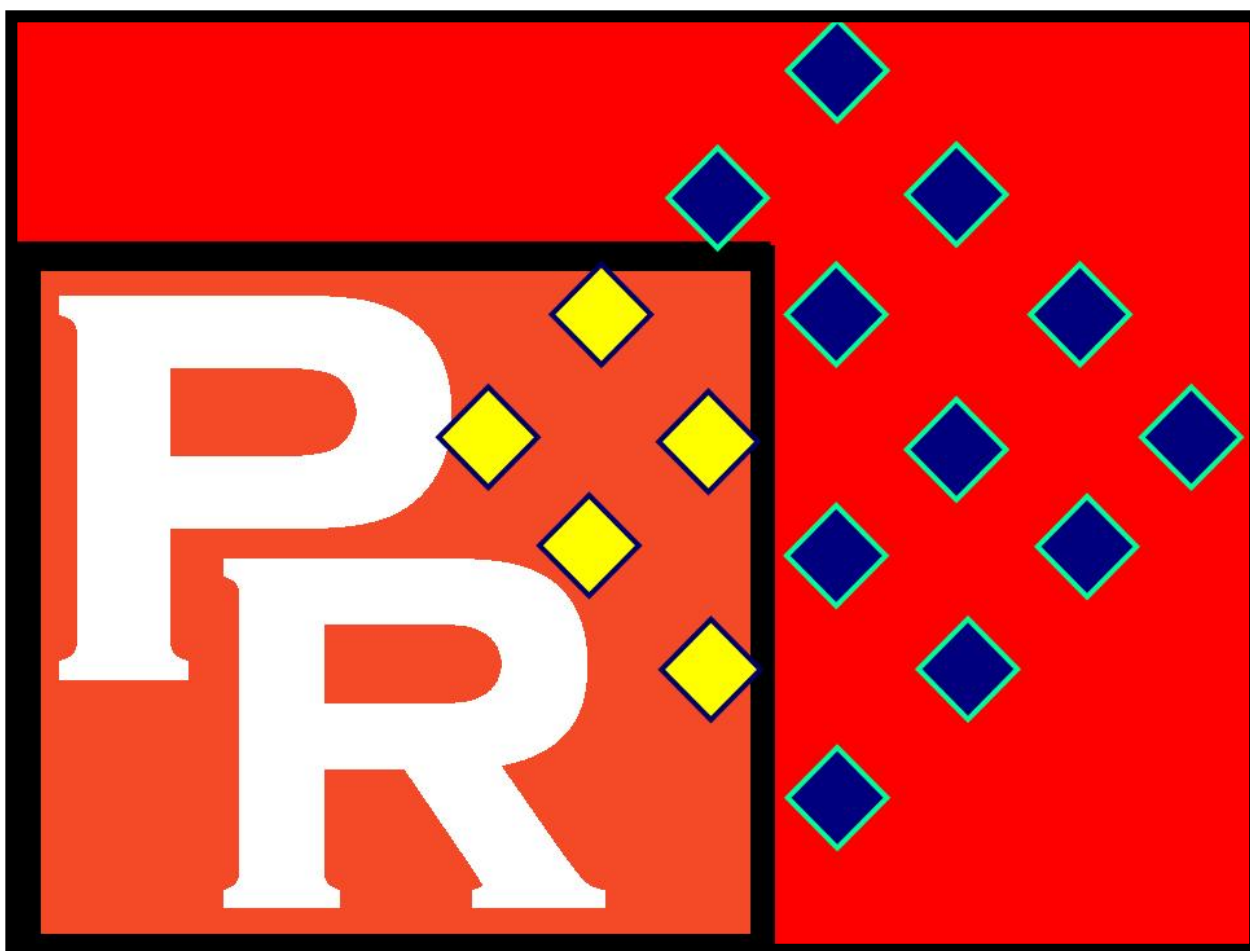


**ECE 09.455**  
**THEORY & APPLICATIONS OF PATTERN RECOGNITION**  
(3 SCH - UNDERGRADUATE)

**ECE 09.555**  
**ADVANCED TOPICS IN PATTERN RECOGNITION**  
(3 SCH - GRADUATE)

**FALL 2009**



**POLIKAR**

**THEORY & APPLICATIONS OF PATTERN RECOGNITION (3) – ECE 09.455**  
**ADVANCED TOPICS IN PATTERN RECOGNITION (3) – ECE 09.555**  
**FALL 2009**



