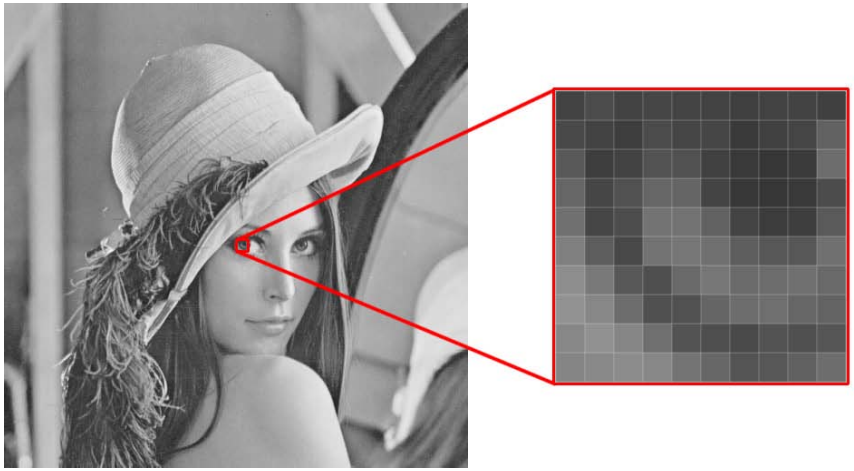
- A ***Verification of Illness Form*** **(also known as a "doctor's note") is currently not required for missed academic work. Faculties or campuses may require documentation in some circumstances.**

- Students who are absent from academic participation for **any reason** (e.g., COVID, cold, flu and other illness or injury, family situation) and who require consideration for missed academic work should report their absence through the online absence declaration. The declaration is available on **ACORN under the Profile and Settings menu.** Students should also advise their instructor of their absence.

- Please check with your faculty or campus for specific procedures regarding absence declarations. In some situations, documentation will be required.

Monochrome Images

- Monochrome images have only one colour with varying intensity
  - “Mono” = one; “Chrome” = colour
  - May also be referred to as a “single channel” or grayscale image
- Image composed of array of pixels – “picture elements”



“Lena” monochrome image

Monochrome Images (cont'd)

- Image can be represented as a matrix
  - $\mathbf{X}_{m \times n} = [x(i,j)]$, where $i = 0 \ldots m-1$, $j = 0 \ldots n-1$
    - (i,j) represents spatial position; $(i,j) = (0,0)$ is typically top-left corner; i is vertical position; j is horizontal position
    - Image is $m \times n$ pixels in size – sometimes called the "resolution," but more accurately called the dimensions
      - Note: In image and video applications, dimensions usually specified as (# cols)x(# rows) – e.g., 640x480. Beware!
- Pixels may be represented by a continuum of real values in the range [0,1]
  - $x(i,j) \in \mathbb{R}$, $0 \leq x(i,j) \leq 1$
  - "0" represents black; "1" represents white

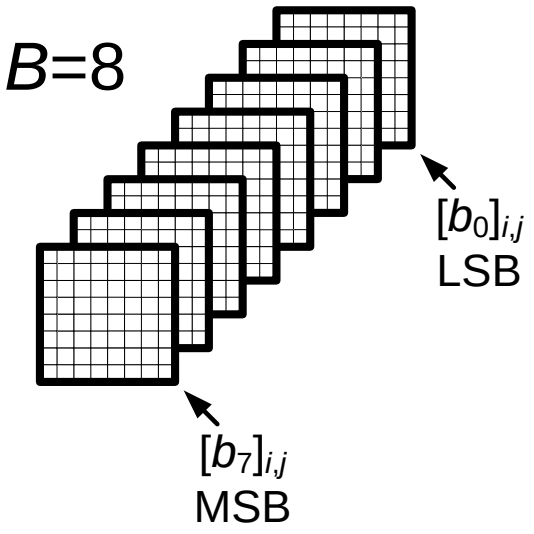
Monochrome Images (cont'd)

- In digital imagery, pixel values are typically stored as finite precision integers
  - 8-bit representation produces integers in the range [0,255] (typical grayscale image)
  - 1-bit representation produces a binary image with pixel values {0,1} (black or white; no gray)
  - In general, *B*-bit representation produces integer values $[0,2^B-1]$
  - Memory requirements: *B* bits per pixel (bpp)

