NANYANG TECHNOLOGICAL UNIVERSITY SINGAPORE

COURSE CONTENT

Academic Year	2023/2024	**Semester**	1
Course Coordinator	Dr. Pui Tze Sian / TBC		
Course Code	BG3104		
Course Title	Biomedical Imaging (Core)		
Pre-requisites	Nil		
No of AUs	3		
Contact Hours	26 hours lecture, 13 hours tutorial		
Proposal Date	14 October 2019		

Course Aims

This course aims to support you in learning the fundamentals of medical imaging, and image processing techniques. Medical imaging techniques include X-ray projection imaging, X-ray Computed Tomography (CT), Nuclear imaging, Magnetic resonance imaging, Ultrasounds, and optical imaging shall be introduced.

Intended Learning Outcomes (ILO)

By the end of this course, you (as a student) would be able to:

1. Describe biomedical imaging and various imaging modalities
2. Analyse the mathematical functions used in biomedical imaging
3. Elaborate on how x-ray imaging is done
4. Describe how CT image acquisition works, and various types of image reconstruction used in CT.
5. Describe Nuclear Imaging. Explain how PET and SPECT is done
6. Explain basic principles of ultrasound imaging, various modes of ultrasound imaging
7. Summarize motivation behind optical imaging, explain the concept of Optical coherence tomography (OCT)
8. Explain the purpose of digital image processing and states examples of how digital image processing is used in biomedical imaging
9. Illustrate the basic of image sampling, quantization, spatial and intensity resolution and their effects on image appearance
10. Explain the mechanics of spatial filtering and how they are applied to enhance image.
11. Apply different approaches for image segmentation
12. Describe the key processes in generation of MR signals from the body, including precession, RF excitation and resonance
13. Describe the slice selection, phase encoding and frequency encoding in the creation of MR images.
14. Explain basic pulse sequence and describe how contrast (T1 weighted and T2 weighted) is achieved in MR imaging.

Course Content

This course introduces Biomedical Imaging at a fundamental level. Medical image processing techniques. X-ray imaging. CT scan. Magnetic resonance imaging. Ultrasounds and ultrasonic imaging. Nuclear imaging. Optical Imaging.

Assessment (includes both continuous and summative assessment)

Component	Course LO Tested	Related Programme LO or Graduate Attributes	Weighting	Team/ Individual	Assessment rubrics
1. Continuous assessment 1(Quiz)	1,2,3,4,5, 6	EAB SLOs a, b	20%	Individual	Refer to appendix 1
2. Continuous assessment 2 (Quiz)	8,9,10,11	EAB SLOs a, b, c	20%	Individual	Refer to appendix 1
3. Final Examination (2hrs, Closed Book)	1,2,3,4,5, 6,7,8,9,10 ,11,12,13, 14	EAB SLOs a, b, c, d, f, j, l	60%	Individual	Refer to appendix 2
Total			100%		

Mapping of Course ILOs to EAB Graduate Attributes

Course Intended Learning Outcomes	Cat	EAB's 12 Graduate Attributes*											
		(a)	(b)	(c)	(d)	(e)	(f)	(g)	(h)	(i)	(j)	(k)	(l)
	Core	●	◐	◐	š		š		š		◐		š
Describe biomedical imaging and various imaging modalities		a, f, j, l											
Analyze the mathematical functions used in biomedical imaging		a, b, d											
Elaborate on how x-ray imaging is done		a, j											
Describe how CT image acquisition works, and various types of image reconstruction used in CT.		a, b, c											
Describe Nuclear Imaging. Explain how PET and SPECT is done		a, j											
Explain basic principles of ultrasound imaging, various modes of ultrasound imaging		a, b, c, j											
Summarize motivation behind optical imaging, explain the concept of Optical coherence tomography (OCT)		a, j											
Explain the purpose of digital image processing and states examples of how digital image processing is used in biomedical imaging		a, d, l											
Illustrate the basic of image sampling, quantization, spatial and intensity resolution and their effects on image appearance		a, b, j											
Explain the mechanics of spatial filtering and how they are applied to enhance image.		a, b, j											
Apply different approaches for image segmentation		a, b, c											

Describe the key processes in generation of MR signals from the body, including precession, RF excitation and resonance	a, j
Describe the slice selection, phase encoding and frequency encoding in the creation of MR images.	a, b, j
Explain basic pulse sequence and describe how contrast (T1 weighted and T2 weighted) is achieved in MR imaging.	a, d, j, l

Legend:
- ● Fully consistent (contributes to more than 75% of Intended Learning Outcomes)
- ◐ Partially consistent (contributes to about 50% of Intended Learning Outcomes)
- š Weakly consistent (contributes to about 25% of Intended Learning Outcomes)
- Blank Not related to Student Learning Outcomes

