CS7637: Knowledge-Based AI: Cognitive Systems
Fall 2016 Syllabus

Last Revised: 09/16/2016

All course documents can be found in this Google folder.

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Class Information

Teaching Team

Our teaching team is evolving at the present time (Aug. 16, 2016). As Phase II registration started on Aug. 13, the student enrollment rapidly increased, calling for the hiring of more TAs. The team should stabilize around Aug. 29 after Phase II registration ends. Here is the current team (as of Aug. 16, 2016):

Ashok Goel, Instructor
Jose Delgado, Head Teaching Assistant
    Office Hours: Mon 6-7pm ET & Thu 2-3pm ET via webex
Angela Smiley
    Office Hours: Tue 11am-12pm ET & Sat 7-8pm ET via webex
Several other TAs (both human and AI)
Several researchers

Research on Learning and AI in Education

As the composition of the Teaching Team above indicates, we are AI educators as well as AI and education researchers. The OMSCS program represents a new genre of online learning, and thus offers a fertile ground for research. We will use this KBAI class as a research laboratory to understand learning in the class and to develop new AI techniques for teaching the class. We will conduct all research in adherence to Georgia Tech IRB protocols. Thus, we will protect student privacy and confidentiality. (More on this research a little later.)

Course Description

This is a core course in artificial intelligence. It is designed to be a challenging course, involving significant independent work, readings, assignments, and projects. It covers structured knowledge representations, as well as knowledge-based methods of problem solving, planning, decision-making, and learning. For additional information on the course, we invite you to read a recent Technical Report and watch our talk to the GVU Brown Bag from last December.

Core Components

This course has five major components.

1. Video Lessons, Exercises, and Readings: This course has 26 videos with about 18 hours of instruction. The videos have ~150 exercises and ~100 “tutors” embedded in them. Most lessons have an accompanying set of readings. While video lessons introduce the basic concepts and methods, the readings provide the detailed algorithms. Some lessons have additional accompanying exercises.
2. Design, Programming and Reflection Projects: 3 challenging projects representing cutting edge research in KBAI to be done individually. Succeeding projects build in preceding ones. The projects are accompanied with a reading list. Please note that the projects do not require any specialized knowledge of computer vision or image processing.
3. Assignments and Examinations: A series of 3 assignments and 2 take home examinations. The assignments/examinations will involve significant amount of essay writing and will test knowledge on the video lessons and accompanying readings.
4. Peer Feedback: Peer feedback on all 3 projects, 3 writing assignments and 2 examinations (total of 8 assignments). We will expect each student to give feedback on the work of 3 randomly selected peers for each of the 8 assignments. We will also select and share the best assignments, which will form another kind of peer feedback.
5. Announcements, question answering and discussions: We will use the Piazza forum for announcements, question answering, discussions, and collaboration. It is important that you log into Piazza regularly and frequently (at least two or three times a week, daily if possible).

Competency

This course requires substantial programming as well as significant writing. To succeed in this course, you should be able to answer 'Yes' to the following questions:

- Are you confident with computer programming in Python (or Java)?
- Are you strongly familiar with basic concepts of data structures and object-oriented programming, such as inheritance and polymorphism?
- Are you strongly familiar with basic concepts of algorithm design, such as algorithms for sorting, searching, and matching?
- Are you comfortable with writing essays, totaling 10-15 thousand words (across the three assignments, three reflection reports and two examinations) throughout the semester?

- Are you willing to deeply engage with your classmates through discussions on the Piazza forum, Peer Feedback, and sharing of exemplary assignments?
- Are you willing to work independently on challenging design, programming and reflection projects all on your own?
- Are you able to read papers on your own that go beyond the video lessons?
- Are you able to meet fixed deadlines for assignments with no possibility of any extension?
- Are you willing and able to spend significant amounts of time and energy on a regular basis to this course?
- Are you ready to adhere to the Georgia Tech code of academic conduct?

If your answer is not a strong "Yes" to all of these questions, this course may not be appropriate for you. If your answer is "No" to any of these questions, this course likely is not appropriate for you.

