TO: The Faculty of the College of Engineering

FROM: The Faculty of the School of Industrial Engineering

RE: New Graduate Course – IE 54900: Machine Vision in Intelligent Robotic Systems

IE 54900 MACHINE VISION IN INTELLIGENT ROBOTIC SYSTEMS
SEM 1 or 2, Lecture 3, Cr. 3
Graduate Standing OR [MA 26500 AND (CS 159000 or CS 15800 or CS 18000) AND IE 23000]

COURSE DESCRIPTION: Introduction to machine vision and learning algorithms from a human-machine interaction standpoint, and application of machine vision techniques to the design of human-integrated cybernetic systems, such as, robotic systems, flexible automation, and wearable electronics.

REASON: Automated systems are a critical component of the future of industry. Supporting many forms of industrial systems, especially those in production environments, are machine vision systems. As an example, they serve to enable high-speed quality control activities in automated conveyor lines. The course develops foundational knowledge in machine vision techniques, and their application to several types of automated systems. Many IE graduates will work for companies designing automated systems for manufacturing facilities, warehouses, etc. Since automation is expanding into many different industries, this course prepares students for a wide variety of industrial roles, as well as for future research in machine vision and automation.

Ab G. Deshmukh

Abhijit Deshmukh
Professor and Head
School of Industrial Engineering

Detailed Graduate Course Proposal for Academic Review

Note: The detailed course proposal is intended for academic review by the appropriate area committee of the Graduate Council. It supplements the Form 40G that is intended for administrative review of the Graduate School and Registrar.

To: Purdue University Graduate Council

From: Faculty Member: Juan P. Wachs
Department: School of Industrial Engineering
Campus: West Lafayette

Date: March 21, 2018

Subject: Proposal for New Graduate Course

Contact for information if questions arise:
Name: Patrick Brunese
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Course Number: IE 54900
Course Title: Machine Vision in Intelligent Robotic Systems
Short Title: Mach Vis Intelligent Robot Sys

Course Description:

Introduction to machine vision and learning algorithms from a human-machine interaction standpoint, and application of machine vision techniques to the design of human-integrated cybernetic systems, such as, robotic systems, flexible automation, and wearable electronics.

A. Justification for the Course

Justification of the need for the course

- Automated systems are a critical component of the future of industry. Supporting many forms of industrial systems, especially those in production environments, are machine vision systems. As an example, they serve to enable high-speed quality control activities in automated conveyor lines. The course develops foundational knowledge in machine vision techniques, and their application to several types of automated systems. Many IE graduates will work for companies designing automated systems for manufacturing facilities, warehouses, etc. Since automation is expanding into many different industries, this course prepares students for a wide variety of industrial roles, as well as for future research in machine vision and automation.
- The course serves at least two major populations within the School of IE, related to areas of focus.
    - Production systems: Students in this area are concerned with the design and control of production and logistics systems, of which automation is a key concern. This course complements topics covered in existing IE production systems courses, in particular IE 57900 – Design and Control of Production and Manufacturing Systems, IE 57400 – Industrial Robotics and Flexible Assembly, IE 58300 – Design and Evaluation of Material Handling Systems, IE 58800 – e-Work and e-Service, and IE 67400 – Computer and Communication Methods for Production Control. Each of these courses has components related to automation.
    - Human factors: Students in this area are concerned with the design of human work. Since many environments mix humans with automation to complete work tasks, this course provides background in the development and usage of machine vision to support the design and control of work systems. This course complements topics covered in existing IE human factors courses, in particular IE 57700 – Human Factors in Engineering, IE 55900 – Cognitive Engineering of Interactive Software, IE 65900 – Human Aspects in Computing. Each of these courses has components related to human-computer or human-machine interaction.
- The course is also likely to be beneficial to students from majors that have are concerned with the development of various parts of automated systems, such as mechanical engineering, electrical and computer engineering, civil engineering, biomedical engineering, and computer science.