Formative feedback

Examination results;
Marker's report on overall examination performance will be uploaded to NTUlearn;
Quiz answers will be discussed in class

Learning and Teaching approach

Approach	How does this approach support students in achieving the learning outcomes?
Lecture	Demonstrate how to carry out a procedure such as working through a problem, use incomplete handouts which enabling students participating in class.
Tutorial	TBL classroom discussion sessions on tutorial questions and related topics

Reading and References

1. Jerry L. Prince, Jonathan Links, Medical Imaging Signals and Systems, Pearson Prentice Hall, 2006
2. L. V. Wang, Biomedical Optics, Wiley, 2007.
3. Rafael C. Gonzalez and Richard e. Woods, Digital Image Processing, 3rd edition, Prentice Hall, 2008.

Course Policies and Student Responsibilities

General: Students are expected to complete all online activities and take all scheduled assignments and tests by due dates. Students are expected to take responsibility to follow up with course notes, assignments and course related announcements. Students are expected to participate in all tutorial discussions and activities.

Continuous assessments: Students are required to attend all continuous assessments.
Absenteeism: Continuous assessments make up a significant portion of students' course grade. Absence from continuous assessments without officially approved leave will result in no marks and affect students' overall course grade.

Academic Integrity

Good academic work depends on honesty and ethical behaviour. The quality of your work as a student relies on adhering to the principles of academic integrity and to the NTU Honour Code, a set of values shared by the whole university community. Truth, Trust and Justice are at the core of NTU's shared values.

As a student, it is important that you recognize your responsibilities in understanding and applying the principles of academic integrity in all the work you do at NTU. Not knowing what is involved in maintaining academic integrity does not excuse academic dishonesty. You need to actively equip yourself with strategies to avoid all forms of academic dishonesty, including plagiarism, academic fraud, collusion and cheating. If you are uncertain of the definitions of any of these terms, you should go to the academic integrity website for more information. Consult your instructor(s) if you need any clarification about the requirements of academic integrity in the course.

Course Instructors

Instructor	Office Location	Phone	Email
Alex Pui	N1.3 B2-12	6790 4485	tspui@ntu.edu.sg
TBC			

Planned Weekly Schedule

Week	Topic	Course LO	Readings/ Activities
1	Introduction of Biomedical imaging	1	Face to face lecture Tutorial 1
2	Signals and Systems	2	Face to face lecture Tutorial 2
3	X-ray imaging	3	Face to face lecture Tutorial 3
4	CT	3, 4	Face to face lecture Tutorial 4
5	Nuclear Imaging	5	Face to face lecture Tutorial 5
6	Ultrasound Imaging	5, 6	Face to face lecture Tutorial 6
7	Optical Imaging	7	Face to face lecture Tutorial 7
8	Fundamentals of image processing	8	Face to face lecture Tutorial 8
9	Image enhancement	9	Face to face lecture Tutorial 9
10	Image segmentation	10	Face to face lecture Tutorial 10
11	Magnetic resonance physics	11	Face to face lecture Tutorial 11
12	Creating images in MRI	12,13	Face to face lecture Tutorial 12
13	Spin echo sequence and image contrast	13,14	Face to face lecture Tutorial 13

Appendix 1: Assessment Criteria

Criteria	Unsatisfactory: <40%	Borderline: 40% to 49%	Satisfactory: 50% to 69%	Very good: 70% to 89%	Exemplary: > 90%
Knowledge Understanding of principles of biomedical imaging	• Lacks understanding of the principles of biomedical imaging. • Unable to apply the principles of biomedical imaging to solve engineering problems.	• Partial understanding of the principles of biomedical imaging. • Can apply the principles of biomedical imaging to solve simple engineering problems.	• Good understanding of the principles of biomedical imaging. • Can apply the principles of biomedical imaging to solve medium level engineering problems	• Good and comprehensive understanding of the principles of biomedical imaging. • Can apply the principles of biomedical imaging to solve engineering problems.	• Very good and comprehensive understanding of the principles of biomedical imaging. • Can apply the principles of biomedical imaging to solve engineering problems.
Evaluation Able to solve numerical problems in medical imaging	• Calculations are attempted but are both unsuccessful and are not comprehensive.	• Calculations are attempted but represent only a portion of the calculations required with some comprehensive to solve the problem.	• Calculations attempted are mostly successful and sufficiently comprehensive to solve the problem.	• Calculations attempted are all successful and sufficiently comprehensive to solve the problem.	• Calculations attempted are all successful and fully comprehensive to solve the problem; calculations are also presented elegantly

