Digital Signal and Image Processing (ELEC 421; 3 Credits)

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Course Syllabus:

Digital image processing (DSP) fundamentals; signal representation; digital filtering; statistical estimation; DSP applications; digital image processing (DIP) fundamentals and applications.

Prerequisite:

ELEC 221 – Signals and Systems.

Rationale:

In this course, we will focus on the basic concepts, methodologies, and tools of digital signal and image processing. This course introduces basic digital signal & image processing theory in the context of real-world applications. Major topics of interest include data acquisition, digital signals and systems, time and frequency domain analysis, Fourier transform, sampling theory, digital filters, linear prediction, and image processing basics. All methods will be developed to address certain concerns on specific data sets in modalities such as audio signals and images. The lectures will be accompanied by signal/image processing assignments using MATLAB. Students will explore the basics of signal and image processing and gain hands-on experience with MATLAB® Signal Processing Toolbox by doing homework assignments and projects.

Learning Objectives:

Here are the main learning objectives of the digital signal processing (DSP) and digital image processing (DIP) course:

- Understand digital signals, systems, and their significance.
- Analyze digital signals using various transforms (e.g., DFT, FFT).
- Design and develop basic digital systems.
- Interpret the functioning of digital filters.
- Cover basic analytical methods widely used in image processing.
- Address issues and technologies specific to images and image processing systems.
- Gain experience using MATLAB to process images.

Course Outline:

1. **Introduction and basics**
   - Introduction to DSP
   - Data acquisition (Sampling and Reconstruction of Signals)
   - The z-transform
2. **Discrete-Time Signals and Systems**
   - Digital filters; LTI systems; Description by difference equations
   - Convolution; Causality and stability
   - Correlation

- Frequency Analysis of Signals and Systems

3. **Frequency representations: Discrete Fourier Transform (DFT)**
   - DFT; properties of DFT; using DFT
4. **Digital Filter Design**
   - General consideration and design rules;
   - Design of digital filter based on least-square method
   - MATLAB implementation of FIR filter design
5. **Multirate digital signal processing**
   - Decimation, interpolation
   - Sampling rate conversion
   - Introduction to Wavelet analysis
6. **Stochastic processes**
   - Linear prediction; Auto-regressive model
   - Matched and Wiener filter
7. **Image processing basics**
   - Image basics: gray image, color image, color models, histograms, etc.
   - Image processing: 2D transforms, filtering, etc.
   - Image compression basics
   - Image processing applications

Course Contents:

- **Digital Signal Processing (DSP)**
  - ✓ **Lecture 0:** Introduction to DSP and DIP
  - ✓ **Lecture 1:** Signals
  - ✓ **Lecture 2:** Linear Time-Invariant System
  - ✓ **Lecture 3:** Convolution and its Properties
  - ✓ **Lecture 4:** The Fourier Series
  - ✓ **Lecture 5:** The Fourier Transform
  - ✓ **Lecture 6:** Frequency Response
  - ✓ **Lecture 7:** Discrete-Time Fourier Transform
  - ✓ **Lecture 8:** Introduction to the z-Transform
  - ✓ **Lecture 9:** Inverse z-Transform; Poles and Zeros
  - ✓ **Lecture 10:** The Discrete Fourier Transform
  - ✓ **Lecture 11:** Radix-2 Fast Fourier Transforms
  - ✓ **Lecture 12:** The Cooley-Tukey and Good-Thomas FFTs
  - ✓ **Lecture 13:** The Sampling Theorem
  - ✓ **Lecture 14:** Continuous-Time Filtering with Digital Systems; Upsampling and Downsampling
  - ✓ **Lecture 15:** MATLAB Implementation of Filter Design

- **Digital Image Processing (DIP)**
  - ✓ **Lecture 1:** Digital Image Modalities and Processing
  - ✓ **Lecture 2:** The Human Visual System, Perception, and Color
  - ✓ **Lecture 3:** Image Acquisition and Sensing
  - ✓ **Lecture 4:** Histograms and Point Operations
  - ✓ **Lecture 5:** Geometric Operations
  - ✓ **Lecture 6:** Spatial Filters

