Title	**Machine Vision and Image Understanding**
Code	**ECCE 633**
Loading	3 Credit-hours
Pre-Requisite	MATH 312 Complex Variables and Transforms (or equivalent), ENGR 112 Introduction to Computing (or equivalent), and ECCE 302 Signal Processing (or equivalent)
Instructor	Dr. Hasan Al Marzouqi hasan.almarzouqi@ku.ac.ae Tel: 2 6075090; Office: SAN campus, Building 3- 108
Catalog Description	The course covers the fundamental principles of machine vision and image processing techniques. This includes multiple view geometry and probabilistic techniques as related to applications in the scope of robotic and machine vision and image processing by introducing concepts such as segmentation and grouping, matching, classification and recognition, and motion estimation.
Goal	To provide a sound understanding of practices and mathematical principles of machine vision for diversified application. Learning to critically examine requirements and constraints of typical applications of machine vision. Developing solutions of exemplary problems using the acquired skills.
Contents	1. Principles of Machine Vision What is machine vision? Brief history; Typical applications. Image Perception and Imaging Devices: B/W and color image functions; 3D to 2D projections; Lighting, reflectance and shading; Images as linear systems (lens distortion); Visual perception of images; Image quality; Noise in images. 2. Image Acquisition and Projective Transformations Image discretization (sampling, quantization, aliasing); Metrics and topology in digital images; 2D and 3D geometric transformations. Projective Transformations. 3. Image Enhancement Point operations; Color transformations; Histogram processing; Image transforms; Image filtering; Edge detection; Morphological processing. 4. Image Segmentation Image thresholding; Hough transform; Edge tracing and linking; Edge-based segmentation; Point and patch features (e.g. Harris, LoG, DoG, MSER); Region-based segmentation (split/merge, watershed); Texture based segmentation (co-

	occurrence, energy, spectral and fractal approaches); Statistical segmentations (mean-shift, Gaussian models). 5. Image and Features Description Contour description (chain codes, Fourier coefficients, Bsplines); Active contours; Shape description (moments, convex hull, signatures, skeleton-based decomposition); Contour and shape invariants; Invariant feature descriptors (SIFT, SURF, GLOH, HOG, etc.). 6. 3D Vision Projective and epipolar geometry; Homography Transformation; Fundamental Matrix; Camera calibration; Stereo correspondence algorithms; Feature-based image matching (least squares and RANSAC algorithm); Range images. 7. Motion Analysis and Tracking Motion analysis and tracking (optical flow, features tracking by Kalman filtering); Instance detection (geometric alignment, large databases). 8. Image Understanding Statistical pattern recognition; classification techniques (AdaBoost, Support Vector Machines), Cluster analysis; Neural networks; Category detection (bag of words, GIST); Syntactic and graph-based recognition.
Recommended Textbooks	Richard Szeliski, *Computer Vision: Algorithms and Applications*, Springer-Verlag, 2011, ISBN: 978-1848829343. Simon J. D. Prince, *Computer Vision - Models, Learning, and Inference*, Cambridge Press, August 2012, ISBN: 9781107011793
Recommended References & Supplemental Material	Milan Sonka, Vaclav Hlavac, Roger Boyle, *Image Processing, Analysis, and Machine Vision*, 3rd ed, CL Engineering, 2007, ISBN: 978-0495082521. Tomas Svoboda, Jan Kybic, Vaclav Hlavac, *Image Processing, Analysis, and Machine Vision: A MATLAB Companion*, CL Engineering, 2007, ISBN: 978-0495295952. *OpenCV* programming library for real-time applications of computer vision (http://opencv.willowgarage.com/wiki/)
Assessment	Coursework: 30%, Project: 30% , and Final exam: 40%
Teaching and Learning Methodologies	The course delivery includes lectures, class discussions, and coursework.
Course Learning Outcomes	1. Apply the principles, concepts and methodologies for machine vision.

	2. Describe the image acquisition pipeline. 3. Apply image enhancement techniques 4. Use different image segmentation techniques. 5. Apply the different image descriptors and their use in image analysis 6. Apply the principles and concepts of 3D Vision 7. Apply target tracking and detection techniques 8. Use the principles and techniques related to image understanding.

