DEPARTMENT OF INSTRUMENTATION AND CONTROL ENGINEERING												
M.Tech. in IMMERSIVE TECHNOLOGIES												
Program Structure												
YEAR	FIRST SEMESTER						SECOND SEMESTER					
	SUB CODE	SUBJECT NAME	L	T	P	C	SUB CODE	SUBJECT NAME	L	T	P	C
I		Applied Mathematics	3	1	0	4		Sensation and Perception	4	0	0	4
		Introduction to Augmented Reality and Virtual Reality	4	0	0	4		Haptics	4	0	0	4
		Content creation for Virtual Reality And Augmented Reality	3	1	0	4		Program Elective 1	4	0	0	4
		Psychophysics	4	0	0	4		Program Elective 2	4	0	0	4
		Advanced Computer Vision	3	1	0	4		Program Elective 3	4	0	0	4
		Research Methodology & Technical Communication*	1	0	3	-		Open elective	3	0	0	3
		Augmented Reality and Virtual Reality simulation lab	0	0	3	1		Research Methodology & Technical Communication*	0	0	3	2
		Computer Vision lab	0	0	3	1		Haptic lab	0	0	3	1
								APP Development Lab	0	0	3	2
	Total		18	3	9	22			23	0	9	28
	THIRD AND FOURTH SEMESTER											
II		PROJECT WORK & INDUSTRIAL TRAINING							0	0	0	25

Program Electives
Spatial Audio
XR Development Techniques
Artificial Intelligence
Deep Learning
Machine Learning
Virtual Instrumentation
3d Shape Analysis
Sound Design

FIRST SEMESTER

APPLIED MATHEMATICS [3 1 0 4]

Finite dimensional vector space, subspaces, linear independence, bases and dimension, algebra of transformations, range and null space of a linear transformation, matrix algebra, simultaneous equations. Sum and intersection of subspaces, direct sum of invariant subspaces, eigen values, characteristic vectors, Cayley-Hamilton theorem, minimal polynomial, Sylvester's interpolation method, various canonical form. Algebra of polynomial matrices, invariant. Polynomial matrices, invariant polynomials, Smith canonical form. Inner-product spaces, Gram Schmidt orthogonalization, decomposition. Some computational methods of linear algebra. Probability theory: review of set theory; introduction to probability, axioms of probability; joint and conditional probability; Bayes theorem.

References:

1) P. L. Meyer, Introductory Probability and Statistical Applications, Addison-Wesley Publishing Company, 1970.
2) Finkbeiner D. T. I, Introduction to Matrices and linear Transformation, D.B. Taraorewala's, 1968.
3) Hoffman. K and Kunze. R, Linear Algebra, Prentice Hall of India, 1972.
4) Gantmocher F. R., The Theory of Matrices, Cheisea, 1960.
5) Goult. R. J, Hoskin. R. P, Milner J. A and Pratt M. J, Computational methods in Linear Algebra, Stanley Thomas Pub. Ltd., 1974.

INTRODUCTION TO AUGMENTED REALITY AND VIRTUAL REALITY: [4 0 0 4]

Definition of X-R (AR, VR, MR), Hardware, sensors, displays, software, virtual world generator, game engines. Geometric modeling, transforming rigid bodies, quaternions, 3D rotation inverses and conversions, homogeneous transforms, canonical view and perspective transform, Interpretation of light, reflection, optical systems. Photoreceptors, Eye and Vision, Motion, Depth Perception, Frame rates and displays. Orientation, Tilt, Drift, Yaw, Lighthouse approach. Touch, haptics, taste, smell, robotic interfaces, telepresence, brain-machine interfaces. Optics, Inertial Measurement Units, Orientation Tracking with IMUs, Panoramic Imaging and Cinematic VR, Audio.

