Research paper

Each student will write a documented research paper of at least 600 words on a topic chosen by the student and approved by the instructor. Sources should be peer-reviewed or from edited periodicals, conference proceedings, or books. Include references within the text of your paper and a bibliography at the end in standard bibliographic format, including author name and publication information.

Research should be in some area covered by the course, with meaningful references to the course's textbook, sources, or handouts. Reference to the course material will be an important aspect of the research paper. Some *technical* aspect about AI research should be included.

The work will be done in three stages, each time with instructor feedback.

Submit all items with name, date, course number and name, professor name, university name. Paginate your paper and subdivide it into sections.

Proposal (due October)

Include:

- title (which like anything else in your proposal, you may change later);
- initial abstract: a paragraph or so about the topic, including some factual assertion about the topic and and optionally a statement of what you hope to learn);
- short initial list of 2-3 sources in bibliographic format (see syllabus). Include at least one non-encyclopedia *academic* source (journal paper, conference paper, non-textbook scholarly book).

For links to papers with sample abstracts and sample bibliographic format, see www.framingham.edu/faculty/dkeil.

For information on formatting and documenting research see, for example, http://owl.english.purdue.edu/handouts/research/r_apa.html or http://webster.commnet.edu/apa/apa_intro.htm.)

Preliminary draft (due November)

Draft, to be submitted in April, should respond to instructor comments on proposal, and should be at least 300 words. Embed references. Use diagrams to illustrate points made.

Final draft (due December)

Final draft should respond to instructor comments about preliminary draft and should be worthy of posting at instructor's web site.

Desired features of research papers

- organization
- presentation
- definition of terms
- abstract, with research question or thesis
- relevance to course material technical aspect
- social or philosophical aspect (optional)
- writing
- specific factual evidence to support thesis
- acknowledgement of alternative views (optional)

Introductory assignment

For all assignments, submit on paper, giving your name, date, assignment number, problem letter, and problem number (e.g., "C.6").

A. Background and self introduction

At the Discussion Board, Forum "Introduction," please describe your background and your expectations for the course or questions about it.

Submit parts B, C and D on paper.

B. Initial impressions and concepts

(a) Describe briefly your past contact with and impressions of the notion of artificial intelligence.
(b) Give some attributes of intelligence as you are familiar with it.

C. Proof in propositional logic [MOVE TO T3, REPLACING WITH A STATISTICS PROBLEM AND A CSII BASED PROBLEM]

Consider these axioms.

a. a is true
b. f is false
c. $a \rightarrow b$
d. $b \rightarrow \neg d$
e. $b \rightarrow c$
f. $\neg a \rightarrow e$
g. $\neg f \rightarrow \neg d$
h. $e \rightarrow \neg f$
i. $g \rightarrow f$
j. $h \rightarrow \neg c$
k. $false \rightarrow q$ for any q (contradiction)
l. $((p \rightarrow q) \wedge p) \rightarrow q$ for any p, q (modus ponens)
m. $((p \rightarrow q) \wedge \neg q) \rightarrow \neg p$ for any p, q (modus tollens)

Prove one of the following, corresponding to your classroom number, referring by letter to the axiom(s) used:

0. c
1. $b \vee \neg e$
2. $c \vee d$
3. $c \wedge \neg d$
4. $e \rightarrow \neg d$
5. $\neg b \vee \neg f$
6. $\neg d$
7. $a \vee e$
8. $\neg g$
9. $\neg h$
10. $f \rightarrow \neg a$

D. Algorithm design

Write an algorithm, in pseudocode, that has an array of numbers as a parameter and that computes

0. Disjunction (OR), assuming all elements are 0 or 1 (false or true)
1. Conjunction (AND), assuming all eleements are 0 or 1 (false or true)
2. Sum of all elements
3. Number of elements, starting with first, that are all the same
4. Number of zeroes
5. Smallest element
6. Subscript of the leftmost 1
7. Subscript of largest element
8. *True* if all values are the same, otherwise *false*
9. *True* if all values are in ascending order, otherwise *false*
10. Length of longest ascending sequence that starts with first element

Topic 1 assignment (Adaption, cognition, computation)

In the case of lists of multiple problems, each student is to solve the problem in each set corresponding to the last digit of the student's classroom ID. Submit 1-2 paragraphs per question on paper.

A. Short and longer answer

See the Study Questions list, topic 1, short and longer answer problems. Solve the problems numbered (*your-classroom-ID*) and (ID + *class-size*).

