COMP 448/548: Medical Image Analysis

Introduction

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Outline for today

- Lecture 1: Introduction
- Course outline
- Course details
- Coursework

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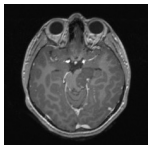
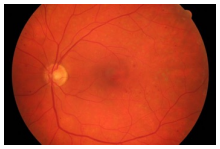
Course objectives

- Today, imaging systems are extensively used in medicine and biology research
- Their primary use is to visualize human body at different levels
- Images are visually analyzed by clinicians/biologists to make decisions
- These analyses rely on visual interpretations/judgments



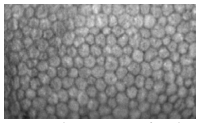
MR scan showing tumor in brain

SPECT-CT bone scan showing joint inflammation

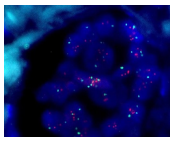


Fundus photography for diabetic retinopathy diagnosis

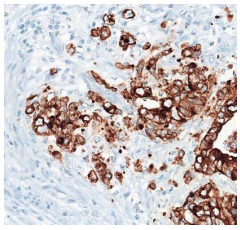
Skin photography for melanoma screening



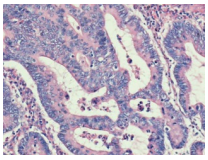
Corneal in vivo confocal microscope photography of endothelial cells for diagnosis



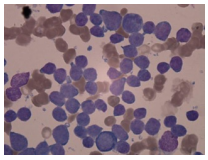
FISH to determine HER2 protein status in breast cancer



Micrograph of IHC stained biopsy to localize tumor buddings, a prognostic indicator for cancer



Micrograph of HE stained biopsy for colon adenocarcinoma grading



Micrograph of peripheral blood smear for leukemia diagnosis

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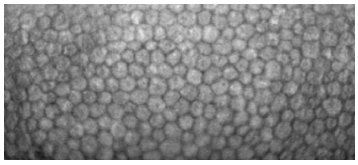
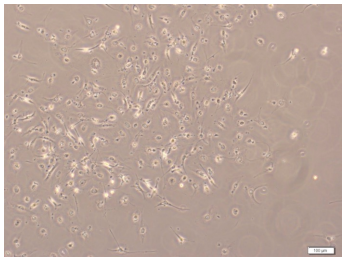
Then, why do we need computers?

1. Some tasks are time-consuming

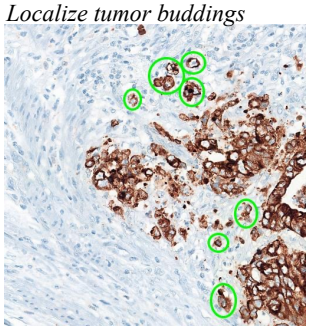


Count endothelial cells in this corneal in vivo confocal micrography

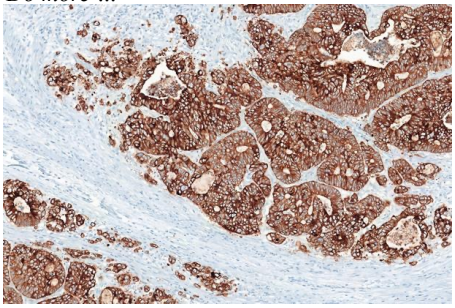


Find the ratio of senescent cells in this micrograph belonging to an in vitro experiment

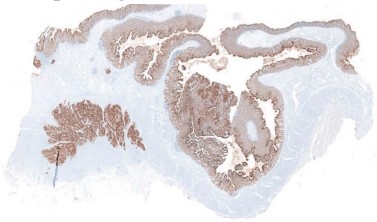
Localize tumor buddings



Do more …



Keep doing …



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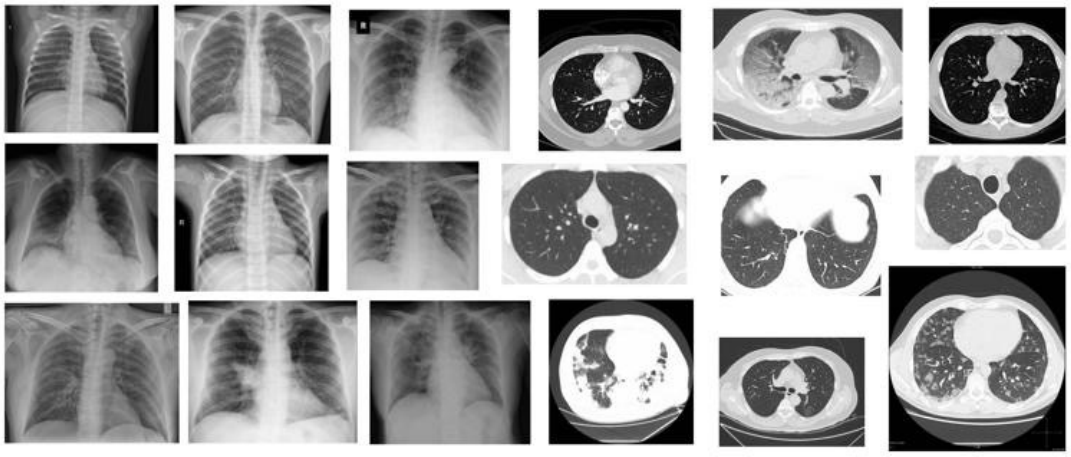
Then, why do we need computers?

