Introduction to Biomedical Engineering Medical Imaging Processing

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February 5, 2026

Abstract

In modern world health care has becom a critical need. The biomedical engineering applies engineering principles to solve issues in healthcare. The medical image analysis is one of the most important tool used by biomedical engineers to early detect the diseases to prevent them from getting worse. The medical image analysis is the use of imaging techniques to visualize the internal structure of the body. The medical image analysis is the use of imaging techniques to visualize the internal structure of the body. This lecture will discuss a brief overview of biomedical engineering and medical image analysis and its applications.

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1 Introduction

It is said that a picture is worth a thousand words. Instead of using words to explain a complex system, we can use images to visualize it. This is especially true in the field of biomedical engineering and medical imaging. For example if you go to a doctor's office, explaining your symptoms for critical disease is difficult and may have bias with repect person's education and experience. Moreover, the internal symptoms will need invasive procedures to be diagnosed, which may lead to more harm than good. Hence, most of the time doctors rely on evidences from medical images to make a diagnosis. However, this needs a special kind of expertise to interpret the images as images may be of different quality, resolution, and orientation. This is where biomedical engineering and medical imaging come into play. Biomedical engineering is the application of engineering principles to medical problems. Medical imaging is the use of imaging techniques to visualize the internal structure of the body. Medical imaging techniques include X-rays, CT scans, MRI, and ultrasound. The leacture will discuss the overview of biomedical engineering and medical imaging and its applications.

2 Biomedical Engineering

Biomedical engineering is the application of engineering principles to medical problems. It is a multidisciplinary field that combines engineering, biology, and medicine to develop new medical technologies and treatments. Biomedical

engineers use their knowledge of engineering principles to design and develop medical devices, implants, and other medical equipment. They also use their knowledge of biology and medicine to understand the biological and medical aspects of medical problems.

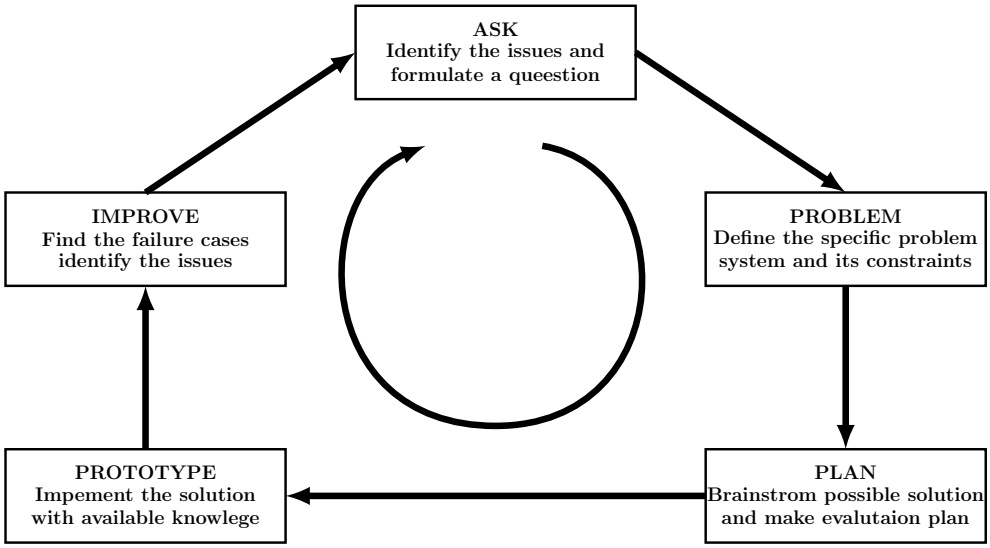


Figure 1: Stages of Problem Solving in Biomedical Engineering

The engineering principles involve Ask questions, define the problem, design a solution, test the solution, and improve the solution.

- Ask questions: Understand the problem and the context.
- Define the problem: Identify the root cause of the problem.
- Design a solution: Create a plan to solve the problem.
- Test the solution: Evaluate the solution and make improvements.
- Improve the solution: Iterate on the solution to make it better.
- The same principles are used to solve biomedical problems. The biomedical engineers try to solve the problems related to human health and well-being.