Appendix 2: Assessment Criterial for Final exam

Criteria	Unsatisfactory: <40%	Borderline: 40% to 49%	Satisfactory: 50% to 69%	Very good: 70% to 89%	Exemplary: >90%
Knowledge & Comprehension Understanding of principles of biomedical imaging	• Lacks understanding of the principles of biomedical imaging. • Unable to apply the principles of biomedical imaging to solve engineering problems.	• Partial understanding of the principles of biomedical imaging. • Can apply the principles of biomedical imaging to solve simple engineering problems.	• Good understanding of the principles of biomedical imaging. • Can apply the principles of biomedical imaging to solve medium level engineering problems	• Good and comprehensive understanding of the principles of biomedical imaging. • Can apply the principles of biomedical imaging to solve engineering problems.	• Very good and comprehensive understanding of the principles of biomedical imaging. • Can apply the principles of biomedical imaging to solve engineering problems.
Application Applying imaging principles to solve problems	• Unable to understand theoretical concepts of biomedical imaging and apply the knowledge to design and optimize medical imaging systems	• Can read and partially understand theoretical concepts of biomedical imaging and apply the knowledge to design and optimize simple medical imaging systems	• Can read and understand theoretical concepts of biomedical imaging and apply the knowledge to design and optimize simple medical imaging systems	• Can read and understand theoretical concepts of biomedical imaging and apply the knowledge to design and optimize medium level medical imaging systems	• Can read and understand theoretical concepts of biomedical imaging and apply the knowledge to design and optimize medical imaging systems
Evaluation Able to solve numerical problems in medical imaging	• Calculations are attempted but are both unsuccessful and are not comprehensive.	• Calculations are attempted but represent only a portion of the calculations required with some comprehensive to solve the problem.	• Calculations attempted are mostly successful and sufficiently comprehensive to solve the problem.	• Calculations attempted are all successful and sufficiently comprehensive to solve the problem.	• Calculations attempted are all successful and fully comprehensive to solve the problem; calculations are also presented elegantly
Analysis Able to analyze problems, make reasonable assumptions, and choose appropriate methods.	• Unable to make reasonable assumptions and judgment according to the nature of the problems, uncertain about drawing any conclusions.	• Can make reasonable assumptions and judgment, but the choice of methods are not appropriate, uncertain about the accuracy of the outcome.	• Can make reasonable assumptions and judgment, can choose appropriate methods and predict the outcome mostly, but not necessarily the best choice.	• Can make reasonable assumptions and judgment, can choose appropriate methods and predict the outcome, can draw reasonable conclusions.	• Can make correct assumptions, can choose appropriate methods to solve the problem and draw conclusions. Can identify potential problems and tailor the process accordingly.

Appendix 3: The EAB (Engineering Accreditation Board) Accreditation SLOs (Student Learning Outcomes)

a) **Engineering knowledge:** Apply the knowledge of mathematics, natural science, engineering fundamentals, and an engineering specialisation to the solution of complex engineering problems
b) **Problem Analysis:** Identify, formulate, research literature, and analyse complex engineering problems reaching substantiated conclusions using first principles of mathematics, natural sciences, and engineering sciences.
c) **Design/development of Solutions:** Design solutions for complex engineering problems and design system components or processes that meet the specified needs with appropriate consideration for public health and safety, cultural, societal, and environmental considerations.
d) **Investigation:** Conduct investigations of complex problems using research-based knowledge and research methods including design of experiments, analysis and interpretation of data, and synthesis of the information to provide valid conclusions.
e) **Modern Tool Usage:** Create, select, and apply appropriate techniques, resources, and modern engineering and IT tools including prediction and modelling to complex engineering activities with an understanding of the limitations
f) **The engineer and Society:** Apply reasoning informed by the contextual knowledge to assess societal, health, safety, legal, and cultural issues and the consequent responsibilities relevant to the professional engineering practice.
g) **Environment and Sustainability:** Understand the impact of the professional engineering solutions in societal and environmental contexts, and demonstrate the knowledge of, and need for the sustainable development.
h) **Ethics:** Apply ethical principles and commit to professional ethics and responsibilities and norms of the engineering practice.
i) **Individual and Team Work:** Function effectively as an individual, and as a member or leader in diverse teams and in multidisciplinary settings.
j) **Communication:** Communicate effectively on complex engineering activities with the engineering community and with society at large, such as, being able to comprehend and write effective reports and design documentation, make effective presentations, and give and receive clear instructions.
k) **Project Management and Finance:** Demonstrate knowledge and understanding of the engineering and management principles and economic decision-making, and apply these to one's own work, as a member and leader in a team, to manage projects and in multidisciplinary environments.
l) **Life-long Learning:** Recognise the need for, and have the preparation and ability to engage in independent and life-long learning in the broadest context of technological change