Course Learning Outcomes Assessment Methodologies:

Outcome / Metric	1	2	3	4	5	6	7	8
Course work	✓	✓	✓	✓	✓	✓	✓	✓
Examinations	✓	✓	✓	✓	✓	✓	✓	✓

Schedule of Laboratory and other Non-Lecture Sessions

There are no formal laboratory sessions. However, the students have access to the lab that has the necessary software tools and hardware setups to enable them to do the coursework and projects.

Out-of-Class Assignments with due Dates

Assignment	Due Date (tentative)
Homework 1 (related to Case study 1)	Week 3
Homework 2 (related to Case study 2)	Week 7
Homework 3 (related to Case study 3)	Week 11
Homework 4 (related to Case study 4)	Week 14
Project	Week 14

Typical Teaching Plan (3 lecture hours per week)

Teaching Week	Topics
1	Principles of Machine Vision What is machine vision? Brief history; Typical applications.
2	Principles of Machine Vision Image Perception and Imaging Devices: B/W and color image functions; 3D to 2D projections; Lighting, reflectance and shading; Images as linear systems (lens distortion); Visual perception of images; Image quality; Noise in images.

3	<u>Image Acquisition and Projective Transformations</u>
	Image discretization (sampling, quantization, aliasing); Metrics and topology in digital images; 2D and 3D geometric transformations; Projective Transformations. Case study 1 (e.g. image degradation analysis for)
4	<u>Image Enhancement</u> Point operations; Color transformations; Histogram processing; Image transforms; Image filtering (smoothing, sharpening noise removal, Wiener filter).
5	<u>Image Enhancement</u> Edge detection; Morphological processing (dilation, erosion, opening and closing, skeletons).
6	<u>Image Segmentation</u> Image thresholding: Hough transform; Edge tracing and linking; Edgebased segmentation; Point and patch features (e.g. Harris, LoG, DoG, MSER); Region-based segmentation (split/merge, watershed).
7	<u>Image Segmentation</u> Textures (co-occurrence, energy, spectral and fractal approaches) and texture based-segmentation; Statistical segmentations (mean-shift, Gaussian models). Case study 2 (e.g. foreground-background segmentation in outdoor images)
8	<u>Image and Features Description</u> Contour description (chain codes, Fourier coefficients, B-splines); Active contours; Shape description (moments, convex hull, signatures, skeletonbased decomposition); Contour and shape invariants; Invariant feature descriptors (SIFT, SURF, GLOH, HOG, etc.).
9	<u>3D Vision</u> Projective and epipolar geometry; Homography Transformation; Fundamental Matrix.
10	<u>3D Vision</u> Camera calibration; Stereo correspondence algorithms; Feature-based image matching (least squares, RANSAC); Range images;
11	<u>Motion Analysis and Tracking</u> Motion analysis and tracking (optical flow, feature based tracking); Kalman filter; Case study 3 (e.g. vehicle tracking in videos)
12	<u>Motion Analysis and Tracking</u> Instance detection (geometric alignment, large databases).
13	<u>Image Understanding</u> Statistical pattern recognition; classification techniques (AdaBoost, Support Vector Machines); Cluster analysis; Neural networks; Hidden Markov models;
14	<u>Image Understanding</u> Syntactic and graph-based recognition; Scene labeling and semantic image segmentation; Category detection (bag of words, GIST). Case study 4 (e.g. face detection and recognition).
15	<u>Revision</u>

Course Contribution to Program Learning Outcomes

	Program Learning Outcomes	Emphasis Level	Relation to Course Learning Outcome
1	Identify, formulate, and solve advanced electrical and computer engineering problems through the application of modern tools and techniques and advanced knowledge of mathematics and engineering science.	H	1, 2, 3, 6
2	Acquire knowledge of contemporary issues in the relevant field engineering.	H	5, 6, 7, 8
3	Design and conduct experiments, as well as analyze, interpret data and make decisions.	H	2, 3, 6, 7
4	Conduct research and document and defend the research results.	M	3, 4
5	Function on teams and communicate effectively.	L	3, 5, 6, 7
6	Conduct themselves in a professional and ethical manner.	L	7, 8

Emphasis Level: **H:** High; **M:** Medium; **L:** Low; **N:** Nothing specific