2.1 The Question

- One of the most important aspect of biomedical engineering is to identify the diseases in early stages and prevent them from getting worse.
- In most of the detection of diseases, require the presence expert medical professionals. However, experts are not readily available in remote areas and developing countries. The computer era has opened up new opportunities to address this issue. Computer can be mad available every where with minimum effort. In modern world, many engineering problems are being solved using computer.
- The leads to the question **“Can the computer detect the diseases in early stages as good as the expert medical professionals?”.**

2.2 The Problem

- In most of the disease cases doctor detects it by symptoms and physical examination. However, due to bias and partial knowledge, the detection may not be accurate.

- This is where medical imaging comes into play. Doctors use medical imaging to have a more depth view of patient condition. Hence, its a fair assumption that a computer can also detect the diseases in early stages as good as the expert medical professionals by analyzing the medical images.
- Which lead to the problem : "**Can a computer analyze medical images and detect the diseases in early stages as good as the expert medical professionals?**".

2.3 Design the Solution

- In this stage an engineer try to come up with all possible alternatives to solve the problem.

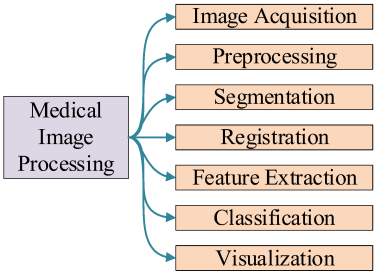


Figure 2: Medical Image Processing

- The analysis of medical images have the following steps:
  - Image Acquisition
  - Image Preprocessing
  - Feature Extraction
  - Classification
  - Postprocessing
- Now each stage is a research in it self. It is complex as the there are many image modalities and each modalities have different characteristics. Moreover, each imaging modality has different resolution, contrast, and noise.
- This is where most of the biomedical engineering researches are focused.

2.4 Test the Solution

- Once the solution is designed, it needs to be tested.
- The testing is done by comparing the output of the solution with the output of the expert medical professionals.
- To make the proposed solution more robust, it is also tested by using different datasets and different image modalities.

2.5 Improve the Solution

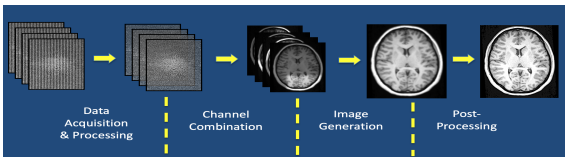
- Once the solution is tested, it needs to be improved.
- The improvement is done by iterating on the solution to make it better.

3 The Role of Medical Imaging in Healthcare

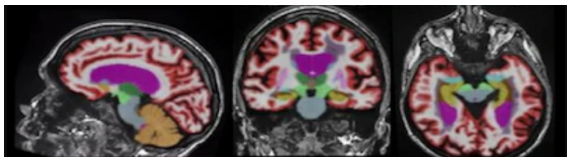
- Medical imaging is the use of imaging techniques to visualize the internal structure of the body. Medical imaging techniques include X-rays, CT scans, MRI, and ultrasound.

3.1 Brain Imaging Analysis

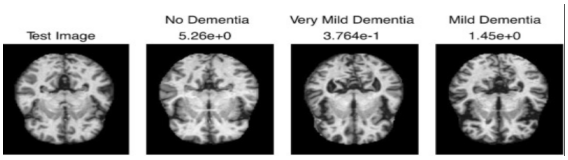
- Brain image analysis is used to enhance and analyze the brain images to detect the diseases in early stages.
- Following are some of the brain image analysis usecases:
- Brain Image Reconstruction
- Brain Image Segmentation
- Brain Image Registration
- Brain Image Classification
- Brain Image Detection