**Class Homepage:** <http://engineering.rowan.edu/~polikar/CLASSES/ECE555>

- Instructor:** Dr. Robi Polikar  
**Office & Phone:** 136 Rowan, 256-5372 (voice-mail available)  
**Office Hours:** Open door policy – You are welcome in anytime when my office door is open.  
**E-mail:** [polikar@rowan.edu](mailto:polikar@rowan.edu)  
**Class Meeting:** Tuesdays & Thursdays 15:15 – 16:45 at Rowan 202  
**Required Text:** 1. Pattern Recognition & Machine Learning, Bishop, Springer, 2006  
 2. Pattern Classification 2/e, Duda / Hart / Stoke, John Wiley & Sons, 2001  
**Reference Texts:** 1. Learning from Data 2/e, V. Cherkassky, F. Mulier, Wiley, 2007.  
 2. Combining Pattern Classifiers: Methods & Algorithms, L.I. Kuncheva, Wiley, 2004.  
 3. Introduction to Machine Learning, Alpaydin, MIT Press, 2004.  
 4. Pattern Recognition 4/e, Theodoridis / Koutroumbas, Academic Press, 2009.  
 5. Computational Statistics Handbook with Matlab, 2/e Martinez, CRC, 2008  
 6. Neural Networks and Learning Machines, Haykin, 3/e, Prentice Hall, 2009.  
**Reference for Web Lectures:** <http://videlectures.net>

### ABOUT THIS CLASS & OBJECTIVES

Pattern recognition deals with automated classification, identification, and / or characterizations of unknown systems. Virtually unlimited number of applications can benefit from pattern recognition techniques. Although it employs elegant and sophisticated mathematical and statistical analysis techniques, pattern recognition is nevertheless a very application driven field. Identification of pathological disorders from various biological indicators, hand written character recognition, finger print analysis, face recognition, iris scan based recognition, financial data predictions, or automated determination of whether one should get a credit card based on his/her past credit history are just a few of such applications that call for pattern recognition techniques.

This class has three main goals:

1. To equip you with basic mathematical and statistical techniques commonly used in pattern recognition. Achieving this objective will not only help you understand, compare and contrast various pattern recognition techniques that will be discussed in this class, but also provide you with an adequate background on probability theory, statistics, and optimization theory to tackle a wide spectrum of engineering problems.
2. To introduce you to a variety of pattern recognition algorithms, along with pointers on which algorithms work best under what conditions, so that you can make sound decisions on what approaches to take when faced with a real world problem. In order to best prepare you for such real world problems, we will routinely use real-world problems in this class.
3. To provide a detailed overview of some advanced topics in pattern recognition and a project opportunity to conduct independent, cutting-edge and publishable research. For graduate students, your project work will provide you many of the skills you will need to be able to conduct independent research on a new topic area and in successfully completing your graduate degree.

There will be a set of objectives for each topic we discuss guiding you towards achieving the goals of this class. Described in considerable detail, they will tell you exactly what I think you should be able to do if you understand the concepts. My expectations of you will therefore be limited to these objectives. All student performance evaluation modalities that will be used in this course (homeworks, exams, projects) will be geared towards testing whether you have achieved these course objectives.

**Upon successful completion of this class**, you will be able to analyze a given pattern recognition problem, and determine which algorithm to use. You will also be able to modify existing algorithms to engineer new algorithms to solve a particular problem at hand. In the mean time, you will gain a working knowledge of some of the most recent developments in pattern recognition, such as incremental learning and learning in nonstationary environments.