"Lena" 1-bit monochrome image

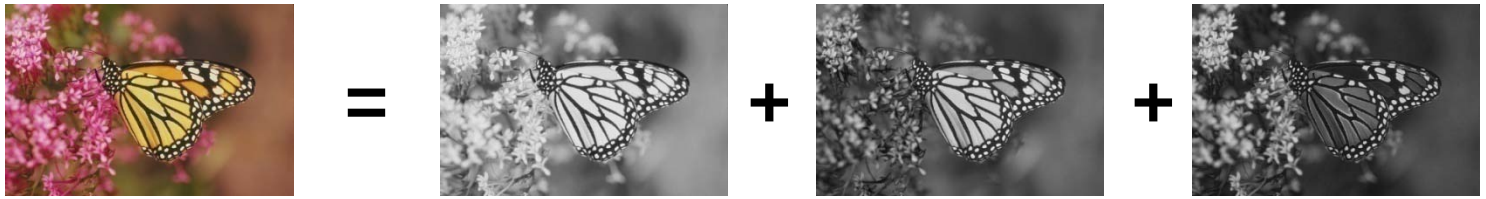
Monochrome Images (cont'd)

- The B-bit binary representation of the pixel values may be viewed as stacked "bitplanes" $\{b_{B-1},\ldots,b_0\}$
  - $x(i,j) = b_{B-1}\cdot 2^{B-1} + \ldots + b_1\cdot 2^1 + b_0$
  - b_{B-1} is the most significant bit (MSB)
  - b_0 is the least significant bit (LSB)
  - Simple application example: converting 8-bit grayscale to 1-bit binary image
    - Retain only the MSB bitplane and discard the rest



Colour Images

- Colour images generally represented using 3 channels (more on this in the next lecture)
  - Each channel can be interpreted as a monochrome image representing one colour component
  - Example: Red, Green, Blue (RGB) colour space



"Monarch" colour image | Red Channel | Green Channel | Blue Channel

  - $\mathbf{X}_{m \times n \times 3} = [x(i,j,k)]$, where $i=0 \ldots m-1$, $j=0 \ldots n-1$, $k=1,2,3$
  - Using 8 bits per channel $\rightarrow$ 24 bpp
    - 16,777,216 different colours – "true colour"

Colour Images (cont'd)

- Different colour image processing techniques may treat the image data differently
  - In colour image compression, most modern techniques perform a decorrelating colour transform (e.g., RGB $\rightarrow$ YCbCr) and then process the channels as independent 2-D, $m \times n$ matrices
    - $\mathbf{X} = \{\mathbf{X}_{m \times n\text{-Y}}, \mathbf{X}_{m \times n\text{-Cb}}, \mathbf{X}_{m \times n\text{-Cr}}\}$
  - In colour image filtering and pattern recognition, correlation between colour components may be important, therefore treat the image as a 2-D, $m \times n$ array of 3 component vectors
    - $\mathbf{X}_{m \times n}: \mathbb{Z}^2 \rightarrow \mathbb{Z}^3$, $\boldsymbol{x}(i,j) = [x(i,j)_R, x(i,j)_G, x(i,j)_B]$

Growing Demand for Video

Video exceeds half of internet traffic to date and will grow to over 80% percent by 2016. Increase in applications, content, fidelity, etc. →→ Need higher coding efficiency!

Ultra--HD 4K broadcast expected for Japan in 2014. London Olympics Opening and Closing Ceremonies shot in Ultra--HD 8K. →→ Need higher throughput!

25x increase in mobile data traffic over next five years. Video is a "must have" on portable devices. →→ Need lower power!

Video Compression

- Uncompressed 1080p high definition (HD) video at 24 frames/second
  - pixels per frame: 1920x1080
  - Bits per pixel : 8-bits x 3 (RGB)
  - 1.5 hours: 806 GB (Gbytes)
  - Bit rate: 1.2 Gbits/second
- Blu-Ray DVD
  - Capacity: 25 GB (single layer)
  - Read rate: 36 Mbits/second
- Video streaming / TV broadcasting
  - 1 Mbits/s to 20 Mbits/s
- Require 30x to 1200x compression