Justification that course will be taught at a graduate level

- The course utilizes multiple advanced textbooks to convey primary content (see syllabus for details). In addition, the course requires advanced mathematics (MA 26500 or MA 51100) and programming capability.
- Each assignment involves two components: theoretical and implementation. Theoretical knowledge is captured by having students synthesize informal proofs

of mathematical concepts in machine vision, or by having the students perform literature searches to identify viable methods for solving a conceptual problem. Implementation questions involve the simultaneous application of multiple concepts from relevant course content to solve a problem within machine vision. Students must synthesize an approach from available techniques that is best suited to generating a solution.

- The course requires a term project, which requires students to determine a problem that can be solved with machine vision techniques, justify the benefits of the project against the current state, and develop and demonstrate the solution. As a part of the project deliverables students must survey current literature. As with the implementation questions from homework assignments, students must develop an approach to solving the problem that synthesizes numerous techniques from the course (and literature).

Justification of the demand for the course

- Anticipated enrollment
    - Undergraduate 1-5
    - Graduate 10-20

Justification for online delivery

Given enrollments for IE, and other graduate engineering programs, this course would be of interest to distance students. The only assignments that would need modification for online delivery would be the laboratories. There are numerous robotic simulators available that could substitute for the physical equipment currently used within the course.

B. Learning Outcomes and Methods of Assessment

Learning Outcomes	Assessment Methods
Analyze and write computer programs to analyze images for tasks such as filtering, edge detection, segmentation, object recognition, and template matching.	• Homework
Describe and use image filtering methods for image processing	• Homework
Describe and use edge detection methods for image processing	• Homework
Use morphological operations to perform shape recognition and template matching	• Homework
Use optical flow methods to study motion	• Homework
Apply techniques for object tracking and motion detection to analyze multiple images or video	• Homework
Apply learning methods such as neural networks, clustering, and linear regression for object recognition	• Homework
Apply a computer vision technique to the control of a robotic arm	• Laboratory Report
Plan and develop a working prototype machine vision interface	• Project Report and Oral Presentation

- Project report: students will form teams and implement a working prototype of a machine vision-based interface. The project design includes four milestones: an initial written project proposal, the design and implementation, and a final presentation with a written report.

- Homework: There are two types of homework assignments. The first is a "mini-homework," which is assigned at the end of particular lectures. These receive a completion-grade only. The second type are formal homework assignments. Each assignment will have a written section and an implementation section. The written section requires thought, self-study, research, and problem solving. The implementation sections are small projects that will allow students to become familiar with various machine vision techniques and programming tools.

- Laboratory assignments: Each assignment is a multi-part, guided activity that focuses on the process of aspects of the development of machine vision tools. This is accomplished through the use of the KINECT

Final Grading Criteria

Describing the criteria that will be used to assess students and how the final grade will be determined. Add and delete rows as needed.

Assessment Methods (should match method types in the previous table)	**Weight Toward Final Course Grade**
Papers and Projects	50%
Homework	30%
Laboratory Exercises	10%
Class Participation	10%

Methods of Instruction

Class Hrs/Week	**Method of Instruction**	**Contribution to Outcomes**
2	Lecture	Foundational concepts are given in the lecture. In addition, discussions of methods provided in the course readings are covered during the lecture period.
1	Laboratory	Small laboratory exercises are conducted during lecture periods, where students are given more elaborate problems for which to design solutions. The instructor and TAs provide support.

C. Prerequisite(s)

- Graduate Standing OR
- MA 26500 – Linear Algebra AND CS 15900 – Programming Applications for Engineers AND IE 23000 – Probability and Statistics in Engineering I

D. Course Instructor(s)

Name	Rank	School, dept., or center	Graduate Faculty or expected date
Juan P. Wachs	Associate Professor	IE	Yes

Juan Wachs' research is focused on two connected disciplines related to machine vision: intelligent systems and human-machine interfaces. In both fields, he is intrigued by the means of interaction between robots to people through visual meaningful features. In human-machine interfaces, he aspires to design visual algorithms that are capable to mimic visual perception tasks such as motion tracking, object recognition, efficient human body-posture recognition, and behavior modeling and understanding. In intelligent systems, his focus is oriented to enable robots and devices to perform high level tasks with speed and efficiency based on visual clues from complex and cluttered environments.