### COURSE PREREQUISITES

- Basic knowledge of probability, statistics and random variables, linear algebra – See introductory material
- Calculus III or Math for Engineering Analysis,
- Signals and systems / digital signal processing
- Expertise of MATLAB or C/C++
- Enthusiasm, genuine interest, and willingness to put forward extra effort
- Time, patience, perseverance

### INTRODUCTORY / BACKGROUND MATERIAL

Many of you might have seen the mathematical background material sometime ago, or perhaps had very little exposure to these areas. While we do not have time review these topics, I have provided extensive material on the class webpage. These include my own notes, links to some very good video lectures, as well as other tutorials. You must review this material before coming to class, or at the latest, within the first week of classes. A take home quiz /homework will be given during the second week of classes on the background material.

### RECOMMENDED CO-REQUISITE

- **Engineering Optimization** class taught by Dr. Chandurapatla is an immensely relevant course that is offered at a most fortunate and timely schedule. I highly recommend all students to take this course concurrently with Pattern Recognition. Engineering Optimization is offered on Tuesday evenings (once a week) immediately following this class.

### CLASS MECHANICS

This class will meet twice a week, for 75-90 (undergraduate-graduate) minutes each. Any class period that cannot meet (due to holidays, weather, etc.) will be made up. We will have regularly scheduled homework or research and implementation exercises, occasional quizzes, daily “oral reviews”, midterm, one final exam and a final project. The oral review is a new concept where every day one or more randomly selected class participants will be asked to review the previous lecture and answer questions from the class. Your performance on these reviews will constitute a meaningful component of your final grade. These oral reviews will ensure that everyone comes to class prepared, having reviewed the previous lecture.

### ATTENDANCE POLICY & ESTIMATED AMOUNT OF WORK

Attendance is absolutely necessary for success in this class, and therefore is required. Since this is a senior / graduate level class, I will not take regular attendance, but only occasional random ones, which will be considered in assigning final grades. If you are absent on the day you are randomly called for oral review, or for a quiz (or for roll call) you will get a zero for that activity – unless you have an excused absence or an extenuating circumstance. I will not call on someone for an oral review if that person informed me of his/her excused absence ahead of time. A Quiz missed due to excused absences may be retaken; those missed due to unexcused absences may not. A missed exam may not be retaken with the exception of most serious and extenuating circumstances that require official and written proof of such circumstances.

**Excused absence** is one where you have given me at least 48 hours of written notice (e-mail is acceptable) of your absence. You may have one – **and only one** – excused absence during the semester, though it can be for any reason.

**Extenuating Circumstances** are those that are truly beyond your control, such as sudden illness, or death of family member. Written documentation must be provided for an extenuating circumstance to be valid (such as a letter from a physician, or an obituary / funeral house notice). Undocumented cases will not be honored.

**Tardiness:** You will be considered present if you are in class during the first 10 minutes of the class, and remain in class during the entire (remaining) duration of the class. One quiz or oral review missed due to tardiness will be counted towards your excused absence. Any additional absences / tardiness will result in a zero grade for the missed activity.

Note that pattern recognition is a fast-paced, mathematically and computationally intensive graduate level course. You will be learning a substantial amount of cutting edge material, and you will be writing simulation programs to test them. Expertise (not just familiarity) with Matlab or some other programming language is absolutely essential. Because this is a graduate level course, you will also be expected to do a substantial amount of reading – not only from the text but also from scientific magazines and journals. Successful completion of this course will demand significant amount of time commitment from you, a good portion of which may be spent on reading and algorithm implementation. As a rule of thumb, **expect to spend three - four hours for each hour we spend in class, i.e. 9 – 12 hours a week** on top of class meetings. As a reference for those who have taken DSP from me, this class is far more challenging than DSP, and it is safe to assume that you will spend more time on this class than you did on DSP. Please budget your time accordingly.