B. Cognition sources

Consider the texts from Thagard, from Simon, and from Weizenbaum. Give one or two of the assertions of Thagard and Simon, and support or refute it with evidence, possibly commenting on Weizenbaum's challenge to Simon's view.

C. Eliza exercise

Have a "therapy" session with Eliza (http://www.chayden.net/eliza/Eliza.html or http://www.manifestation.com/neurotoys/eliza.php3). In what ways does Eliza resemble a human therapist? In what ways is it apparent that this is not a human?

D. The rational-agent approach to AI (optional)

Choose one, corresponding to your classroom ID, from *either* of the following sets of exercises in Russell-Norvig:

pp. 31-33, #1.1-1.15
pp. 61-63, #2.1-2.13.

Topic 2 assignment (State-space search)

A. Concepts

For the terms below whose numbers match your classroom ID, define the term in your own words and discuss it, relating it to the course material. Give sources used.

1. backtracking
2. backward chaining
3. best-first search
4. breadth-first search
5. constraint satisfaction problem
6. data-driven search
7. depth-first search
8. depth-limited search
9. evaluation function
10. exploration
11. forward chaining
12. goal condition
13. goal test
14. goal-driven search
15. heuristic
16. hill climbing
17. informedness
18. initial state
19. local search
20. minimax
21. optimization problem
22. path
23. production rule
24. production system
25. state
26. state transition
27. state-space search
28. tree search
29. triangle inequality
30. uninformed search

B. Short-answer questions

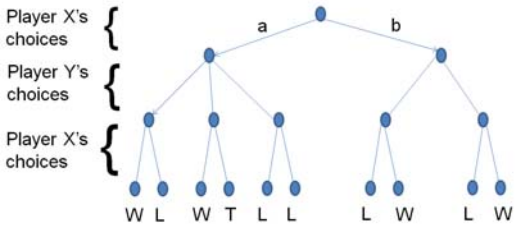
See the Study Questions, Topic 2, Short and longer answer questions,. Answer the questions match your classroom ID.

C. State-space problems

Solve the problem below corresponding to your classroom ID.

(1-2, 10) Consider the following game trees. Player *X* is at the game state denoted by the root vertex and may choose between move *a* and move *b*, denoted by edges, leading to a game state that is a vertex adjacent to the root. Then player *Y* will move, followed by player *X*. After *X*'s second move, that player will immediately be in a game state that is a win (W), tie (T), or loss (L). Decide whether player *X*'s better move is *a* or *b*, and explain. What is the maximum size of the state space of paths for a game tree of depth *n*, where players have a maximum of *k* choices in making a move? (Adapted from Brookshear.)

1.



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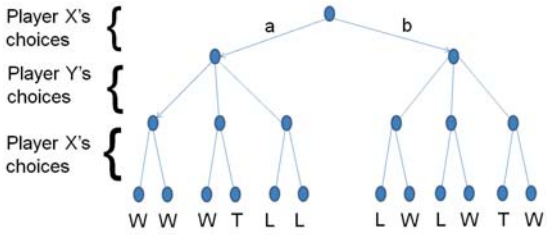

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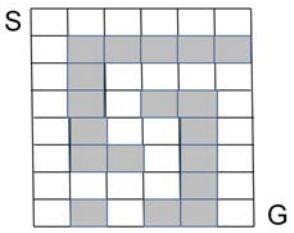
(3-4, 11) Consider the mazes below, where the player starts at *S* and tries to reach goal *G*.

(a) Convert to graph form

(b) Perform partial depth-first and breadth-first searches by giving the order in which the graph vertices are to be visited

(c) If *n* two-way branches are encountered in a maze, then how large is the state space of paths?

3.



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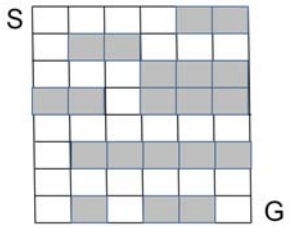


(5-9) Consider the following tic-tac-toe positions.

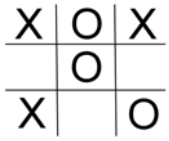
(a) Draw a game tree, using the notation

1 2 3
4 5 6
7 8 9

to denote moves

(b) Use game tree to choose X's next move and predict game outcome

5.