Learning Goals

The class is organized around three primary learning goals. First, this class teaches the **concepts, methods, and prominent issues** in knowledge-based artificial intelligence. Second, it teaches the **specific skills and abilities** needed to apply those concepts to the design of knowledge-based AI agents. Third, it teaches the **relationship** between knowledge-based artificial intelligence and the study of human cognition.

Learning Strategies

This structure of this course is driven by several pedagogical motivations:

- **Learning by example:** Each topic is taught through examples of the way in which humans and artificial intelligence agents approach certain problems, often building from human thought toward AI agents and subsequently referring back to human cognition.
- **Learning by doing:** you will participate in the reasoning within each particular lesson, and subsequently tie the topic back to a broader problem.
- **Project-Based Learning:** This class has three projects, each of which build on the previous one, and the overall goals and motivations of KBAI are presented through these projects.
- **Personalization:** Individualized feedback will be given on your performance on the exercises, assignments, projects, and tests. Additionally, you are welcome and encouraged to proceed at your own pace throughout the lessons, including viewing them outside of the designed order to better align with your interests.
- **Collaborative Learning:** We encourage collaboration and the development of communities of practice surrounding the course material and projects. We are excited

to see you borrow one another's ideas and build on them, as well as spin off your own study groups.

- **Peer-to-Peer Learning:** During this class you will give your peers feedback on their work on the same assignments you complete. This lets you see additional approaches to the problems, provides you extra feedback, and puts you in the position of a teacher, which has been shown to be a pedagogically useful role reversal.
- **Self-Reflection:** At the conclusion of each lesson, we ask each student to reflect on what they learned in the class. Each design project requires the writing of a project reflection that explains and critiques, and reflects on the student's work on the project.
- **Authenticity:** The project that you will explore in this class is an open research question in the AI and Cognitive Systems research communities. Two students from our lab have completed dissertations working on these questions in the past two years, and we have had papers published on these topics within the past several months.

Learning Outcomes

At the conclusion of this class, you will be able to accomplish three primary tasks. First, you will be able to **design and implement a knowledge-based artificial intelligence agent** that can address a complex task using the methods discussed in the course. Second, you will be able to **use this agent to reflect on the process of human cognition**. Third, you will be able to **use both these practices to address practical problems in multiple domains**. The Technical Report mentioned earlier provides a more detailed account of learning goals, strategies and outcomes of this course.

Class Materials

Course Schedule

CS7637: Knowledge-Based AI is typically run as a 16-week class. Note that all assignments are due at the end of the week, on Sunday at midnight UTC-12 (Anywhere On Earth time). This translates to an early-morning Monday deadline in the Americas, a midday Monday deadline in Europe, etc. For example, Assignment 1 is due on September 4th at midnight UTC-12, which translates to Monday, September 5th at 8AM Eastern time, 5AM Pacific time.

Precise due dates and times can be found in T-Square on each assignment page. Make sure to set T-Square to your local time zone to see due dates in your time.

The following is a short version of the course calendar; the full version, with links to the various assignments and T-Square submission pages, can be found here. Numbers in parentheses below are the estimated amounts of time (in minutes) each lesson should take, including exercises. Your experience may vary, especially if you watch the videos at an increased speed at first (highly recommended!).

Full Calendar for Knowledge-Based AI: Cognitive Systems (Fall 2016)

Week	Week Of	Lessons*	Assignment
1	Aug. 22	Introduction to KBAI (45); Introduction to CS7637 (60)	Survey & Introduction
2	Aug. 29	Semantic Nets (60); Generate & Test (30)	Assignment 1
3	Sep. 5	Means-Ends Analysis (60); Production Systems (60)	PF , Project 1
4	Sep. 12	Frames (45); Learning by Recording Cases (30)	
5	Sep. 19	Case-Based Reasoning (60)	
6	Sep. 26	Incremental Concept Learning (60); Classification (45)	PF, Assignment 2
7	Oct. 3	Logic (90)	PF, Mid-Term Exam
8	Oct. 10	Planning (75); Understanding (30)	PF, Project 2, Survey
9	Oct. 17	Common Sense Reasoning (60); Scripts (30)	