If you miss a class, you are responsible for any missed material, and given the pace and level of this course, even a single missed lecture will be difficult to catch up. **So don't miss class!**

### REASON FOR TAKING THIS CLASS

Pattern Recognition is a challenging, yet intellectually very rewarding course! I therefore assume that you are in this class because you are truly interested in subject. You should not be in this course if you signed up for it for any other reason than enthusiastic and genuine interest in learning the contents of this course.

### TEAM POLICY FOR CLASS RELATED WORK

You are not only allowed, but in fact encouraged to work in teams (usually of no more than two) for most class related work, including certain homework assignments (unless stated otherwise) – but not for exams / quizzes. Whether you can use a team for the final project will depend on the complexity of the project. You are free to form / deform as many teams as you wish during the semester for all homework / implementation assignments. As long as all team members contribute equally and their names appear on the homework assignments, one can be submitted by each team. Each team member, however, needs to explicitly state the sections that were his/her primary responsibility. Team members may inform me – under the condition of anonymity – of other team members who are not equally cooperating or participating in team effort.

### HOMEWORK / RESEARCH & IMPLEMENTATION ASSIGNMENTS

There will be regular homework / research / implementation assignments that will challenge you, however, you will realize that you learn a lot from these exercises. As an added bonus, you will notice that your analytical thinking, problem solving will also improve significantly, not to mention your math skills. You will also find out – much to your pleasant surprise – that the skills you developed in DSP will be of great benefit in implementing algorithms and completing these assignments. Assignments must be neatly and professionally prepared and typed, using proper and formal technical writing language. See IEEE style guide for guidance. All assignments will be due one (or two) week from the day they are assigned, unless indicated otherwise.

Late Policy: Late submissions will not be accepted.

### READING AND VIDEO ASSIGNMENTS

As in most graduate level courses, you will be asked to read certain portions of the course material on your own from your text, other texts, or research articles. I will also ask you to watch certain video lectures that are available on the web (<http://videlectures.net>). Homework, exam and oral review questions may be drawn from such assignments.

**COURSE PROJECT**

A final project to help you put all course-developed skills to work will be assigned. You may choose from one of the three options below, on which you will have a minimum of one month to work. All project ideas must be pre-approved by the instructor for appropriate scope and depth.

**Graduate Students: (Undergraduate students get 15% bonus for selecting this option)**

Develop a new technique, either from scratch, or by suitably modifying an existing technique for a specific problem of your interest; test it on at least ten standard benchmark databases available at the UCI Machine Learning Repository (<http://www.ics.uci.edu/~mlearn/MLSummary.html>), and two real-world databases. If this is an application specific project, then it should be tested on the data generated by that application.

**Undergraduate Students:**

Identify a new pattern recognition algorithm not covered in class – that is relevant to class material – from a recent journal article (>2006). Implement the algorithm and evaluate it on at least 10 datasets from the UCI Repository and two real world datasets that are of general interest.

**All students:**

Suggest your own project topic. Must be pre-approved by the instructor.

Furthermore, a paper submission (possibly after semester ends) to a conference is required for all graduate students to get an A/A- from this course. Many pattern recognition related conferences have deadlines after the semester ends. Therefore, a letter of intent to submit, and a draft version of the paper – in the appropriate conference required format - that shows justifiable progress on the final project that would warrant a reasonable chance of acceptance will be sufficient for this purpose. Acceptance of your paper to the conference is not a condition for the “A,” just the submission. If your paper is accepted, financial assistance will be available to cover – at least a part of – the travel and attendance costs, provided by the instructor and/or the department. Here are some conferences that are either directly on pattern recognition or accept a large number related application papers that have already published their submission deadlines:

International Conf. on Pattern Recognition – Istanbul, Turkey, <http://www.icpr2010.org/> Jan 15.

