Recursion

• As with many things taught in school, one of the classic questions that frequently arises...

  “When will I ever use this stuff?”

• So far, we’ve examined a few data structures which utilize recursion and recursive properties.
Artificial Intelligence

• Recursion is also quite useful for artificial intelligence purposes.
  – Yay! Another cool Comp Science discipline.

• Consider how the majority of games involve two or more participants.
  – Chess
  – Checkers
  – Tic-tac-toe
  – Tekken
  – Mario Kart
  – Halo
Artificial Intelligence

• Since most games involve having two participants (be they “players” or “enemies” within the game’s context), what can be done when there are less users of a program than participants?
  – Clearly, part of the program itself must fulfill the role of participant.
Artificial Intelligence

• How, then, can a program even attempt to make intelligent decisions within the context of a game?
  – A quick side note: this discussion’s impact reaches past games, but for simplicity, we’ll stick to this context for today’s lecture.
Artificial Intelligence

• The definition of AI – the capability of a machine/software to imitate intelligent human behaviors.
  – General Intelligence (e.g., deduction, reasoning, problem solving, natural language processing)
  – Expert Systems (e.g., diagnosis systems)
  – Perception (e.g., computer vision)
  – Social Intelligence (e.g., affective computing)
Artificial Intelligence

• But AI can also be defined more specifically (e.g., IBM’s Chess software “Deep Blue”)

• The aspect we’ll be focusing on – “future prediction”.
  – What moves will the other participants likely make? What effects will result?
  – How can these potential situations be manipulated to a participant’s favor?
Artificial Intelligence

• Humans and Computers are functioning differently
  – Humans start learning at the child-birth and function independently at the age of ??
  – Computers need software, and never function with the total independence
  – computers are incredibly good at – performing millions, even billions of small calculations per second
Artificial Intelligence

• Humans and Computers are built and functioning differently
  – Humans store the long-term memory and forget the short-term memory
  – Computers can store everything and never forget (e.g., Google “Lewinsky Scandal”)
  – Humans are incredibly good at creativity, and always generate new ideals and products
AI vs Machine Learning

• An important note – due to Hollywood’s love of using “artificial intelligence” in the movies, there’s a bit of a misconception as to what it actually is.

• There are actually two different, somewhat related areas that are focused on modeling intelligence through computers.
AI vs Machine Learning

• Artificial intelligence – Creating an algorithm based directly on our own thought processes regarding a problem.

• Machine learning – uses mathematical modeling + statistics to (hopefully) enable the computer to learn from data and draw its own conclusions.
  
  – spam filtering and search engine
Artificial Intelligence

• Taking these observations into account, one commonly used strategy is that of “search.”
  – The core idea: see what happens if a participant were to make any particular move from a given set of “candidate” moves.
  – From there, take the move that gives the “best” result.
Search

• For this class’s purposes, we’ll just use the entire set of possible moves as the “candidate set” of moves.
  – There’s an AI class in the department that will look at alternative situations and get into more detail.
Search

• In the context of a game, say... tic-tac-toe...
Search

• this means checking how desirable each of “O”s potential moves is.
Search

• Problem: what is a “good” state for the game to be in?
  – Related question: does searching through our potential moves – and only the one participant’s potential moves – give us enough data to reach a proper decision about what is a “good” state?
Search

• A frequent approach: search not only through “O”s moves, but *also* through “X”s moves!

```
  O   X   X
 X   X   X
 X   X   X
```

Search

• Repeat this for a while to search through a greater magnitude of such potential states.

```
  o  o  x
 x  x  o
 x  x  o
  o  x  x
```
For a game like tic-tac-toe, it is easy enough for a computer to search through absolutely every state.

```
 o o x
 x x o
 o x x
```
Search

• Now, how can we search through all of these states effectively?
  – Generate them recursively!
  – A participant may predict the actions of another participant by using its own move evaluation techniques for that other participant.
Search Space
Search

• For other games (like chess), the search space is too large to fully check every possible state.

• For such cases, each potential original move can be evaluated based on the potential consequences of that move.
State Evaluation

• A few remaining questions:
  – How can we evaluate a move based on its potential future outcomes?
  – What makes a “good” state “good”?
State Evaluation

• For tic-tac-toe and many other games, one such example is known as the minimax search.
  – The idea: minimize the other player’s maximum gain.
  – Or vice-versa: maximize the participant’s potential minimum gain.
  – The number of game states it has to examine is exponential in the number of moves.
  – Alpha-beta pruning technique helps
State Evaluation

• Keep in mind: in tic-tac-toe, blindly making the move that gives yourself the chance to win is not necessarily the best.

  – It’s important to make sure that the same move doesn’t cause you to lose!
While O “could” win if it took the move on the top… that move is actually a guaranteed loss.
Search

- The best move is to take the blocking move on the right.
  - Maybe X will slip up later...

```
  O   O

 X   X   O
```