10	Oct. 24	Explanation-Based Learning (45); Analogical Reasoning (60)	
11	Oct. 31	Version Spaces (60); Constraint Propagation (45)	PF, Assignment 3
12	Nov. 7	Configuration (45); Diagnosis (45)	PF, Project 3
13	Nov. 14	Learning by Correcting Mistakes (45); Meta-Reasoning (30)	
14	Nov. 21	Advanced Topics (60); Wrap-Up (30)	
15	Nov. 30		PF, Final Exam
16	Dec. 5		PF, KBAI Survey, CIOS Survey

This schedule of the lessons is merely provided as a guide. In practice, you are free and encouraged to watch the lessons in any order and at any pace you choose. Note only that you are responsible for all lecture material for the final exam, and that each assignment is based on some of the immediately preceding lesson topics.

Make sure to consult the full schedule for additional assignments (Peer Feedback reminders, survey reminders) and links to T-Square submission pages.

Reading List

There are two sets of recommended readings. The first set accompanies the video lessons and the second set accompanies the projects. Both can be found in the reading list. Readings will either be publicly available online or will be provided to you in the T-Square Resources section for this class.

We strongly recommend the readings that accompany the video lessons as well as the projects. The readings accompanying the videos add depth to the lessons: for example, they cover algorithms for the conceptual methods discussed in the videos. Similarly, the readings accompanying the projects describe the conceptual and algorithmic basis for the projects.

Class Assessments

Grade Categories

Your final grade in this class will be based on four components.

Category	**%**	**Description**
Assignments	10%	3 written assignments (~1000 words each). 3.3% for each assignment.
Projects	45%	3 programming projects with accompanying project reflections (~1500 words each). 15% for each project.
Exams	33%	2 unproctored take-home exams (11% for mid-term exam - ~2000 words; 22% for final exam - ~3000 words).
Peer Feedback	12%	~24 peer feedback activities based on written assignments, project reflections, and examinations

Grading Policies

After submission, all written work (assignments, project reflections, and examinations) will go through a round of peer feedback. During peer feedback, your peers will score your assignment according to the same rubric used by the graders, as well as leave you written feedback. Your peers will have one week to submit this peer feedback. *After* peer feedback is done, the graders will have one week to grade your assignments. Thus, you will get your assignment grades by two weeks after the original submission deadline. The structure of the class assignments and projects also means that you can always receive a grade before the next time a similar assignment is due.

Note that the grades assigned by your peers have *no* direct effect on the grades you receive from the graders. All actual grades are assigned by the graders and the graders alone. The primary purpose of supplying the graders with the results of the peer feedback process is to help the graders ensure every student gets useful feedback, as well as to ensure that the peer feedback received is accurate.

Grades will generally be delivered via both T-Square and Peer Feedback. Written feedback from the graders, however, will only be delivered via Peer Feedback. For Projects, sub-scores for your agent's performance on the problems and for your project reflection will be returned via the assignment submission page, and the overall project score will be posted to the