References:

1) Shirley, M., Fundamentals of Computer Graphics, 4th Edition, CRC Press, 2016.
2) LaValle, Virtual Reality, Cambridge University Press, 2016.
3) Schmalstieg D, and Hollerer T., Augmented Reality: Principles & Practice, Pearson Education India, 2016

CONTENT CREATION FOR VIRTUAL REALITY AND AUGMENTED REALITY: [3 1 0 4]

Introduction: 3D Viewport Work Modes, Rotating in 3D Space, Adding vertices by subdivision, last operator panel, Storyboard, camera view, quick effects. Editor types, 3D viewport features, scene manipulation, Headers Menus and Panels. Navigate and Save, Objects in the 3D View Editor, Materials – Textures – Nodes, Procedural Texture, Adding Texture Nodes, Image as a Texture, Texture mapping, Texture properties, Node Systems and usage, Scene lighting and cameras, Viewport shading. Rendering, Animation, Armatures and Character Rigging, 3D Text. Viewing scene in VR, importing, Introduction to the interface and Scene Setup. Creating a VR App, Creating an AR App with above content

References:

1) Blain, J. M., The complete guide to Blender graphics: computer modeling & animation. AK Peters/CRC Press, 2019.
2) Hess, R., Blender Foundations: The Essential Guide to Learning Blender 2.5. Routledge, 2013.

PSYCHOPHYSICS: [4 0 0 4]

Sensation: Introduction to perception, basics of psychophysics, Psychophysical laws: Weber's law, Fechner's law and Steven's Power law; Psychophysical measurement of thresholds: Absolute Sensitivity, Differential Sensitivity. Theory of Signal detection (TSD): receiver operating characteristics, sensitivity, response bias, procedures of TSD, applications of TSD, Measurement of Sensory Attributes and Discrimination scales. Classical Psychophysical Methods, Psychophysical Ratio Scaling methods: Evaluation of ratio scaling methods. Statistical Hypothesis testing methods: z-test, t-test, F-test, ANOVA.

References:

1) G. A. Gescheider, "Psychophysics: The Fundamentals," 3rd ed., Lawrence Erlbaum Associates, Publishers, 1997.
2) E. B. Goldstein, "Sensation and Perception," 7th Ed., Thomson Wadsworth, 2007

ADVANCED COMPUTER VISION: [3 1 0 4]

Fundamentals for Advanced CV: 3D Deep Learning, Generative Models. Point, Cloud and Mesh Representation, 3D Feature Learning, Correspondences Estimation. Neural Radiance Fields, Neural Rendering. 3D Capture and Reconstruction: RGB-D scanning (Kinect, RealSense), camera tracking, sensor calibration. Non-Rigid Registration, Implicit Representation Learning, Completion. Motion Capture, Body-, Face-, and Hand-Tracking. Modeling and Animating 3D Humans: Body Models, SCAPE, SMPL, Bodies from RGBD, 3D Faces and Expressions. Clothing Capture and Modeling, Capturing Contacts, 3D Hands-Object Interaction. Putting People into 3D scenes, Inferring Actions, Modeling Human Movements.

References:

1) Szeliski, R., Computer vision: algorithms and applications. 2nd edition. Springer, 2022
2) Botsch, M., Kobbelt, L., Pauly, M., Alliez, P., & Lévy, B., Polygon mesh processing. CRC press, 2010.

RESEARCH METHODOLOGY AND TECHNICAL COMMUNICATION [1 0 3 -]

Research methodology: basic concepts: types of research, significance of research, research framework. Sources of data, methods of data collection. Research formulation: components, selection and formulation of a research problem, objectives of formulation, and criteria of a good research problem. Research hypothesis: criterion for hypothesis construction, nature of hypothesis, characteristics and types of hypothesis, elements of research design, introduction to various sampling methods sources of data, collection of data, research reports, references styles, effective presentation techniques, research ethics.

References:

1) Sekaran, U., & Bougie, R. (2016). Research methods for business: A skill building approach. John Wiley & Sons.
2) Zikmund, W. G., Babin, B. J., Carr, J. C., & Griffin, M. (2013). Business research methods. Cengage Learning.
3) Creswell, J. W., & Creswell, J. D. (2017). Research design: Qualitative, quantitative, and mixed methods approaches. Sage Publications.
4) Donald R Cooper & Pamela S Schindler, Business Research Methods, McGraw Hill International, 2018.

AUGMENTED REALITY AND VIRTUAL REALITY SIMULATION LAB: [0 0 3 1]

Interfacing and modelling, Texturing and Shading, viewing scene in VR, importing, Introduction to the interface and Scene Setup, Creating a VR App, Creating a AR App with above content

References:

Relevant references for the tools used (shall be shared during the lab appropriately)

COMPUTER VISION LAB: [0 0 3 1]

3D Deep Learning, Generative Models, 3D Feature Learning, RGB-D scanning (Kinect, RealSense), camera tracking, 3D Capture and Reconstruction, Motion Capture, Modeling and Animating 3D Humans.