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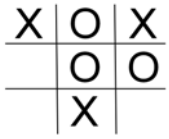

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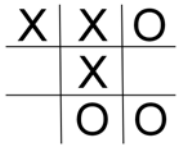

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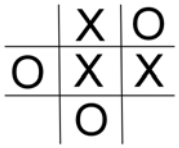

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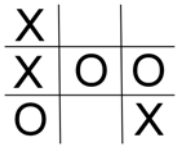

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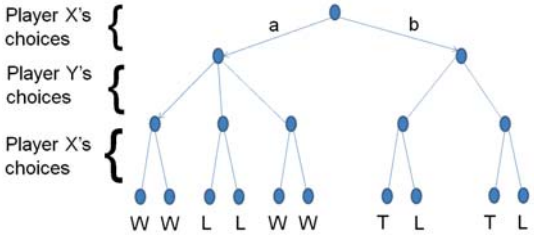

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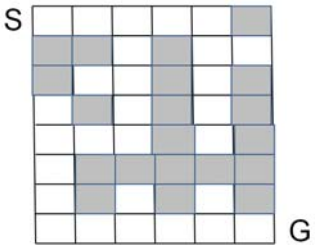


Topic 3 assignment (Knowledge representation)

A. Concepts

For the terms below whose last digits match your student number, define the term in your own words and discuss it, relating it to the course material.

1. belief
2. causal rule
3. containment
4. diagnostic rule
5. domain knowledge
7. inheritance
8. knowledge
9. knowledge engineering
10. knowledge-based agent
11. model-based reasoning
12. situation
13. state
14. arity
15. completeness
16. conjunction
17. consistency
18. disjunction
19. entailment
21. existential quantifier
22. first-order logic
23. formula
24. implication
25. inference rule
26. interpretation
27. knowledge representation
28. modus ponens
29. modus tollens
30. negation
31. predicate calculus
32. proof procedure
33. propositional calculus
34. satisfiability
35. soundness
36. truth table
37. universal quantifier
39. validity
40. expert system
41. Horn clause
42. inference rule
43. knowledge base
44. logic program
45. premise-conclusion production
47. resolution proof
48. associationist theory of meaning
50. case frame
51. case-based reasoning
52. closed-world assumption
53. conceptual dependency theory
56. frame
59. planning
60. script
62. semantic network
64. truth maintenance
65. unification algorithm

B. Objectives-related questions

See the Study Questions, topic 3, Short and longer answer. Answer the question numbered (your-ID + 8) and (your-ID + 15).

C. Proof in propositional logic

Consider these axioms.

a. a is true
b. f is false
c. $a \rightarrow b$
d. $b \rightarrow \neg d$
e. $b \rightarrow c$
f. $\neg a \rightarrow e$
g. $\neg f \rightarrow \neg d$
h. $e \rightarrow \neg f$
i. $g \rightarrow f$
j. $h \rightarrow \neg c$
k. $false \rightarrow q$ for any q (contradiction)
l. $((p \rightarrow q) \wedge p) \rightarrow q$ for any p, q (modus ponens)
m. $((p \rightarrow q) \wedge \neg q) \rightarrow \neg p$ for any p, q (modus tollens)

Prove one of the following, corresponding to your classroom number, referring by letter to the axiom(s) used:

0. c
1. $b \vee \neg e$
2. $c \vee d$
3. $c \wedge \neg d$
4. $e \rightarrow \neg d$
5. $\neg b \vee \neg f$
6. $\neg d$
7. $a \vee e$
8. $\neg g$
9. $\neg h$
10. $f \rightarrow \neg a$

D. Inference

Russell-Norvig, p. 280, #7.4(a-l); solve the problem whose letter corresponds to your ID. Justify your answer.

E. Proof

Russell-Norvig, p. 281, #7.5-7.6. Answer one. Classroom ID 1 = 7.5(a), 2 = 7.5(b), ..., 6 = 7.6(a), 7 = 7.6(b).

F. Predicates

Russell-Norvig, p. 317, #8.10(a-g). Answer one, as before.

G. Concept representation

Russell-Norvig, p. 476, #12.7(a-g). Answer one, as before.

Topic 4 assignment (Uncertainty)

For each question, restate the question and give its number. Solve the problems you can; some will be given extra credit if solved.

A. Concepts

For each term below whose last digit matches your student number, restate and define the term in your own words, and briefly relate it to the course material.