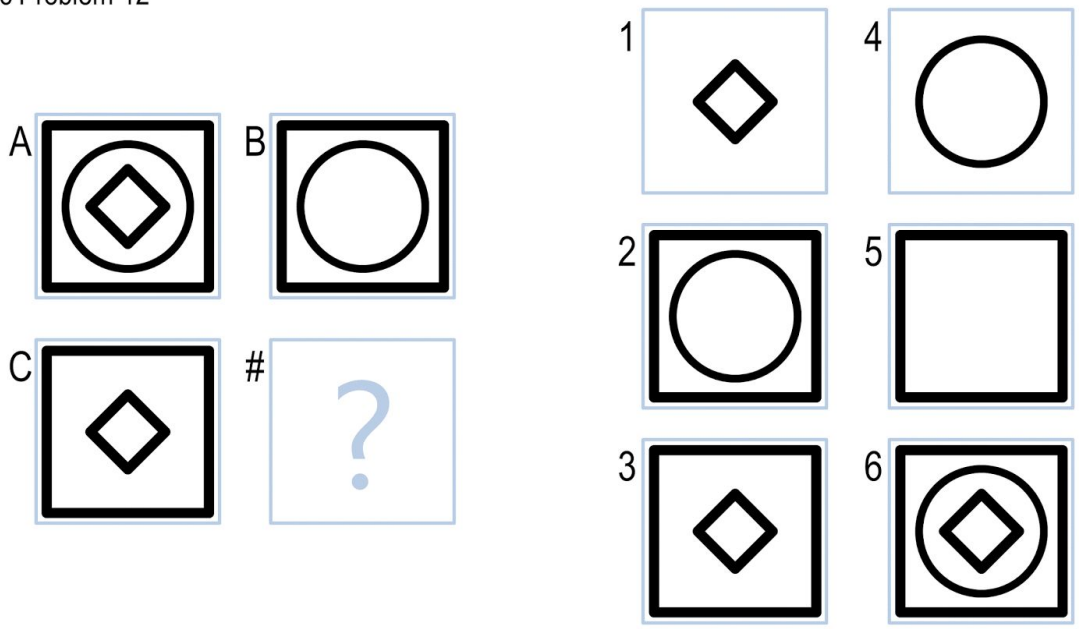
gradebook. Checkmarks for Peer Feedback participation will be provided throughout the semester via the assignment submission pages for those tasks, and a final Peer Feedback score (based both on completion and quality of participation) will be assigned at the end of the semester.

Lastly, it is important to note that this course does *not* follow the normal grading buckets (90 or above for A, 80 to 90 for B, etc.). Instead, this class is graded on a curve. A 90% is certainly not the threshold for an A in the class. For the Fall 2015 KBAI class, the average was in the low 80s, and only about 10% of the class ended with a raw score over 90; well over half the class still received an A, though. If you try to interpret your grade according to the traditional categories, you will likely think you are doing *far* worse in the class than you actually are. Make sure to pay attention to the announcements on Piazza after each assignment and project is graded to understand where your grade sits in the big picture; otherwise, you're likely to think you're doing *much* worse than you actually are. Although we understand the importance of grades, we encourage you to focus first on doing the best you can on all assignments; if you do, your grade should take care of itself.