2. There are too many cases, but limited manpower

Analyze many X-ray and CT images to diagnose covid-19 infected patients



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Then, why do we need computers?

3. There may be variations in image interpretations among different clinicians *(inter-observer variability)*

Which ones do you call chair and which ones armchair?

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Then, why do we need computers?

3. There may be variations in image interpretations among different clinicians *(inter-observer variability)*

Which ones do you call chair and which ones armchair?

4. Moreover, interpretations rely on qualitative visual analyses, but no quantitative metrics, which may make consistent decision-making difficult *(intra-observer variability)*

What are the colors of the circles?

White, light-gray or dark-gray?

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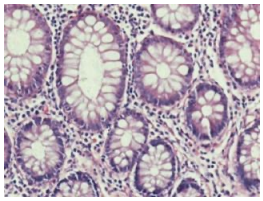
Then, why do we need computers?

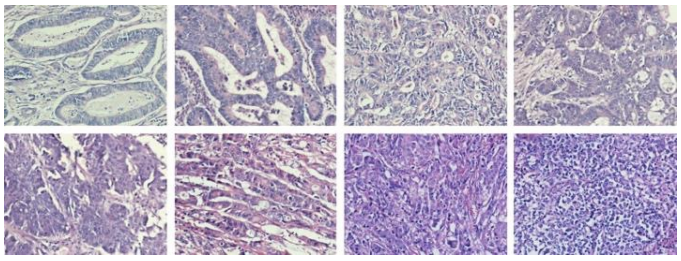
3. There may be variations in image interpretations among different clinicians *(inter-observer variability)*

4. Moreover, interpretations rely on qualitative visual analyses, but no quantitative metrics, which may make consistent decision-making difficult *(intra-observer variability)*

This is how a normal colon tissue looks like



Now grade cancer in tissues below based on the degree of their deformations. Low-grade or high-grade?



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Then, why do we need computers?

1. Some tasks are time-consuming
2. There are too many cases, but limited manpower
3. There may be variations in image interpretations among different clinicians *(inter-observer variability)*
4. Moreover, interpretations rely on qualitative visual analyses, but no quantitative metrics, which may make consistent decision-making difficult *(intra-observer variability)*

Thus, there is need for (semi)automated systems for medical image analysis as they facilitate ***rapid analyses with better reproducibility***

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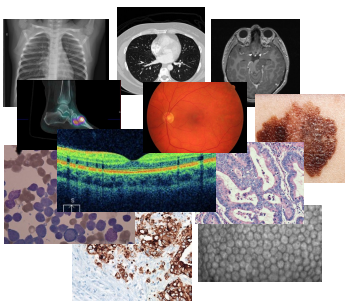
Computational analysis tools

- The goal is to go from medical images to understanding



Diagnosis

Screening

Treatment planning

Prognosis

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Computational analysis tools

- The goal is to go from medical images to understanding *for different medical imaging modalities*
  - Pathology
  - Radiology
  - Nuclear medicine
  - Ophthalmology
  - Dermatology
  - Microscopy
  - …

Lecture 2: Imaging modalities

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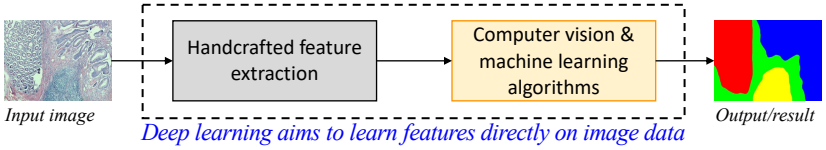
Computational analysis tools

- For computers to understand images, they must
  - Represent an image with mathematical features and
  - Use these features in the design of their algorithms



- Most commonly studied algorithms are for ***segmentation and classification***
- However, feature extraction and algorithm design might be, indeed most of the time are, challenging

Rest of the lectures: Computational techniques for feature extraction and algorithm design

Lecture 3: Design pipeline and challenges

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Course objective and outcomes

- The objective of this course is to provide you with the basic concepts and computational and mathematical methods in medical image analysis