[Uncertainty]
1. action monitoring
2. belief state
3. nonmonotonic reasoning
4. plan monitoring
5. truth maintenance

[Probability theory]
6. probability theory
7. atomic event
8. chain rule
9. combination
10. conditional probability
11. event
12. expected outcome
13. permutation
14. prior probability
15. probability density function
16. random variable
17. resolution proof
18. sample space
19. unconditional probability

[Bayes' Theorem and hidden Markov models]
20. Bayes' theorem
21. Bayesian inference
22. Bayesian belief network
23. Markov model
24. Markov assumption
25. Markov decision process

B. Short-answer questions

See the Study Questions list, topic 4. Solve the short-answer problems *for each objective* (4a, 4b, 4c) that have the same last digit as your classroom student number.

C. Combinatorics

Solve Russell-Norvig, p. 507, #13.7(c). Show your work. Instructor will solve (a), (b).

Classroom ID 1 = royal straight flush;
2 = five cards straight, 3 = pair, 4 = three of a kind,
5 = four of a kind; 6 = four queens; 7 = five hearts.

D. Conditional probability

Suppose $P(P) = 0.5$, $P(Q) = 0.3$, $P(R) = 0.4$, $P(P \cap Q) = 0.2$, $P(Q \cap R) = 0.25$, $P(P \cap R) = 0.3$. Showing your work, find:

0. $P(P \mid Q)$
1. $P(Q \mid P)$
2. $P(P \mid R)$
3. $P(Q \mid R)$
4. $P(R \mid Q)$
5. $P(R \mid P)$
6. $P(P \mid Q \cap R)$
7. $P(R \mid P \cap Q)$

E. Bayesian network

Showing your work, label the network on slide 41, given the following variants of the data on slide 42:

1. .3, .1, .05, .55
2. .2, .3, .1, .4
3. .1, .1, .1, .7
4. .1, .2, .2, .5
5. 25, .25, .05, .45
6. .1, .2, .3, .4
7. .05, .1, .3, .55

F. Construct Bayesian network (optional)

See Russell-Norvig, p. 559, #14.4. Construct a new Bayesian network based on some scenario other than burglaries and earthquakes. Pose a problem based on this network. *Extra credit.*

G. Markov models

See the weather model on a slide in subtopic 4. Showing your work, based on that data, and given that it is sunny today, calculate the probability that:

1. The next three days will not all be sunny
2. The next three days will be cloudy
3. The next three days will be sun, clouds, rain
4. The next three days will be rainy
5. The next two days will be rain, then sun
6. Two of the next three days will be rainy
7. The next four days will all be sunny or cloudy
8. It will be cloudy two days from now
9. It will *not* be sunny two days from now

Topic 5 assignment (Supervised learning)

For each question, restate the question and give its number.

A. Concepts

For each term below whose last digit matches your student number, restate and define the term in your own words, and briefly relate it to the course material.

[Supervised learning]
1. abduction
2. analogical reasoning
3. concept
4. decision tree learning
5. decision tree learning
6. explanation based learning
7. inductive bias
8. inductive inference
9. inductive learning
10. learnability
11. learning
12. PAC learning
13. supervised learning

[Connectionist learning]
14. associative memory
15. attractor
16. backpropagation
17. connectionist learning
18. neural network
19. perceptron

[Evolutionary computation]
26. evolutionary computation
27. genetic algorithm
28. classifier system
29. genetic programming
30. function-optimization problem
31. fitness function
32. No Free Lunch theorem
33. static environment
34. coevolution
35. particle swarm optimization
36. evolutionary algorithm

genetic operator

[Natural language]
20. grammar
21. language
22. nonterminal symbol
23. parse tree
24. pragmatics
25. semantics

B. Objectives-related questions

See the Study Questions, topic 5, Short and longer answer. Answer the questions *for each objective* (5a, 5b, 5c, 5d) that have the same last digit as your classroom student number.

C. Decision-tree learning

See the slide on decision-tree learning (subtopic 5.1). Use a similar method to construct decision trees for the following examples. Instructor will solve problem 0. *Challenge:* use the *Decision-tree-learning* algorithm on Russell-Norvig, p. 702 (see also p. 764, #18.6) to generate a decision tree.

	x_1				x_2				x_3				x_4				x_5			
	A_1	A_2	A_3	y	A_1	A_2	A_3	y	A_1	A_2	A_3	y	A_1	A_2	A_3	y	A_1	A_2	A_3	y
0.	0	0	1	0	1	0	1	0	0	1	0	0	1	1	1	1	1	1	0	1
1.	1	0	0	1	0	1	0	1	0	0	1	0	0	1	1	1	1	1	1	0
2.	1	1	0	0	1	0	1	0	1	0	0	1	0	0	1	1	1	1	1	1
3.	0	1	0	1	0	1	1	0	1	0	1	0	0	1	0	0	1	1	1	1
4.	1	1	0	1	0	0	1	0	1	0	1	0	0	1	0	0	1	1	1	1
5.	0	0	1	0	1	0	1	0	0	1	0	0	1	1	1	1	1	1	0	0
6.	1	0	1	0	0	1	0	0	1	1	1	1	1	1	0	0	1	0	0	1
7.	0	0	1	0	0	1	1	1	1	1	1	0	1	1	0	1	0	1	0	0