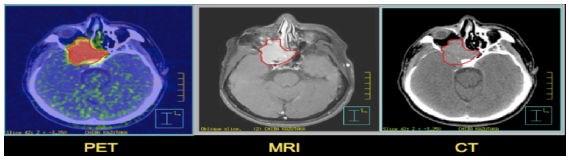
(a) Brain image reconstruction



(b) Brain image segmentation



(c) Brain image classification

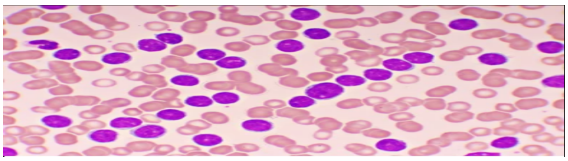


(d) Brain image fusion

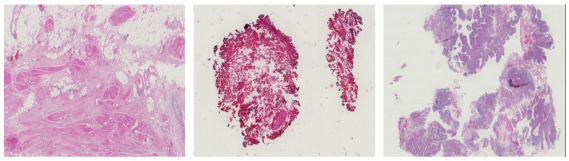
Figure 3: Brain Image Analysis

3.2 Pathology Image Analysis

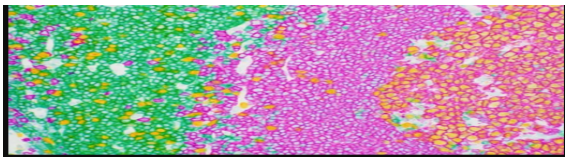
- Pathology image analysis is used to enhance and analyze the pathology images to detect the diseases in early stages.
- In the microscopic images are taken from the tissue samples and analyzed to detect the diseases in early stages.
- Some the usecases are:
- Cance cell detection (Lukemia, Cervical Cancer, Breast Cancer, etc.)
- Immunohistochemistry (IHC) analysis (It involves the process of selectively identifying antigens in cells and tissue.)
- Classification Tissue Images (Histopathology images are classified based on the type of tissue and the presence of diseases.)



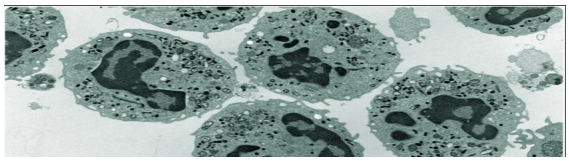
(a) Leukemia detection



(b) Classification of tissue images



(c) Immunohistochemistry (IHC)



(d) Microscopic image classification

Figure 4: Pathology Image Analysis

3.3 Dermatology Image Analysis

- Dermatology image analysis is used to study the skin images to detect the diseases in early stages.
- Some the use cases are:
  - Skin Cancer Detection
  - Skin Lesion Segmentation
  - Skin Lesion Classification
  - Skin Lesion Detection

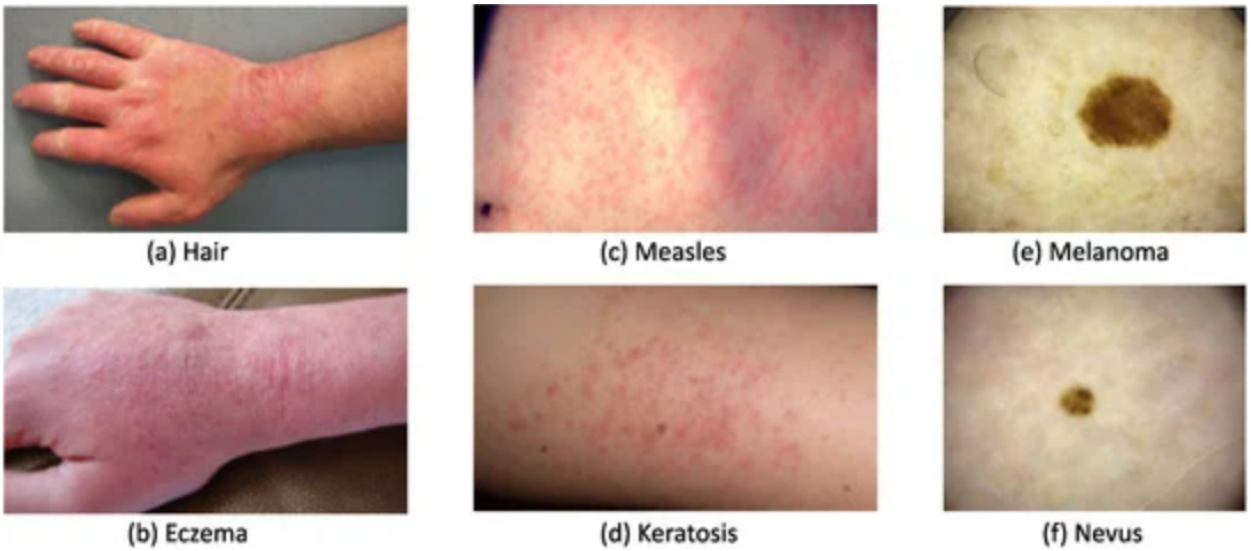
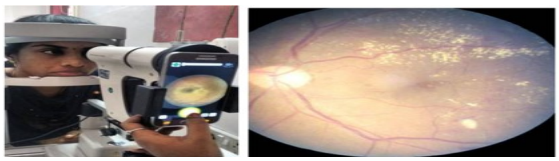