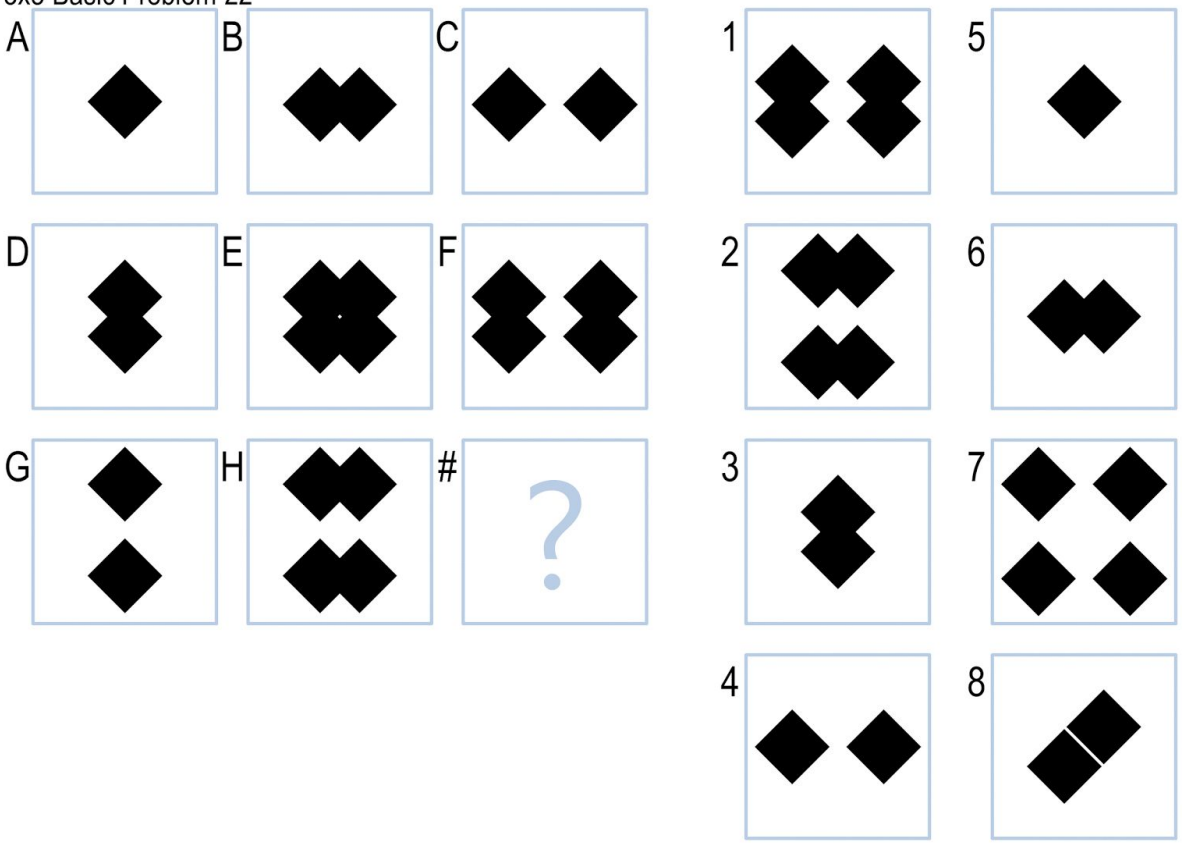
Projects

The course consists of three design, programming and reflection projects, each of which build on the previous one. We will post exemplary solutions to each project at the end of each project to give others a chance to learn from the best submissions. For complete information on the projects, consult the Overall Project Description and the documents for Project 1, Project 2, and Project 3.

2x2 Basic Problem 12



3x3 Basic Problem 22



In all three projects, you will design agents that solve intelligence test problems like the two shown above. These problems are broken into four sets of roughly ascending difficulty: set B, set C, set D, and set E. Set B consists of 2x2 problems, while sets C, D, and E consist of 3x3 problems. In some projects, your agents will be able to operate on both verbal and visual representations of these problems. Visual representations are images themselves, while verbal representations are words expressing parameters and relationships. For example, a verbal representation of figure G above might specify that the figure has two shapes, both shapes are filled diamonds, and one diamond is above the other.

The three projects ascend as follows:

- Project 1: Solve Set B (both visual and verbal).
- Project 2: Solve Sets B and C (both visual and verbal).
- Project 3: Solve Sets B, C, D, and E (visual only for D and E).

Generally speaking, verbal representations are easier to work with than visual representations because some human reasoning has already simplified the problem. So, verbal representations are supplied for the first couple projects to scaffold your agent's reasoning. However, we also provide the visual representations from the beginning so that you can shift to using visual representations as early as you'd like.

Many humans struggle to get all these problems correct. The current state of the art in computer algorithms to solve these problems currently gets roughly 80% of these problems correct. You're encouraged to try to design the smartest agent you can, but please make sure you're not holding yourself to the usual standard of "90% or above is an A". Think about how humans solve these problems, try to design an agent that solves these problems, and use the agent's performance to reflect on how humans solve these problems. The goal of this project is to explore the relationship between AI and human cognition; the number of problems your agent gets correct is merely a barometer to measure how much you've explored that relationship.

More information about the projects and their learning goals can be found on the individual project assignment pages. It is important to note that these projects do not require any special knowledge of computer vision or image processing. Note that no external libraries like OpenCV are permitted for use on any of these projects, excepting the Python's image processing library Pillow and mathematical library Numpy. Each project should also be accompanied by a ~1500 word project reflection describing the mechanics, strengths, and weaknesses of the agent as well as what it tells us about human cognition.

You will have three weeks to complete each project. We strongly recommend that you start early because these projects are harder than they may appear. We suggest using the first week of a project for initial design, programming and testing, the second week for iterative redesign, reprogramming and retesting, and the third week for writing the project reflections.

Assignments

There are three writing assignments in this class. Each assignment should be approximately 1,000 words (neither a minimum nor a maximum, just a heuristic), and should relate a certain topic or set of topics in the course material to some problem. For Assignments 1 the problem should be the class project. For Assignments 2, we will provide a list of problems that you can choose from. For Assignments 3, you may choose from that same list, or you may select a problem of your own.