E. Course Schedule or Outline

Week	Topic(s)	Activity (optional)
1	• Course Introduction • Basics of Image Representation	• [Activity]
2	• Sampling, Quantization, and Enhancement • Filters, Colors, and Features	• [Activity]
3	• Filters and Convolutions	• [Activity]
4	• Edges, Blurring, and Scale • Canny Edge Detection and Thresholding	• [Activity]
5	• Correlation and Template Matching • Image Moments and Hough Transform	• [Activity]
6	• Morphology Operations • Dynamic Background Segregation	• [Activity]
7	• Optical flow • Using the Kinect	• Laboratory
8	• Laboratory: Gesture Challenge	• Laboratory
9	• Classification and Learning • Learning by Clustering	• [Activity]
10	• Learning using Linear Regression • Neural Networks	• [Activity]
11	• Deep Convolutional Neural Networks • Robotic Arm Control I	• Laboratory
12	• Robotic Arm Control II • Introduction to Robotics	• Laboratory
13	• Forward Kinematics • Backward Kinematics	• [Activity]
14	• Programming with MYO and Sensors	• [Activity]
15	• Other Sensing Technologies (e.g., Leap)	• [Activity]

Week	Topic(s)	Activity (optional)
16	• Project Presentations	

F. Reading List (including course text)

Primary Reading List

- Image Processing, Analysis and Machine Vision. Milan Sonka, Vaclav Hlavac, Roger Boyle, Publisher: Thomson, Third Edition, 2008.
- Digital Image Processing. Rafael Gonzalez, Richard Woods. Publisher: Pearson. Third Edition 2008

Secondary Reading List

- Learning OpenCV Computer Vision with the OpenCV Library. Gary Bradski, Adrian Kaehler. Publisher O'Reilly Media, 2008.
- Robotics, vision and control: fundamental algorithms in MATLAB. Corke, Peter. Vol. 73. Springer, 2011.
- Computer vision: a modern approach. Forsyth, David A., and Jean Ponce. Prentice Hall Professional Technical Reference, 2002.

G. Library Resources

Name of journal, proceedings, book, video, or other acquisition	Already in Libraries?
Image Processing, Analysis and Machine Vision. Milan Sonka, Vaclav Hlavac, Roger Boyle, Publisher: Thomson, Third Edition, 2008.	Yes
Digital Image Processing. Rafael Gonzalez, Richard Woods. Publisher: Pearson. Third Edition 2008	Yes
Robotics, vision and control: fundamental algorithms in MATLAB. Corke, Peter. Vol. 73. Springer, 2011.	Yes
Computer vision: a modern approach. Forsyth, David A., and Jean Ponce. Prentice Hall Professional Technical Reference, 2002.	Yes
Learning OpenCV Computer Vision with the OpenCV Library. Gary Bradski, Adrian Kaehler. Publisher O'Reilly Media, 2008	Yes

H. Course Syllabus (now required)

- ***Attached***

IE 590: Machine Vision and Robotics
FALL 2017 SEMESTER

INSTRUCTOR: Dr. Juan P. Wachs Grissom Hall 262 Tel: 49-67380 jpwachs@purdue.edu
CLASSES: T-TH 3pm –4:15pm Grissom Hall 134
OFFICE HOURS: Tuesdays 4:00-5:00 PM, Grissom Hall 262

COURSE TEXTBOOK:
Image Processing, Analysis and Machine Vision. Milan Sonka, Vaclav Hlavac, Roger Boyle, Publisher: Thomson, Third Edition, 2008.
Digital Image Processing. Rafael Gonzalez, Richard Woods. Publisher: Pearson. Third Edition 2008
Robotics, vision and control: fundamental algorithms in MATLAB. Corke, Peter. Vol. 73. Springer, 2011.
Computer vision: a modern approach. Forsyth, David A., and Jean Ponce. Prentice Hall Professional Technical Reference, 2002.

ADDITIONAL TEXTBOOKS AND RESOURCES:
Learning OpenCV Computer Vision with the OpenCV Library. Gary Bradski, Adrian Kaehler. Publisher O'Reilly Media, 2008.
PCL - Point Cloud Library (PCL): http://pointclouds.org/

PREREQUISITE:
Linear Algebra, Probability, Introduction to Programming (C, Python and Matlab)

COURSE DESCRIPTION:
IE 590 introduces students to robotics, machine vision from a human-machine interaction standpoint. The course focuses on applying techniques from machine vision to the design of cybernetic systems with humans in through lectures, readings, hands-on-tools, discussions, and team projects.