Figure 5: Dermatology Image Analysis

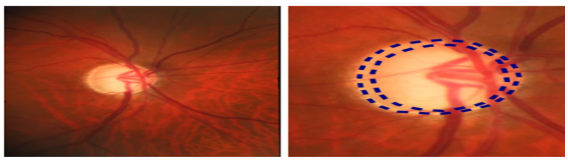
3.4 Ophthalmology Image Analysis

- Ophthalmology image analysis is used to study the eye images to detect the diseases in early stages.
- Some the use cases are:
  - Diabetic Retinopathy Detection
  - Glaucoma Detection

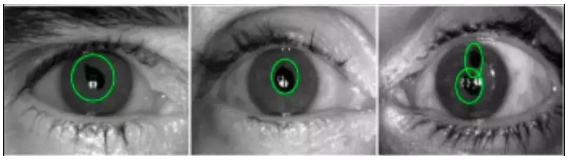
- Cataract Detection
- Macular Degeneration Detection



(a) Diabetic Retinopathy Detection



(b) Glaucoma Detection



(c) Cataract Detection

Figure 6: Ophthalmology Image Analysis

3.5 Pulmonary Image Analysis

- Pulmonary image are used to study the condition of lungs. It is essential for the patient with respiratory problems.
- Some the use cases are:
  - Pneumonia Detection
  - Tuberculosis Detection
  - Lung Cancer Detection
  - COVID-19 Detection

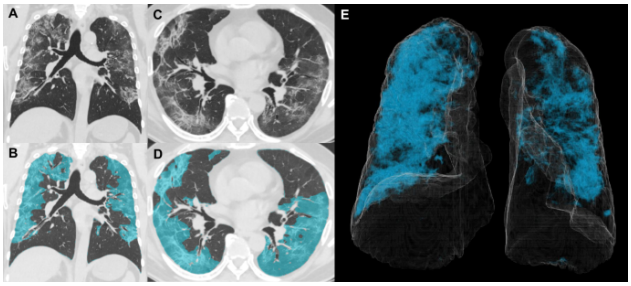


Figure 7: Pulmonary Image Analysis

3.6 Dental Image Analysis

- Dental image analysis is used to study the condition of teeth and oral cavity. It is essential for the patient with dental problems.
- Some the use cases are:
  - Dental Caries Detection
  - Dental Implant Planning
  - Dental Implant Placement
  - Dental Implant Removal

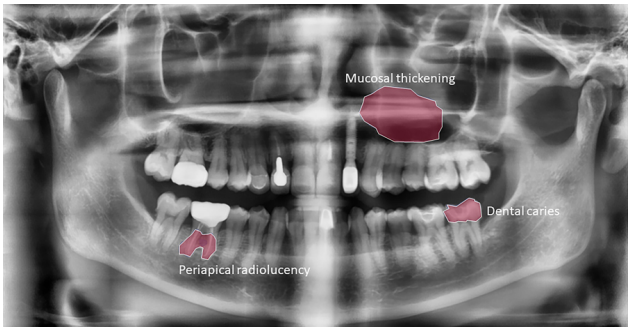


Figure 8: Dental Image Analysis

3.7 Natural Language Processing in Electronic Health Records

- NLP on precrption and clinical note can be used to find pattern and relations between diseases and drugs. It can also be used to detect the diseases which may be overlooked by the doctors.
- Some the use cases are:
  - Disease Detection
  - Drug Discovery
  - Treatment Recommendation
  - Patient Monitoring

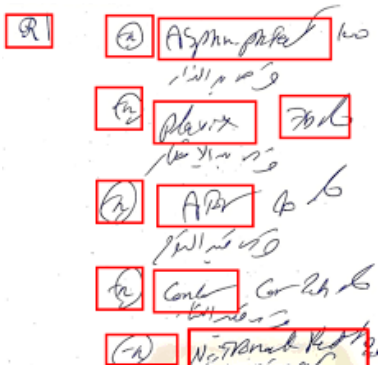


Figure 9: Natural Language Processing in Electronic Health Records

4 Conclusion

The modern era has brought many new challenge related to health and medical field. These challeges can only be solved by using engineering principle to design solutions. Biomedical engineering is evloved to apply engineering principles to medical field to solve these challenges. Medical image processing is one of the most important field in biomedical engineering. It helps in design of effecient system for patient diagnosis and treatment. The future of medical image processing needs inclusion of patient emmotion and behavior in the system. The study of new modalities and new techniques is required to make the medical image processing more accurate, efficient and cost effective.