(over)

D. Constructing a perceptron neural net

(a) Visit the following site:
http://www.eee.metu.edu.tr/~alatan/Courses/Demo/AppletPerceptron.html
and left-click some points on the grid; right-click some other points in another part of the grid [SCREEN SHOT]. Press the "step" button to run the learning algorithm and report the result in a sentence or two. From your knowledge of perceptrons, describe what happened at each learning step when you clicked "step".

(b) Using the perceptron learning rule (Russell-Norvig, p. 724), and possibly using the Java code at http://en.literateprograms.org/Perceptron_(Java), construct a two-input, one-output perceptron that implements the predicate designated by a linear function below, numbered 0 to 7. (Instructor will solve #0.) The perceptron is to output 1 if input pair (x_1, x_2) is below-left of the linear graph of the designated function, otherwise 0. Show your work.

For training data, classify each of 20 or 30 points in the square defined by ((0,0), .. (9.9)) as valued 0 or 1. The resulting triples are your training data. For example, (x, y) is valued 1 if it is below-left of the line defined by the linear function below. Start by drawing the graph of your function; then classify some points.

0. $y = -1.1x + 10$
1. $y = -1.2x + 14$
2. $y = -1.8x + 10$
3. $y = -.5x + 4$
4. $y = -.3x + 6$
5. $y = -.8x + 10$
6. $y = -2x + 12$
7. $y = -3x + 20$

(Based on example from Luger, 2005, p. 461.)

E. Natural language

Russell-Norvig, p. 924, #23.6. All students are to solve the same problem this time, which requires writing three sentences. Solutions written by different students should be significantly different.

F. Context-free grammar

Write a context-free grammar for

0. very simple English sentences
1. assertions in propositional logic
2. arithmetic expressions that may include whole numbers, parentheses, +, –, ×, ÷
3. assertions in predicate logic, consisting of quantifications followed by predicate expressions, where predicate expressions are identifiers as predicate names with parenthesized parameter lists consisting of predicate expressions, identifiers, or numerals
4. statements in Java, where you may assume that *expression* has already been defined
5. reverse Polish notation expressions (e.g., "2 5 3 + *" for "2 * (5 + 3)")
6. floating-point numerals, e.g., "–12.345"
7. the LISP language, defined as parenthesized lists of identifiers, numerals, or lists

G. Eliza exerci

Referring to your earlier exercise with Eliza (Assignment 1), describe some natural-language features of Eliza, including some limitations that you can find by writing sensible things that Eliza can't make sense of.

Topic 6 assignment (Reinforcement learning)

A. Concepts

For each term below whose last digit matches your student number, restate and define the term in your own words, and briefly relate it to the course material.

[Interaction and intelligent behavior]

1. accessible environment
2. action
3. adaptation
4. amnesic environment
5. game theory
6. Markov decision problem
7. online search
8. ontogenetic learning
9. percept
10. persistent environment
11. phylogenetic learning
12. physical environment

[Decision theory and expected utility]

13. rational agent
14. utility theory
15. decision theory
16. expected utility

[Reinforcement learning and POMDPs]

17. adaptive dynamic programming
18. exploitation
19. exploration
20. partially observable environment
21. policy
22. policy iteration
23. policy search
24. POMDP
25. Q learning
26. reinforcement learning
27. reward
28. temporal difference learning
29. utility
30. value function
31. value iteration
32. value of information

[Robotics and embodied intelligence]

33. effector
34. feature extraction
35. image processing
36. information-gathering action
37. localization
38. mobile
39. object recognition
40. passive sensor
41. reactive control
42. sensor
43. subsumption architecture
44. tactile sensor
45. tracking

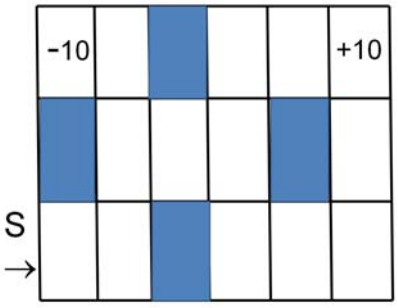
B. Objectives-related questions

See the Study Questions, topic 6, Short and longer answer. Answer the questions *for each objective* (6a, 6b, 6c, 6d) that have the same last digit as your classroom student number.