In addition to the basic principles of machine vision and relevant literature, the course will explore some ways in which it has been applied to human-robot interaction, and the involved challenges and opportunities that this presents. The students will learn the practical details of how computer vision methods can be used effectively in robotics through applications tools.

COURSE OBJECTIVES:
1. Overview of HCI and Robotics research as it relates to computer vision.
2. Teach students how to apply computer vision techniques for interface between users and devices.
3. Develop the critical thinking elements to build useful applications based on computer vision.

COURSE ASSIGNMENTS:
Readings: Each lecture topic will be linked to a reading assignment. Students should complete the reading assignment before the lecture and be prepared to discuss and participate in the class about the readings.

Individual Assignments: Three individual home works are assigned during the semester. Some of these assignments have a written section and an implementation section. The written section requires thought, self-study and problem solving. The implementation sections are small projects that will allow students to become familiar with various machine vision techniques and programming tools.

Project Assignments: During the second half of the semester, students will form teams and implement a working prototype of a machine vision-based interface. The project design includes four milestones: an initial written project proposal, the design and implementation, and a final presentation with a written report.

Laboratories: during the semester, the students will be required to complete a number of laboratories requiring them to solve some real challenge in computer vision. The labs require individual work, and do not involve a frontal lecture.

GENERAL INFORMATION

Since the homework and/or projects may require special software and hardware, they can be done at the intelligent systems and assistive technologies lab, MGL 1332. The lab spaces are limited to 6 stations, and therefore, time slots need to be agreed with the instructor beforehand.

A term project will be conducted in teams of two students per project group. The purpose of the project is to design and implement a human-machine interface using machine vision algorithms. Students can decide to which group they want to be assigned, otherwise those students without a group will need to address the instructor to be assigned to a new group. Each group will select a specific topic and conduct a project during the semester. The result of this work will be reflected in a written report, an oral presentation and optionally a conference paper. **Successful completion of a conference paper to a major robotics, computer vision or human computer interfaces will result in a significant bonus to the final score**.

COURSE POLICIES

GRADING: The final grade will be based on the total number of points earned during the semester. The general policy will be approximately 90% for an A, 80% for a B, etc. However, the final scores might be adjusted at the prerogative of the course instructor. Each homework assignment and final project will be graded on the basis of 100 points but will be assigned different weights in terms of the final grade. The specific range of scores for the assignment of letter grades will not be designated at the onset of the course. The conventional A through F grading scale will be used without the plus and minus option. Class evaluation is part of the class participation.

The weighting procedure for determining final letter grades will be as follows:

Homework (3)	30%
Project (phase 1+2+3)	20%
Oral presentation	20%
Participation	10%
Report	10%
Lab completion	10%
Submission to conference	10% (bonus)
TOTAL	110%

CLASS CONDUCT: Class conduct is expected to conform to the Student Code of Honor. The commitment of the acts of cheating, stealing, and deceit in any of their diverse forms will not be tolerated. Plagiarism, copying during examinations, the use of substitutes for taking examinations, illegal cribs, and ghost-written papers are considered serious acts of dishonesty. Knowingly to aid and abet, directly or indirectly, other parties in committing dishonest acts is in itself dishonest

GRADE CORRECTIONS: A given paper (homework or project), can be submitted for re-grading if it appears that insufficient credit was received. In order to request a re-grade:

1) On the back of the paper, indicate which items should be reviewed and briefly state why additional credit should be given. (For example: Problem 9, page 3 – According to the text…). The final grade of the paper can be higher, equal or even lower than the original grade.
2) The paper must be submitted to the laboratory instructor ***within one week*** of the date that the paper was returned. Papers will not be re-graded after the one-week deadline.

LATE ASSIGNMENTS: Students are expected to complete all assignments and turn them in on the due date. Late assignments will not be accepted unless accompanied by a valid excuse and some points might be deducted depending upon the circumstances.