References:

1) Szeliski, R., Computer vision: algorithms and applications. 2nd edition. Springer, 2022.
2) Botsch, M., Kobbelt, L., Pauly, M., Alliez, P., & Lévy, B., Polygon mesh processing. CRC press, 2010.

SECOND SEMESTER

SENSATION AND PERCEPTION: [4 0 0 4]

Introduction – history and philosophy, Methods & Techniques: Signal Detection Theory. Physiology of Perception, Neuroimaging, Bottom-Up vs. Top-Down, Cutaneous Senses, Pain, Olfaction (smell), Gustation (taste), Flavor, Speech, Visual System: Pathways, Visual Functions. Auditory System: Pathways, Fundamental Auditory Functions, Auditory Localization, Auditory Scene Analysis. Object Perception, Visual Attention, taking action, Motion Detection. Color Vision, Depth and Size Perception, Constancy & Illusions, and Camouflage

References:

1) Goldstein, E. B. & Brockmole, James R., Sensation and Perception, 10th Edition. Cengage Learning, 2017.

HAPTICS: [4 0 0 4]

Human Haptics: Haptic Sensations- Kinesthetic and Tactile, Physiology of Human Touch, Overview of Haptic Interfaces, Applications of Haptics. Haptic Perception- Kinesthetic/Tactile, Multisensory Interactions, Psychophysics for Haptic Perception: \ Classical and Modern Psychophysical Methods. Basic Concepts and Steps of Haptic Rendering, Rendering Stability. 3 DoF Rendering, Haptic Volume Rendering; Texture/Tactile Rendering, Friction Rendering, Measurement-based/Data-driven Haptic Rendering. Overview of a TPTA system, Issues for Haptic Transmission, Kinesthetic Data Compression, Tactile Data Compression, Haptics over Shared Network. Emerging areas in Haptics Surface Haptics- Electrostatic vs Ultrasonic; Mid-air Haptics, Haptic Interaction in Virtual and Augmented Reality (VR/AR).

References:

1) Bhardwaj and S. Chaudhuri, Kinesthetic Perception: A Machine Learning Approach, Springer Publishers, 2017.
2) MC Lin and MA Otaduy (Eds), Haptic Rendering: Foundations, Algorithms, and Applications, AK Peters, Ltd; London: 2008.
3) G. A. Gescheider, Psychophysics: The Fundamentals, 3rd ed., Lawrence Erlbaum Associates, Publishers, 1997.

RESEARCH METHODOLOGY AND TECHNICAL COMMUNICATION [0 0 3 2]

Students will work with faculty mentor towards converting literature survey with possible extension into a publication at the end of second semester.

HAPTIC LAB: [0 0 3 1]

Haptic Sensations- Kinesthetic and Tactile, Haptic Perception- Kinesthetic/Tactile, Multisensory Interactions, 3 DoF Rendering, Measurement-based/Data-driven Haptic Rendering, Kinesthetic Data Compression, Tactile Data Compression, Haptics over Shared Network, brain computer interface.

References:

1) Bhardwaj and S. Chaudhuri, Kinesthetic Perception: A Machine Learning Approach, Springer Publishers, 2017.
2) MC Lin and MA Otaduy (Eds), Haptic Rendering: Foundations, Algorithms, and Applications, AK Peters, Ltd; London: 2008.
3) G. A. Gescheider, Psychophysics: The Fundamentals, 3rd ed., Lawrence Erlbaum Associates, Publishers, 1997.

APP DEVELOPMENT LAB: [0 0 3 2]

Specifying components of a VR application, Software modules in a VR application, Senses and VR device for those senses, Device APIs, and their integration, 3D world, Gaze, Tracking, Touch, Pseudo-physics for VR, Manipulation and Interaction with objects, Integrating traditional interfaces in VR, The notion of cognitive load on human sensing and memory, Multi-user VR and Social interaction, Setup AR Foundation, Create a face filter using AR Foundation, Create the web-based AR application using AR.js Studio, Create a spark AR Filter, Publish the spark AR filter, Create a simple Augment Reality App build.