World Congress on Computational Intelligence – Barcelona, Spain <http://www.wcci2010.org/> Jan 31

Computer Vision and Pattern Rec. – San Francisco, CA, <http://cvl.umiacs.umd.edu/conferences/cvpr2010/> Nov. 19

IEEE Int. Conf on Multisensor Fusion & Integration – Utah <http://www.cs.utah.edu/mfi2010/> April 1

IEEE Int. Conf. Eng. in Medicine and Biology – Buenos Aires, Argentina <http://embc2010.embs.org/> April 1.

**Note that without a paper submission, the best attainable graduate grade is a B+.**

**CLASS ETHICS:**

- No eating /drinking in class (except bottled water). Absolutely no dinner! Please time yourself accordingly.
- **Cell phones must be kept outside of class or shut-off during class. No exceptions!** If your cell-phone rings during class / lab (or you use it in any other way, such as texting), you will be asked to leave and counted as unexcused absent. It will also cause very difficult-to-repair damage to “professionalism” part of your grade (see below). Furthermore, I reserve the right to answer any cell phone going off in the class.
- No web surfing, instant messaging and / or other unrelated use of computers, when we use computers in class / labs.
- In-class discussions are welcome, and in fact encouraged, within the limits of mutual respect and courtesy. I also expect proper business conduct in the class – I am all about in-class discussions, so long as such discussions include the entire class, and not between two students.
- You are responsible for checking the class web page often for announcements, homework / exam solutions.
- You are encouraged to work with other students for all exercises, except exams and quizzes.
- Please come to class in proper (business casual) attire. Slacks and shirts are fine; PJs and flip-flops (yes, it did happen) are not!

- Although I do not anticipate, and certainly hope that it will never be an issue, it is my responsibility to remind you that academic dishonesty – in any form, shape or manner – will not be tolerated, and will be dealt with according to university rules and regulations. In general, presenting any work, or a portion thereof, that does not belong to you, as if it does – or even attempting to do so – is considered academic dishonesty. **DO NOT DO IT, DO NOT EVEN ATTEMPT IT!** See the pledge of honesty at the end of this syllabus.

### E-MAIL ETIQUETTE & POLICY:

In general, I prefer that class related questions be asked in the class, so that everyone can benefit from the discussion. If your answer requires a longer time to answer, then please ask in person. Use e-mail as a last resort only.

If you do use e-mail, I expect you to follow proper business etiquette for electronic communications, including a formal greeting (for example, “Dear Dr. Polikar”, and not “Hey!” or “Listen, Robi, help me out here...<sup>1</sup>”), formal language and formal signature line (including your name, last name and Banner ID). E-mails that do not follow proper etiquette will not be answered, and will affect the professionalism portion of your grade.

Also, and this is very important: make sure that your Rowan e-mail account is active. I will use your Rowan e-mail address exclusively, and cannot / will not follow up with messages that bounce back for over quota issues or non-Rowan addresses. All e-mails sent to me **MUST come from your Rowan e-mail address**, preferably with a subject line starting with “PR”. My e-mail client is configured to recognize all e-mails coming from Rowan addresses as legitimate. Any other e-mail address may – and probably will – be automatically classified as spam and I may not notice it in a timely manner.

### GRADING SCALE

An absolute grading scheme will be used to assess your final grade:

Midterm Exams: 25%	100-95: A,	95-90: A-	
Assignments: 25%	89-87: B+,	86-83: B,	82-80: B-
Project <sup>2</sup> : 30%	79-77: C+,	76-73: C,	72-70: C-
Oral review/quizzes: 10%	69-67: D+,	66-63: D,	62-60: D-
Professionalism: 10%	59-0: F		

Professionalism includes good academic citizenship, professional conduct, and active class participation.

### OFFICE HOURS & CONTACTING THE PROFESSOR

I will hold open office hours for this class. This means that you may come in at any time to ask questions if my office door is open (which it usually is). A couple things to note however: Please do not come in if the door is closed, even if my light is on, or you know that I am, in fact, inside. My door is typically open, but if it is closed, that means either I am not in, or I am working on something and prefer – and request – not to be interrupted.