Peer Feedback

We will use a tool called Peer Feedback -- peerfeedback.gatech.edu -- to give peer-to-peer feedback in this class. Peer-to-peer feedback provides a number of opportunities: it gives you the opportunity to see your classmates' work, it gets you more feedback on your work than you would otherwise receive, and it puts you in the position of critiquing and analyzing course material. You will give peer-to-peer feedback to your classmates on all six assignments (including the three you do not personally complete) and on all three project reflections.

Peers will evaluate one another on the same rubric that graders will use; however, the scores you assign to your peers will *not* factor into their actual grades on the assignment. All grades will be assigned by TAs. TAs will see the feedback you give to your peers in order to ensure that all students receive adequate feedback.

Completing peer feedback exercises is 15% of your average. Your peer feedback average will be determined not only based on whether or not you completed all assigned peer feedback exercises, but also based on the quality of the feedback you provided as evaluated by the TAs and by the recipients of the feedback.

Exams

There will be two exams: a Mid-Term Exam and a Final Exam. Both exams will be an unproctored, untimed, "take-home" tests. Both will consist of a number of different questions asking you to synthesize multiple parts of the course material.

Class Policies

Course Communication

Any new class information that you are responsible for knowing (such as changing due dates or changes to assignment requirements) will be sent in two ways:

- A T-Square announcement with an email notification.
- A pinned Piazza announcement in the 'announcements' folder with an email notification.

Thus, any new information you are required to know will arrive in your inbox twice, as well as be visible on the T-Square page and Piazza forum for the class.

If we have any questions for you, such as your assignment could not be opened or your project would not run, we will email you. Georgia Tech generally asks that you check your GT email at least once every 24 hours on weekdays. While likely will be few items in this course that requires an answer that fast, we ask that you check your GT email with that level of regularity to make sure you see any important announcements in plenty of time and respond to any TA questions quickly. If we contact you and do not hear back, your grade may be affected (and we don't want that!).

Note that (with the exception of the Final Exam) all assignments are due on Sunday nights based on popular request among OMSCS students. However, remember that for the instructors and TAs of this class, this is a job, and we may not check Piazza on weekends. Please make sure to start the projects and assignments early enough to ask questions in advance.

Office Hours

Generally speaking, questions should be posed first to Piazza. This opens up the question to input from everyone in the class and creates a self-documenting history of the answer to the question. However, there are certain questions that are better-suited for office hours, like more conversational discussions on course material and discussions about individuals' grades.

We will have weekly synchronous office hours sessions run via Webex, one with the instructor and one with the head TA. These sessions will be accessible via the link found in Piazza.

Clicking that link should allow you to set up Webex and participate in the teleconference. If you have any difficulty, please contact the TAs and let us know. Note that generally, these office hours will not be recorded. Synchronous office hours are intended for conversations about individual projects, discussions about course material, etc. rather than straightforward question-and-answer; because they are more personal to the individual attendees, they are not as useful when recorded and posted. Additionally, the pressure of knowing 400 people may watch a private chat tends to dampen natural conversation. If anything comes up in these office hours that is relevant to the rest of the class, it will be recorded or posted on Piazza. In the event that synchronous office hours are not offered during a time that you can make, let us know and we'll try to add times to the schedule.

If your question is about a private issue, such as a grade on an examination, you should post a private Piazza message (visible only to instructors). Please remember, however, that the instructor and TAs are together responsible for a class of 250 students and other responsibilities, so please be patient in awaiting responses and, whenever possible, post your questions publicly on the forum first.

Posting of Exemplary Assignments

As we mentioned above, peer-to-peer learning is known to be a powerful learning strategy. Thus, this course will provide opportunities for peer-to-peer feedback. To provide additional opportunities for peer-to-peer learning, for each assignment and project and exam, we will select a small set of exemplary assignment and post them on Piazza for everyone to see and learn from. In past semesters, we have found this strategy to be very effective in fostering a community of learners. Of course let us know if you have any questions about any of these strategies and policies.