Open ended experiments: application of AR/VR in gaming, health care, media, sports, education, and industrial case studies

References:

1) Greengard, Samuel. Virtual reality. Mit Press, 2019.
2) M. Nebling, Developing AR/VR/MR/XR Apps with WebXR, Unity & Unreal, University of Michigan, https://www.coursera.org/learn/develop-augmented-virtual-mixed-extendedreality-applications-webxr-unity-unreal

PROGRAM ELECTIVES:

SPATIAL AUDIO: [4 0 0 4]

Introduction to spatial audio: importance of audio in immersive AR/VR experience. Audio as physical phenomenon, properties of hearing, cues in spatial hearing, time and level difference for audio perception. Auditory events and vector-base panning: loudness, directionality, vector models. Binaural audio: head related transfer function (HRTF) basics, HRTF measurement in practice, use of HRTF in audio rendering, binaural audio reproduction technology. Amplitude panning techniques, Introduction to ambisonics, Format conversion, ambisonic rendering engines and use-cases. Use-cases of spatial audio for immersive AR/VR: Immersive walkthrough, gaming, event simulation etc.

References:

1) Zotter, F., & Frank, M., Ambisonics: A practical 3D audio theory for recording, studio production, sound reinforcement, and virtual reality (p. 210). Springer Nature, 2010.
2) Rumsey F., Spatial Audio, Routledge Publisher, 2012.

XR DEVELOPMENT TECHNIQUES: [4 0 0 4]

Introduction of Virtual Reality: Fundamental Concept and Components of Virtual Reality. Input -Tracker, Sensor, Digital Glove, Movement Capture, Video-based Input, 3D Menus & 3DScanner etc. Output – Visual. Auditory / Haptic Devices: Fundamentals of Computer Graphics. Software and Hardware Technology on Stereoscopic Display. Advanced Techniques in CG, Environments & Real Time Rendering, Interactive Techniques in Virtual Reality, Application of VR in Digital Entertainment, Introduction of Augmented Reality (AR), Development Tools and Frameworks in Virtual Reality, X3D Standard; Vega, MultiGen, Virtools etc.

References:

1) Mobeen Tahir, Mark Ghattas, Dawit Birhanu, Syed Natif Nawaz, “Cisco IOS XR Fundamentals”, 2009.
2) Wiley, “Emerging Extended Reality Technologies for Industry 4.0”, 2020.
3) Carmine Elvezio, “XR Development with the Relay and Responder Pattern”, 2021

ARTIFICIAL INTELLIGENCE: [4 0 0 4]

Introduction, agents and rationality, task environments, agent architecture types-search and knowledge representation-search spaces-uninformed and informed search- hill climbing, simulated annealing, genetic algorithms - logic based representations (PL, FOL) and inference, Prolog- rule based representations, forward and backward chaining, matching algorithms- probabilistic reasoning and uncertainty- Bayes nets and reasoning with them - uncertainty and methods to handle it – learning - forms of learning - statistical methods: naive-bayes, nearest neighbor, kernel, neural network models, noise and over fitting - decision trees, inductive learning - clustering - basic agglomerative, divisive algorithms based on similarity/dissimilarity measures - applications to nlp, vision, robotics.

References:

1. Russel,S., and Norvig,P., (2015), Artificial Intelligence: A Modern Approach, 3rd Edition, Prentice Hall.

2. Stuart Russell and Peter Norvig, Artificial Intelligence: A Modern Approach (3e), Pearson, 2012.
3. Elaine Rich, Kevin Knight and Shivashankar B. Nair, Artificial Intelligence (3e), Tata McGraw Hill, 2012.
4. David Poole and Alan Mackworth, Artificial Intelligence: Foundations of Computational Agents (2e), Cambridge University Press, 2017.
5. Nils Nilsson, Artificial Intelligence: A New Synthesis, Morgan Kaufmann, 1998.

DEEP LEARNING: [4 0 0 4]

Contents Neural networks: DL Optimizers (SGD, MBGD, AdaGrad, Adam) and Regularization, Initialization Methods. DL Models: Autoencoder, Convolutional Neural Networks, Recurrent Neural Networks, LSTM, Network Architecture Search (NAS). Deep Generative Models: Deep Belief Networks, Variational Autoencoders, Generative Adversarial Networks, Deep Convolutional GAN. Representation learning: Unsupervised Pre-training, Transfer learning and Domain adaptation, Distributed representation, Discovering underlying causes.