Also, you may always make appointments (for example, if you need my uninterrupted attention for an extended period of time), or you wish to discuss something in private.

### ACCOMMODATION FOR DISABILITY

If you have a documented physical and/or learning disability, please feel free to inform me or the Center for Academic Success – CAS (director, Ms. Melissa Cox – [cox@rowan.edu](mailto:cox@rowan.edu), or 256-4260) regarding what kind of accommodation you need to help you succeed in this class. While you are not required to disclose your disability to me, you must provide appropriate documentation to the CAS to receive official university assistance. All such requests will be held confidential to the extent possible.

<sup>1</sup> Actual examples from previous student e-mails.

<sup>2</sup> 10% of project component will come from preparing an appropriately formatted and edited, near final version of the draft conference manuscript that is ready for submission.

TENTATIVE SCHEDULE

Week of	MATERIAL TO BE UNCOVERED		Chapters in the text Duda/Hart Bishop
<b>Pre-class</b>	Mathematical background including some probability, statistics, vector calculus and linear algebra. See class webpage.		<b>Appendix A</b> <b>Appendix B, C, D, E, Ch1, 2</b> See class web page
<b>Sept.</b>	1*	Introduction and motivation: What is in this course? Fundamentals of pattern recognition. Concepts, terminology, evaluation of algorithms	<b>Chapter 1</b> <b>Chapter 1</b>
	8	Bayes theory, normal density, discriminant analysis for normal density, error probability.	<b>Chapter 2,3</b> <b>Chapter 4</b>
	15	Density estimation: Parzen windows, k nearest neighbor, Probabilistic neural networks	<b>Chapter 4</b> <b>Chapter 2</b>
	22	Feature extraction and selection: Principal component analysis (PCA), Fisher's linear discriminant and other linear approaches	<b>Chapter 3</b> <b>Chapter 2</b>
	29	The perceptron model – multiplayer perceptron neural networks, gradient descent optimization	<b>Chapter 5, 6</b> <b>Chapter 5</b>
<b>Oct.</b>	6	<b>Midterm exam I (on Friday**)</b> Multilayer Perceptrons (cont.) – Part II; Radial basis function networks.	<b>NAC / NAC</b> <b>POLIKAR</b>
	13	Kernel Methods Introduction	<b>NAC</b> <b>Chapter 6, 7</b>
	20	Kernel methods – Part II: Support Vector Machines	<b>NAC</b> <b>Chapter 6, 7</b>
	27	Other Kernel Methods – Relevance Vector Machines, Kernel PCA	<b>NAC</b> <b>Chapter 6, 7, 12</b>
<b>Nov.</b>	3	Other kernel based approaches, mixture of Gaussians, EM algorithm	<b>NAC</b> <b>Chapter 9</b>
	10	Multiple Classifier Systems. Concept of diversity, ensemble creation algorithms I – Bagging, boosting and AdaBoost, Bias – variance dilemma.	<b>Ch.9, NAC/Ch.14, NAC</b> <b>KUNCHEVA</b>
	17	Applications of ensemble systems II – Feature selection, missing feature, error correcting output codes, learning in nonstationary environments	<b>NAC/NAC</b> <b>POLIKAR</b>
	24*	<b>Midterm exam II</b> Unsupervised Learning, clustering algorithms, self organizing maps.	<b>Chapter 10</b> <b>NAC</b>
<b>Dec</b>	1	Decision Trees, CART algorithm (time permitting)	<b>Chapter 8 /NAC</b>
<b>Dec.</b>	8	Hidden Markov Models (time permitting)	<b>Chapter 3, NAC</b> <b>Chapter 13</b>
	15	Project presentations	<b>YOU</b>

\* Dr. Polikar may be out of town on this day/week.

**NAC/NAC: Not adequately covered in Duda / Bishop**

Missed classes will be rescheduled

\*\* Please clear Friday, Oct 9 morning from your schedule. The exam will be 9AM to 1:30 PM which will give you much additional time then the class period and remove time pressure from the exam.

