Rutgers University, Department of Electrical and Computer Engineering
ABET COURSE SYLLABUS
COURSE: 14:332:472

Course Catalog Description: 14:332:472 – Introduction to Robotics and Computer Vision (3) Introduction to computer vision and robotics. Image formation and analysis. Rigid body and coordinate frame transformations. Low-level vision and edge detection. Models for shading and illumination. Camera models and calibration. 3-D Stereo reconstruction. Epipolar geometry and fundamental matrices. Motion estimation. Object Recognition.

Pre-Requisite Courses: 14:332:345, 346 or permission of instructor

Co-Requisite Courses: None.

Pre-Requisite by Topic:
1. Basic signal processing, convolution, filtering
2. Solution of linear algebraic equations
3. Matrix operations
4. Matlab

Recommended Textbooks: E. Tresso and A. Verri, *Introductory Techniques for 3-D Computer Vision*, Prentice-Hall, 1998.
R. Szeliski. *Computer Vision: Algorithms and Applications,* Springer 2010.
D. Forsyth and J. Ponce, *Computer Vision: A Modern Approach,* Prentice-Hall, 2003.

References: *Learning Open CV,* Bradsky & Kaehler, O'Reilly; *MatLab: Student Version,* Current Edition, The MathWorks, Inc., J. Knudsen

Overall Educational Objective: To develop skills in building real world computer vision systems. These skills include modeling and utilizing the photometry and geometry of image formation to build computational algorithms for automated understanding of visual scenes.

Course Learning Outcomes: A student who successfully fulfills the course requirements will have demonstrated:

1. an ability to formulate a 2D signal processing description of images including filtering procedures, discrete approximations of the gradient operator, gaussian filtering, image pyramids, and image warping.

2. an ability to state the matrix operations which model the geometry of image formation. These include matrices for coordinate frame transformations, perspective projection, orthographic projection and conversion to image coordinates using the intrinsic parameters of a camera.

3. an ability to state and implement the methods of camera calibration to recover a camera's intrinsic and extrinsic

parameters.

4. an in depth understanding of stereo vision that enables the recovery of 3D structure from 2D images including the methods of recovering the fundamental matrices.

5. an ability to formulate the equations for the photometry of image formation including the prediction of radiance based on irradiance and surface parameters using models of Lambertian and specular reflectance.

6. an ability to apply linear algebra concepts to computer vision algorithms including solving homogeneous systems of equations using singular value decomposition and related methods.

7. an ability to implement motion estimation algorithms and image warping to perform basic image alignment.

8. An ability to formulate an appearance based recognition algorithm using principle components analysis.

9. An ability to formulate a feature-based recognition algorithm using feature vectors computed around key points

10. An ability to formulate statistical pattern recognition algorithms for automated understanding of visual scenes

How Course Outcomes are Assessed:
HW Problems (15 %)
Exams (35 %)
Final & Final Project (50 %)

N = none S = Supportive H = highly related

Outcome	**Level**	**Proficiency assessed by**
(a) an ability to apply knowledge of Mathematics, science, and engineering	H	HW Problems, Exams
(b) an ability to design and conduct experiments and interpret data	S	Design Problems in HW and Exams
(c) an ability to design a system, component or process to meet desired needs within realistic constraints such as economic, environmental, social, political, ethical, health and safety, manufacturability, and sustainability	H	
(d) an ability to function as part of a multi-disciplinary team	H	Design Problems
(e) an ability to identify, formulate, and solve ECE problems	H	HW Problems, Exams
(f) an understanding of professional and ethical responsibility	N	
(g) an ability to communicate in written and oral form	S	HW Problems
(h) the broad education necessary to understand the impact of electrical and computer engineering solutions in a global, economic, environmental, and societal context	N	
(i) a recognition of the need for, and an ability to engage in life-long learning	S	Home-work, discussions during lectures
(j) a knowledge of contemporary issues	N	
(k) an ability to use the techniques, skills, and modern engineering tools necessary for electrical and computer engineering practice	H	HW Problems, Exams
Basic disciplines in Electrical Engineering	H	HW Problems, Exams
Depth in Electrical Engineering	S	HW Problems, Exams
Basic disciplines in Computer Engineering	S	P-Spice Simulations
Depth in Computer Engineering	H	Design Problems
Laboratory equipment and software tools	S	HW Problems, Mid-Term Exams
Variety of instruction formats	S	Lecture, office hour discussions

Topics Covered week by week:

Week 1: Computer Vision Overview, robot kits
Week 2: Extension of One-Dimensional Signal Processing to Two-Dimensions, Convolution, Image filtering, Discrete Fourier transforms, Sampling theory
Week 3: Linear Algebra, Basic principles
Week 4: Numerical Methods, Least squares estimation, Singular value decomposition
Week 5: Image Analysis, Image pyramids, Image features, Edge and corner detection
Week 6: Rigid body transformations, rotation, translation, homogeneous coordinates
Week 7: Coordinate frame transformations
Week 8: Image Formation and Camera Models, Perspective projection, Homography
Week 9: Camera Calibration
Week 10: Stereo Vision, Point correspondences, Epipolar geometry
Week 11: Three-Dimensional reconstruction, Generating depth maps
Week 12: Motion, Optical flow, Affine motion models, Image stabilization
Week 13: Feature-based object recognition using statistical inference
Week 14: Appearance-based modeling, Eigenspace methods, Object recognition
Week 15: Review
Week 16: Final Examination

Computer Usage: Students use Matlab and Intel OpenCV software to do homework and in laboratory.

Laboratory Experiences: Mobile robots are created in the lab experience.

Design Experiences: Mobile robots with cameras are designed and programs implemented for interaction with visual scenes.

Independent Learning Experiences: 1. Home-Work

Contribution to the Professional Component:
(a) College-level mathematics and basic sciences: 0.25 credit hours
(b) Engineering Topics (Science and/or Design): 2.75 credit hours
(c) General Education: 0 credit hours
Total credits: 3
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