C. Policy search

See the diagram below and see the following helpful passages in Russell-Norvig, 2010:

p. 653 (value iteration)
p. 657 (policy iteration)
p. 663 (POMDP value iteration)
pp. 832ff. (passive reinforcement learning)
pp. 834ff. (adaptive dynamic programming)
pp. 836ff. (temporal difference learning)
pp. 844ff. (Q learning)



Answer the question below that corresponds to your classroom number. Read all the questions. The questions correspond to increasingly challenging environments. Suggestion: answer all questions.

Your agent environment is a two-dimensional grid (see above). The cells of the grid are *states*. The agent's *policy* is a mapping from states to actions. Possible actions are to move up, down, left, or right. Some states have positive or negative rewards associated with them.

0. Sketch a good policy for the environment above, using arrows to denote actions.
1. Describe a way to compute a good policy, by estimating utilities of states, assuming that rewards are known beforehand.
2. Given an existing policy in an accessible environment, describe a way to try to improve it
3. Suppose that actions have their desired effects only with a certain probability, describe how policy search is affected by this constraint.
4. Given an environment that is observable only by exploring to obtain information about rewards, describe a method to search for a good policy.
5. Describe how *temporal difference learning* will operate in such an environment.
6. Describe how *Q learning* will operate in such an environment.
7. Suppose reward values of states, and accessibility of states, may change dynamically as policy search occurs. How does this shape a good learning strategy?

Topic 7 assignment (Distributed AI)

For each question, restate the question and give its number.

A. Concepts

For each term below whose last digit matches your student number, restate and define the term in your own words, and briefly relate it to the course material.

[Distributed AI and emergent intelligence]

1. distributed AI
2. emergent intelligence
3. multi-agent system
4. sociogenetic adaptation

[Multi-agent systems]

5. autonomy
6. concurrent action list
7. indirect interaction
8. joint plan
9. locality
10. mobility
11. multi-stream interaction
12. situatedness

[Stigmergy]

13. anonymity
14. asynchrony
15. decentralized system
16. self-organizing system
17. social biology
18. space decoupling
19. stigmergy

B. Objectives-oriented questions

See the Study Questions, topic 7, Short and longer answer. Answer the questions *for each objective* (7a, 7b) that have the same last digit as your classroom student number.

C. Multi-agent policy search

See the grid environment pictured and described in Assignment 6. Consider a much bigger version of the problem in which multiple agents explore a partially observable version of the environment and may communicate among themselves in some way. The agents must not only discover the reward state, but must also carry parts of the reward back to the starting point, a little bit carried at a time by an agent. Agents are autonomous and may not be directed or coordinated from a central place.

Describe ways to solve this version of the problem, in which the policy problem consists of giving these autonomous mobile agents each a uniform set of rules of behavior, including actions *pick-up* and *drop* for bits of the reward.

D. Cellular automata (optional)

Download and run the Game of Life. Comment on the complex behavior that results from the parallel execution of simple rules at each cell.

E. Exercises with multi-stream interaction (optional)

Install *StarLogo* (a downloadable Java app created at MIT) on your computer. Run several of the demo programs. Comment.

Topic 8 assignment
(Philosophical issues and future prospects)

For each question, restate the question and give its number.

A. Concepts

For each term below whose last digit matches your student number, restate and define the term in your own words, and briefly relate it to the course material.

[Theories of mind]

1. dualism
2. empiricism
3. epistemology
4. intentional state
5. monism
6. rationalism

[Objections to weak, strong AI]

7. phenomenology
8. strong AI
9. weak AI

[Future prospects]

10. constructivism
11. metareasoning
12. reflective architecture
13. perfect rationality
14. bounded rationality
15. bounded optimality
16. satisficing
17. anytime algorithm

B. Objectives-oriented questions

See the Study Questions, topic 8, Short and longer answer. Answer the questions *for each objective* (8a, 8b) that have the same last digit as your classroom student number.

C. Textbook problems

Russell-Norvig, p. 1043, #26.1-26.10

D. Readings

Review the writings of Simon, Thagard, and Weizenbaum (topic 1), and read the recent NY Times item on chess playing. Give your view of the claims of these writers and others about strong AI, supporting your view with facts and reasoning.