Late Work

Running such a large class involves a detailed workflow for assigning assignments to graders, grading those assignments, and returning those grades. As such, work that does not enter into that workflow presents a major delay. **Thus, we cannot accept any late work in this class.** All assignments (complete or partial, including projects and examinations) must be submitted by the posted deadlines. If you have technical difficulties submitting the assignment to T-Square, post privately to Piazza **immediately** and attach your submission. Once again we have very modest teaching resources for this large class and thus we cannot and will not accept any late submissions.

If you have an emergency and absolutely cannot submit an assignment by the posted deadlines, we ask you to go through the Dean of Students' office regarding class absences. The Dean of Students is equipped to address emergencies that we lack the resources to address. Additionally, the Dean of Students office can coordinate with you and alert all your classes together instead of requiring you to contact each professor individually. You may find information on contacting the Dean of Students with regard to personal emergencies here: https://studentlife.gatech.edu/content/class-attendance

The Dean of Students is there to be an advocate and partner for you when you're in a crisis; we wholeheartedly recommend taking advantage of this resource if you are in need. Justifiable excuses here would involve any major unforeseen disruption to your classwork, such as illnesses, injuries, deaths, and births, all for either you or your family. Note that for foreseen but unavoidable conflicts, like weddings, business trips, and conferences, you should complete your work in advance; this is why we have made sure to provide all assignment and project resources in advance. If you have such a conflict specifically with the final exam, let us know and we'll try to work with you.

Collaboration & Academic Honesty

In general, we strongly encourage collaboration in this class. You are encouraged to use the Piazza forum to discuss the course material, the exercises, the written assignments, and the projects with your classmates, both before and after assignments and projects are due. Similarly, we will be posting the best projects for public viewing so you may learn from the success of others' designs.

However, in collaborating, we draw the line at the following:

- You may not directly copy any code from anyone else. This includes tweaking variable names. Your project must be your own work.
- You may not directly copy any text from anyone else's written assignments. This includes directly paraphrasing. Your assignments must be your own work.
- You may not collaborate at all on the Mid-Term and the Final Exams. Do not discuss the questions and answers with your classmates until after the tests are due.

We have mechanisms in place to prevent plagiarism and we will do our utmost to check for instances of plagiarism. We have caught instances of it each semester that we've delivered this course, and the experience has been unpleasant, time-consuming and emotionally draining for both the students and the teaching team. Please don't be the next person to do this. We assure you that the consequences for a poor grade on a project or assignment are far, far less than the consequences for plagiarism. Again, it isn't worth the risk; please don't do it. Any instances of violation of this policy will (a) incur a significant penalty and (b) be

referred to the Dean of Students. If you are unsure of whether a certain type of collaboration is acceptable, please ask first, preferably on Piazza. The full Georgia Tech honor code is available at: http://www.catalog.gatech.edu/rules/18b.php. We will be stringent about this aspect of the course to protect the overwhelming majority of students who will honor the academic code of conduct.

Feedback

Every semester is a learning experience for us as we administer this course. We made many changes to the Summer offering of this course based on the Fall and Spring offerings, and we have continued to make changes based on the Summer offering. There are still bound to be things we can (and will) improve. First, we ask that you be patient and understanding with anything that might go wrong; we promise that we, too, will be fair and understanding, especially with anything that might impact your grade or performance in the class. Second, we ask you to give us feedback on anything that we could be doing better, as well as feedback on anything you are particularly enjoying. You may take advantage of the feedback box on Piazza, as well as the surveys we will send out over the course of the semester.

We will request that you complete the course surveys. There will be four course surveys: we will administer 3 of them during the course Georgia Tech will administer the fourth called CIOS at the end of the term. These surveys provide us with structured feedback and help us improve the course.

Back to Research on Learning and AI in Education

These course surveys are elements of the research we had briefly mentioned earlier: they help us understand the student demographics, student attitudes, and student perceptions of the KBAI class. Our goal is to continually innovate to improve learning in the class. In particular, we want to use AI to teach AI, as evidenced by the ~100 AI agents acting as tutors embedded in the video lessons as well as the 3 projects that represent authentic cutting edge AI research. As this term unfolds, we will share more details on our research on learning in this class. Past research in the KBAI class has led to several publications, some involving students in the class. Please let us know if you have any questions about our research. Thank you.