EMERGENCY PREPAREDNESS

EMERGENCY NOTIFICATION PROCEDURES are based on a simple concept – if you hear a fire alarm inside, proceed outside. If you hear a siren outside, proceed inside.

- **Indoor Fire Alarms** mean to stop class or research and immediately **evacuate** the building.
  - Proceed to your Emergency Assembly Area away from building doors. **Remain outside** until police, fire, or other emergency response personnel provide additional guidance or tell you it is safe to leave.

- **All Hazards Outdoor Emergency Warning Sirens** mean to immediately seek shelter (**Shelter in Place**) in a safe location within the closest building. ○ "Shelter in place" means seeking immediate shelter inside a building or University residence. This course of action may need to be taken during a tornado, a civil disturbance including a shooting or release of hazardous materials in the outside air. Once safely inside, find out more details about the emergency*. **Remain in place** until police, fire, or other emergency response personnel provide additional guidance or tell you it is safe to leave.

**In both cases, you should seek additional clarifying information by all means possible…Purdue Home page, email alert, TV, radio, etc…review the Purdue Emergency Warning Notification System multi-communication layers at http://www.purdue.edu/ehps/emergency_preparedness/warning-system.html*

Week	Class #	Day	Date	Class Chapter	Lecture Topic	Paper Readings	Book
1	1	T	21-Aug	Introduction	Course Information, Goals, Schedule, etc		
	2	TH	23-Aug		Basics of image representation	Piccardi	Gonzales
2	4	T	28-Aug	Image Processing I	Sampling , Quantization, Enhancement	Presented by TA	Gonzales
	5	TH	30-Aug		Filters & colors & features	Presented by TA	Gonzales
3		T	4-Sep		**LABOR DAY**		
	6	TH	6-Sep	**Project Phase 1 - Out**	Filters & Convolutions		Sonka
4	7	T	11-Sep	**Team Registration**	Edges, Blurring and Scale		Forsyth
	8	TH	13-Sep	**Homework 1 - Out**	Canny Edge Detection and Thresholding		Forsyth
5	9	T	18-Sep	**Project proposal**	Correlation and Template matching	Presented by TA	Sonka
	10	TH	20-Sep	**Object Detection I**	Image Moments and Hough Transform		Sonka
6	11	T	25-Sep	**Homework 1 due**	Morphology Operations, Sobel and Canny		Gonzales
	12	TH	27-Sep	**Homework 2 - Out**	Dynamic Background Segmentation		Sonka
7	13	T	2-Oct	**Project phase 1 - Due**	Optical flow		Sonka
	14	TH	4-Oct	**Motion and Tracking**	**Using the Kinect (Laboratory)**	Self Study	Sonka
8		T	9-Oct		**OCTOBER BREAK**		
	15	TH	11-Oct	**Project Phase 2 - Out**	**ChaLearn - Gesture Challenge (Laboratory)**	Self Study	Sonka
9	16	T	16-Oct		Classification and Learning	Fails02	Bishop
	17	TH	18-Oct		Learning by Clustering		Bishop
10	18	T	23-Oct	**Homework 2 due**	Learning using Linear Regression		Bishop
	19	TH	25-Oct	**Homework 3 - Out**	Neural networks		Bishop
11	20	T	30-Oct		Deep Convolutional Neural Networks		Bishop
	21	TH	1-Nov		**Robotic Arm control (Laboratory)**	Self Study	Corke
12	22	T	6-Nov		**Robotic Arm control II (Laboratory)**	Self Study	Corke
	23	TH	8-Nov		Intro to robotics		Corke
13	24	T	13-Nov		Kinematics (forward)		Corke
	25	TH	15-Nov	**Homework 3 due**	Kinematics (backward)		Corke
14	26	T	20-Nov	**Project Phase 2 due**	Programming with MYO and sensors		Web resources
		TH	22-Nov		**THANKS GIVING BREAK**		
15	27	T	27-Nov		Other sensing technologies (Leap, MYO)		
	28	TH	29-Nov		Project Presentations		Demo
16	29	T	4-Dec		Project Presentations		Demo
17	30	TH	6-Dec	**Full project due**	Project Presentations		Demo