References:

1) GoodFellow, Y. Bengio, A. Courville, Deep Learning, The MIT Press, 1st Edition, 2016.
2) Zhang, Z. Lipton, M. Li, A. Smola, Dive into Deep Learning (Release 0.7.1), https://d2l.ai/d2l-en.pdf, 2020.
3) D. Foster, Generative Deep Learning, O'Reilly Media, 1st Edition, 2019.

MACHINE LEARNING [3 0 2 4]

Introduction to machine learning, mathematical preliminaries, supervised learning: logistic regression, generative learning algorithms, GDA, SVM, model selection, ensemble methods, learning theory: bias/variance tradeoff, union, Chernoff and Hoeffding bounds, VC dimension. Unsupervised Learning: K-means, EM, GMM, factor analysis, PCA, ICA, reinforcement learning and control: MDPs, Bellman equation, LQR, LQG, and Q-learning

References:

1. Kevin P Murphy, Machine Learning: A Probabilistic Perspective, MIT Press, 2012.
2. Mehryar Mohri, Afshin Rostamizadeh, and Ameet Talwalkar, Foundations of Machine Learning, MIT Press, 2012.
3. Christopher M.Bishop, Pattern Recognition and Machine Learning, Springer, 2011.
4. Andrew Ng, CS229 Machine Learning, Autumn 2018, Stanford University

VIRTUAL INSTRUMENTATION: [4 0 0 4]

Introduction to LabVIEW: Software environment, modular programming: modular programming in LabVIEW, creating an icon, creating subVIs from sections of VIs, creating standalone applications. strings and file I/O: creating string controls and indicators, string functions, instrument control: GPIB communication, hardware and software architecture and specifications, instrument I/O assistant, data acquisition: transducers, signal conditioning, DAQ hardware configuration, DAQ hardware, IMAQ vision: vision basics, image processing and analysis, building a complete machine vision system.

References:

1. Jovitha Jerome, Virtual Instrumentation using LabVIEW, PHI, 2010.
2. Gary Johnson, LabVIEW Graphical Programming, Second edition, McGraw Hill. 1997

3D SHAPE ANALYSIS: [4 0 0 4]

Basics of differential geometry of curve and surfaces and estimating the quantities such as normals and curvature. 3D Surface Representation, Parametric and Non-parametric, Implicit, Signed Distance Function, Data structures for surface representation, 3D surface reconstruction from point clouds. Isometry, geodesics on triangle meshes, Scalar functions on shapes, discrete Laplace Beltrami operator on triangle meshes, Heat Diffusion on Shapes. 3D Shape Descriptors, Rigid and Non-rigid registration, Functional Maps, 3D Shape correspondences, Intrinsic Symmetry, Shape Repairing: Shape completion, generating printable 3D models from raw point clouds.

References:

1) Botsch, M., Kobbelt, L., Pauly, M., Alliez, P., & Lévy, B., Polygon mesh processing. CRC press, 2010.
2) Solomon, J., Numerical algorithms: methods for computer vision, machine learning, and graphics. CRC press, 2015.

SOUND DESIGN: [4 0 0 4]

Introduction to Sound forge pro – -Workspace, Main Window, Docking and Floating Window, Data Window, Toolbars, Metadata Windows, ACID properties Window, Extracting Audio from CD, Working with Projects, Editing Audio, Navigating, Selecting, And Zooming. Changing File Property and Format, Editing Multichannel Audio, Using Markers, Regions, Commands, Use of Event Tool. Pre-processing Audio. Working with Effects. Use of Acoustic Mirror and Wave, working with video. Digital audio fundamentals, Extracting audio from CDs, Recording audio, Editing audio files, Working with markers, Inverting, reversing, and silencing audio. Effects controls, applying effects in the Multitrack Editor, Effects reference, Multitrack Editor overview, Video and surround sound, Importing video and working with video clips, surround sound, Saving and exporting files. Audio in Game engines – XR BG Music – XR Mono Spatial Audio – XR audio reverbs

References:

1) Audio Engineering Tip's Audio Engineering - Narrated by Donald Reed.
2) Scott-James, Kahra. Sound Design for Moving Image: From Concept to Realization. Bloomsbury Publishing, 2018.
3) Sound Design, Mixing and Mastering with Ableton Live 9 – Jake perrina