INSTRUCTOR EVALUATION, QUESTIONS, COMMENTS, SUGGESTIONS

Questions, constructive criticisms, comments, and suggestions are always welcome. Please feel free to share your opinions about all aspects of the class: content, math level, workload, instructor's communication skills (or lack thereof), etc. There will be a box outside of my office for anonymous comments. Feel free to use this box, if you wish to remain anonymous regarding your comments. Also, you may use the "I've got something to say" form, available at class homepage for your comments. A copy is attached to this syllabus. I will also give you a mid-semester evaluation form, so that you can have a formal opportunity to voice your concerns or appreciations (if any at all...).

# I'VE GOT SOMETHING TO SAY!<sup>©</sup>

I am having difficulty in understanding the following concepts:

This week's class was informative / interesting / entertaining / \_\_\_\_\_ (circle all that apply) because:

This week's class was confusing / boring / too fast / too slow / \_\_\_\_\_ (circle all that apply) because:

It would have been much better / beneficial if you could...:

Please continue the following activities as I find them useful in \_\_\_\_\_

While you are at it, please provide your feedback on the following **on a scale of 1 – 5**,

**1: Poor / Strong disagreement with the phrase, 5: Excellent / strongly agree with the phrase**

1. The professor's ability to communicate in a clear and understandable manner: \_\_\_\_\_
2. The professor's responsiveness to student's needs, questions and ideas: \_\_\_\_\_
3. The professor treat students in a professional manner: \_\_\_\_\_
4. The professor is enthusiastic about the subject and genuinely believes in its importance: \_\_\_\_\_
5. The professor's knowledge of the subject material is thorough: \_\_\_\_\_
6. The professor is well prepared for the classes: \_\_\_\_\_
7. The professor's ability to impart knowledge about the subject is: \_\_\_\_\_
8. The professor encourages questions and comments during the class session: \_\_\_\_\_
9. The professor's use of the class time is: \_\_\_\_\_
10. The professor actively involves students in the teaching / learning process: \_\_\_\_\_
11. The professor's availability outside of class hours is: \_\_\_\_\_
12. The professor satisfactorily answers students' questions in class and in the office: \_\_\_\_\_
13. Professor clarifies /repeats material that is difficult to understand: \_\_\_\_\_
14. Professor makes use of the latest technology to improve student's learning experience: \_\_\_\_\_
15. Lecture materials (e.g. slide) are helpful for the understanding of the subject material: \_\_\_\_\_
16. The professor is genuinely concerned that students take valuable experience from the class: \_\_\_\_\_
17. Considering everything, how would you rate this teacher: \_\_\_\_\_

What do you not like about Dr. Polikar's teaching, if any, and what would you suggest that he can do improve?

What do you enjoy about Dr. Polikar's teaching, if any, that he should continue in this and future classes?

**HONESTY STATEMENT**

*I, \_\_\_\_\_, have carefully read and understood this document, and clarified any questions or issues I may have (if any) with the instructor. I understand the class expectations, agree to follow the class rules, and in particular I attest that all work I present as my own will be my own. I will not represent other's work as mine. Collaborations for mutual work notwithstanding, I will not accept nor offer any help from/to anyone for work individually expected of me, and I will not use any unauthorized sources, including but are not limited to books, notes, preprogrammed calculators, the internet, other students, etc. during the exams / quizzes. I understand that showing others' work as mine, or attempting to do so, is considered academic dishonesty, and such acts are subject to forfeit of any grade obtained from the exam as well as other disciplinary action from the university. I also attest that, I will not share any exam questions with other students - past, current or future - with the understanding that doing so will also be considered academic dishonesty.*

\_\_\_\_\_  
*Name*

\_\_\_\_\_  
*Banner ID*

\_\_\_\_\_  
*Signature*

\_\_\_\_\_  
*Date*