Course Materials:

All the course materials will be posted online. They will be in the form of class lecture notes. Various textbooks and references can be used for this course, but the major reference for the course will be my course materials that will be posted on Canvas. All the assignments will be available on Canvas in a timely manner. **All the course materials (lectures, announcements, etc.) will be placed in the folder entitled "Files" on Canvas.** I have prepared two sets of lecture notes, one with less text (in the subfolder of **SV**, for the shorter version) and one with a detailed explanation of the slides (in the subfolder of **LV**, for the longer version). A few of the optional useful textbooks for this course are:

- ***Digital Signal Processing***; 2014; 4th Edition, John G. Proakis, Dimitris Manolakis. Publisher: Pearson New International Edition.
- ***Discrete-Time Signal Processing***; 2009; 3rd Edition, Alan Oppenheim, Ronald Schafer. Publisher: Prentice Hall.
- ***Handbook of Image and Video Processing***; 2010; 2nd Edition, Alan C. Bovik. Publisher: Academic Press.
- ***Artificial Tactile Sensing in Biomedical Engineering***; 2009; Siamak Najarian, Javad Dargahi, Ali Abouei Mehrizi. Publisher: McGraw Hill.
- ***Mechatronics in Medicine: A Biomedical Engineering Approach***; 2011; Siamak Najarian, Javad Dargahi, Goldis Darbemamieh, Siamak Hajizadeh Farkoush. Publisher: McGraw Hill.
- ***Biomedical Signal and Image Processing***; 2012; Kayvan Najarian, Robert Splinter, 2nd Edition. Publisher: CRC Press (Taylor & Francis Group).

Course Schedule:

Tuesday, Sep 03, 2024 to **Friday, Dec 06, 2024**

Activity	Days	Start Time	End Time	Classroom Location
Lecture	Tue	9:00 am	11:00 am	MCLD-Floor 3 (Room 3018)
Lecture	Thu	9:00 am	11:00 am	MCLD-Floor 3 (Room 3018)

Statutory Holidays and Midterm Break:

Statutory Holidays: Monday, September 30; Monday, October 14; Monday, November 11.
Midterm Break: Monday to Wednesday, November 11 to November 13.

Canvas Website:

The Canvas website (**www.canvas.ubc.ca**) can be used only by students enrolled in the course. Students will be able to access the course from both UBC and home. Instructions are given on the main Canvas page.

Instructor's Office Location and Office Hours:

My office hours are on Tuesdays and Thursdays from 1:00 pm to 2:30 pm. My office location is ICICS 371. If you need to reach me, my email address is: **s.najarian@ubc.ca** (or **siamakn@ece.ubc.ca**).

TAs Contact Details:

Your TAs for this course are **Ms. Hosna Kazerooni Haghighat (hosna@ece.ubc.ca)** and **Ms. Adriana Cowan (acowan01@student.ubc.ca)**. For any issues related to your assignment marking, group assignments formation, group project formation, or other relevant inquiries, please contact your TAs directly. Shortly after the term begins, your TAs will post an announcement, and after introducing themselves, they will go over their responsibilities. All your work will be marked by the TAs and feel free to contact them for further details.

Grading System:

Group Assignments	15%
Quizzes (3×5% each)*	15%
Midterm Exam	35%
Term Group Project**	25%
Class Participation	10%
Total	**100%**

* We will have **4 quizzes** in this course. However, the lowest quiz grade will not be counted. This is done in case you miss a quiz for reasons, such as illness, travel, or any other activities or your get a lower grade in of the quizzes. There will be no make-up quiz or midterm exam.

** Due to the nature of this course, this course does not have a final exam. Instead, nearly one week to the end of term, a take-home MATLAB project will be given to you. You will complete and submit your work before the deadline of **Thursday**, **December 05, 2024.** The same group that you have for your assignments will be also doing this group term project (unless you have different assignments and project team members). Before the deadline, you will need to upload just one submission per each group.