- By the end of this course, you will be equipped with:
  - Basic understanding of medical imaging modalities
  - Familiarity with medical image analysis applications and their challenges
  - Traditional image processing techniques for medical image analysis, and
  - Deep learning for medical image analysis

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Course outline

Week	Subject	Homework
1	Introduction, an overview of imaging modalities	
2-3	An overview of applications and challenges in medical image analysis, filters for medical image enhancement	
4-5-6	***Medical image segmentation*** (region-based segmentation, edge-based segmentation, thresholding, clustering, texture analysis, distance transforms, mathematical morphology, segmentation evaluation, case study on cell segmentation in microscopy images)	
7	***Medical image representation*** (feature extraction for medical images, morphological features, textural features, structural features)	HW1 out
8-9	***Medical image classification*** (basics of classifiers, basics of artificial neural networks, classifier evaluation)	HW2 out
10	***Deep learning*** (basics of convolutional neural networks, convolutional neural networks for medical image classification)	
11-12	***Deep learning*** (encoder-decoder networks, semantic segmentation in biopsy images, tumor/organ segmentation in CT images, retinal layer segmentation in OCT images, multi-task networks for instance segmentation in microscopy images)	HW3 out
13	***Deep learning*** (generative adversarial networks for medical image synthesis, reconstruction and artifact correction in MR images)	
14	***Deep learning*** (multiple-instance learning and self-supervised learning for medical image analysis)	

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Course Details

- ***Instructor*** : Çiğdem Gündüz Demir
  ENG 108A
  cgunduz@ku.edu.tr
  Office hours: through Zoom, by appointment
- ***TA*** : Mehmet Bahadır Erden, merden22@ku.edu.tr
  Seher Özçelik, sozcelik19@ku.edu.tr
  Office hours: through Zoom, by appointment
- ***Lectures*** : TuTh 10:00AM – 11:10AM
- ***Textbook*** : No required textbook
  Course slides and extra material will be available

COMP 448/548 is offered online/ synchronously over Zoom. This teaching method might be changed in early April 2023 according to the YÖK's new regulations. **Lecture recordings will not be available after the class.**

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Prerequisites

- Basic background in calculus, probability, and linear algebra
- Programming ability with any programming language
- Basic knowledge of Python would be helpful
- No knowledge of computer vision and machine learning is necessary

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Coursework

Homework assignments and late policy

- Homework assignments will be posted on the course website
- This will be small programming assignments that help you understand how you can apply the methods that you will learn in class to real-world applications
- For the late assignments, 10 percent of the grade will be deducted per day after the assignment's due date
- You may work individually or in a group of two

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Coursework

Survey

- You will work in a group of two and three
- Each group will prepare a survey on the topic of their interest (of course related to medical image analysis) by
  - Reading at least 8-10 scientific papers and
  - Writing a short report (maximum of 3 pages including citations)

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Coursework

In your survey report,

- Give the problem/topic definition
- Discuss the motivation behind the studies working on this problem/topic (just try to answer the question of "why have all these studies worked on this problem? is it really important?"), and then explain the studies
- While explaining the studies, do NOT list the studies and do NOT explain them one by one. Instead, understand the contribution and methodology of each study, try to group the studies according to their contributions and methodologies, and then explain/discuss the studies as groups (like writing a good introduction section to a scientific paper)
- The quality of the survey as well as those of the selected papers will affect your grade (select good papers published in prestigious conferences and journals)
- Additionally, the format, structure, and writing style of your report (including writing the citations properly) will be a part of your grade

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Coursework

Project

- You will also work in a group of two or three, preferably with the same groupmates
- Each group is expected to select a publicly available medical image dataset and to apply the methods discussed in class for solving the problem defined on the selected dataset
  - Check https://grand-challenge.org
  - There are more publicly available datasets, search for one you will be interested in
- Quality of your selection and the methods applied will affect your grade
- At the end of the semester, as a group, you will write a report (maximum of 5 pages)

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Coursework

In your project report,

- Give the details of your selected dataset and the problem defined on this dataset
- Explain the methods that you will have applied together with the experimental results you will have obtained using these methods
- Discuss and interpret these results, explaining the advantages and limitations of these methods on your selected dataset
- The content of your report as well as its format, structure, and writing style will affect your grade

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Grading Policy

- Homework: 30% (3 homework assignments), *individually or in a group of two*
- Survey: 20%, *working in a group of two or three*
- Term project: 20%, *working in a group of two or three*
- Final: 30%, *individually*

Academic Integrity: This course follows the Koç University Policy on Academic Integrity and the Rules and Regulations of the Higher Education Council. Violations of these rules in the exam, survey, project or homework assignments will be punished subject to these policies.

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Thank you!

Next lecture:

An overview of imaging modalities

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