Group Assignments:

To encourage teamwork activities, group assignments will be given out periodically and form an important part of the course. Each group should consist of about **6 members** and the selection of the members will be decided by the students themselves. There will be 3 sets of assignments. The electronic version of your group assignment solutions (one assignment solution per each group) should be submitted through Canvas before its due date. Late assignments will be given a mark of zero. Each set of assignments is submitted with an **Assignment Group Self-Assessment** form signed by all members of the group. You will find a copy of this form in the subfolder of Assignments on Canvas.

The names of the assignments group members along with the name of the member in charge of correspondence with the TAs (on behalf of your group) should be uploaded on Canvas. The same process should be repeated for the names of the term projects group members. These two have separate submission boxes. These two tasks should be done before the deadline (please refer to **Important Dates and Deadlines**). If for any reason the list of assignments and project group members is not uploaded on Canvas by the set deadline, the TAs will set up the remaining group members themselves and will let the

students know the group arrangements a couple of days after the deadline is passed. Once a group is formed we encourage you not to change it. However, if for any reason you need to switch or change your group, you can do it **only once** by informing your TAs in advance. You will not be asked about why you decided to change your group. Assignments are to be done by each group, so copying from other groups is not allowed. Possible penalties for plagiarism include a mark of zero for all assignments.
I suggest that the same members who form the assignments groups also form the term project groups. This is not mandatory, but it would make both your job and the TA's job more manageable.

Quizzes:

There will be 4 quizzes that are done in class. Quizzes are multiple-choice questions (closed notes/book). If there is a need for any formula, it will be provided. As pointed out before, the lowest quiz grade will not be counted. That is, **only the highest 3 quiz grades will be counted towards your total quiz grade**.

Midterm Exam:

The structure of the midterm exam will be very similar to that of the quizzes, but more questions will be included in the midterm exam. The midterm exam will have a multiple-choice questions format (closed notes/book). If there is a need for any formula, it will be provided.

Term Group Project:

The term group project is an opportunity for students to apply what they have learned in this course in order to tackle real-world engineering problems. It is also a good opportunity to practice teamwork activities when doing an engineering project. More details on this will be posted at a later time.

Important Dates and Deadlines:

Event	Date
Deadline for submitting assignments group/project group members names	Friday (5:00 pm), September 20, 2024
Quiz 1	Tuesday, October 8, 2024
Midterm exam	Thursday, October 17, 2024
Quiz 2	Thursday, November 7, 2024
Quiz 3	Thursday, November 21, 2024
Quiz 4	Thursday, December 5, 2024
Deadline for online submission of the term group project	Thursday (5:00 pm), December 5, 2024

Requirements:

The main requirements for this course are: attending lectures on a regular basis, participating in the in-class activities, completing assignments and projects on time and delivering them before the deadlines, and successfully taking various exams and quizzes. **Students are expected to come to lectures regularly and to be always on time**.

Class Participation:

It should be noted that there is a strong correlation between attendance and grades. In order to understand the posted material better, you will need to be present in class. Regular attendance is necessary in order to be most successful. Please note that arriving late to a class is considered unprofessional. The grading scheme for calculating class participation marks is as follows: Students are allowed to miss a total of 4 class sessions without losing any participation marks. This is done in case you miss a class session due to illness, travel, or any other activities. If you miss a class, please do not email the TAs/instructor to provide the reason for absence since it is automatically considered as one of the 4 sessions that you can miss without any penalties. Class participation will be done by passing on a sign-in sheet in every class session.

Cell Phone Policy:

As a matter of courtesy, students are expected to turn off their cell phones during class. If extraordinary circumstances require an exception to this policy, the student is expected to discuss this with the instructor before class begins.

Contacting the Instructor:

When contacting me, please kindly make sure that you include the course code in your subject heading. Also, please include your name (as appeared on Canvas) and student ID number in all communications. Before contacting me on course-related policies, please first refer to the Course Outline and Syllabus document (i.e., this document) and relevant announcements on Canvas. This is because in most cases the information you seek may already be published.

Acknowledgments:

Many resources and references have been used in the preparation of the materials for this course. However, special thanks should go to Prof. Kayvan Najarian and Prof. Z. Jane Wang for sharing some of the materials for this course with me.