CS61B Lecture #35

[The Lecture #32 notes covered lectures #33 and #34.]

Today: Enumerated types, backtracking searches, game trees.

Coming Up: Graph Structures: *DSIJ*, Chapter 12

Enumeration Types

- Problem: Need a type to represent something that has a few, named, discrete values.
- In the purest form, the only necessary operations are == and !=; the only property of a value of the type is that it differs from all others.
- In older versions of Java, used named integer constants:

```
interface Pieces {
  int BLACK_PIECE = 0,    // Fields in interfaces are static final.
      BLACK_KING = 1,
      WHITE_PIECE = 2,
      WHITE_KING = 3,
      EMPTY = 4;
}
```

- C and C++ provide *enumeration types* as a shorthand, with syntax like this:

```
enum Piece { BLACK_PIECE, BLACK_KING, WHITE_PIECE, WHITE_KING, EMPTY };
```

- But since all these values are basically **ints**, accidents can happen.

Enum Types in Java

- New version of Java allows syntax like that of C or C++, but with more guarantees:

```
public enum Piece {
  BLACK_PIECE, BLACK_KING, WHITE_PIECE, WHITE_KING, EMPTY
}
```

- Defines `Piece` as a new *reference* type, a special kind of class type.
- The names `BLACK_PIECE`, etc., are static, final *enumeration constants* (or *enumerals*) of type `PIECE`.
- They are automatically initialized, and are the only values of the enumeration type that exist (illegal to use **new** to create an enum value.)
- Can safely use ==, and also `switch` statements:

```
boolean isKing (Piece p) {
  switch (p) {
    case BLACK_KING: case WHITE_KING: return true;
    default: return false;
  }
}
```


Operations on Enum Types

- Order of declaration of enumeration constants significant: `.ordinal()` gives the position (numbering from 0) of an enumeration value. Thus, `Piece.BLACK_KING.ordinal ()` is 1.
- The array `Piece.values()` gives all the possible values of the type. Thus, you can write:

```
for (Piece p : Piece.values ())
    System.out.printf ("Piece value #%d is %s%n", p.ordinal (), p);
```

- The static function `Piece.valueOf` converts a String into a value of type `Piece`. So `Piece.valueOf ("EMPTY") == EMPTY`.

Fancy Enum Types

- Enums are classes. You can define all the extra fields, methods, and constructors you want.
- Constructors are used only in creating enumeration constants. The constructor arguments follow the constant name:

```
enum Piece {
  BLACK_PIECE (BLACK, false, "b"), BLACK_KING (BLACK, true, "B"),
  WHITE_PIECE (WHITE, false, "w"), WHITE_KING (WHITE, true, "W"),
  EMPTY (null, false, " ");

  private final Side color;
  private final boolean isKing;
  private final String textName;

  Piece (Side color, boolean isKing, String textName) {
    this.color = color; this.isKing = isKing; this.textName = textName;
  }

  Side color () { return color; }
  boolean isKing () { return isKing; }
  String textName () { return textName; }
}
```


New Topic: Searching by "Generate and Test"

- We've been considering the problem of searching a set of data stored in some kind of data structure: "Is $x \in S$?"
- But suppose we *don't* have a set S, but know how to recognize what we're after if we find it: "Is there an x such that $P(x)$?"
- If we know how to enumerate all possible candidates, can use approach of *Generate and Test:* test all possibilities in turn.
- Can sometimes be more clever: avoid trying things that won't work, for example.
- What happens if the set of possible candidates is infinite?

Backtracking Search

- Backtracking search is one way to enumerate all possibilities.
- Example: *Knight's Tour.* Find all paths a knight can travel on a chessboard such that it touches every square exactly once and ends up one knight move from where it started.
- In the example below, the numbers indicate position numbers (knight starts at 0).
- Here, knight (N) is stuck; how to handle this?

6							
		5					
4	7						
	10		2				
8	3	0					
N		9		1			

General Recursive Algorithm

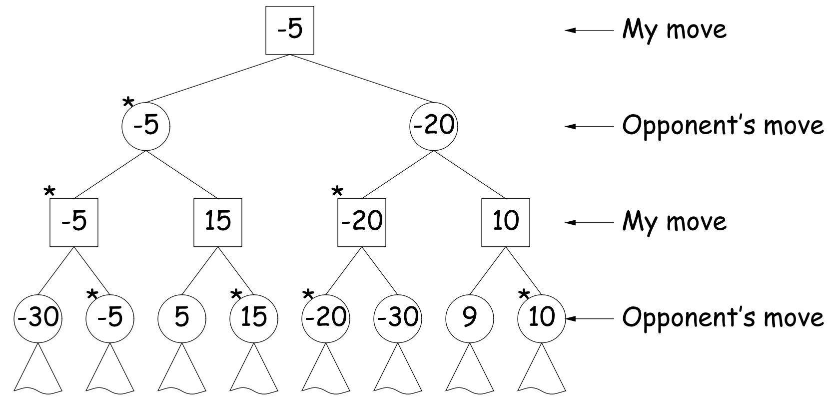
```
/** Append to PATH a sequence of knight moves starting at ROW, COL
 *  that avoids all squares that have been hit already and
 *  that ends up one square away from ENDROW, ENDCOL. B[i][j] is
 *  true iff row i and column j have been hit on PATH so far.
 *  Returns true if it succeeds, else false (with no change to L).
 *  Call initially with PATH containing the starting square, and
 *  the starting square (only) marked in B. */

boolean findPath (boolean[][] b, int row, int col,
                  int endRow, int endCol, List path) {
  if (L.size () == 64)   return isKnightMove (row, col, endRow, endCol);
  for (r, c = all possible moves from (row, col)) {
    if (! b[r][c]) {
      b[r][c] = true; // Mark the square
      path.add (new Move (r, c));
      if (findPath (b, r, c, endRow, endCol, path))  return true;
      b[r][c] = false; // Backtrack out of the move.
      path.remove (path.size ()-1);
    }
  }
  return false;
}
```

Another Kind of Search: Best Move

- Consider the problem of finding the *best* move in a two-person game.
- One way: assign a value to each possible move and pick highest.
  - Example: number of our pieces - number of opponent's pieces.
- But this is misleading. A move might give us more pieces, but set up a devastating response from the opponent.
- So, for each move, look at *opponent's* possible moves, assume he picks the best one for him, and use that as the value.
- But what if *you* have a great response to his response?
- How do we organize this sensibly?

Game Trees, Minimax

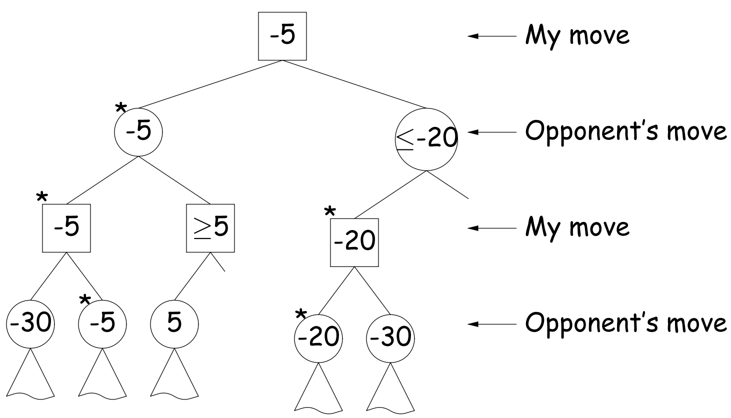
- Think of the space of possible continuations of the game as a tree.
- Each node is a position, each edge a move.



- Numbers are the values we guess for the positions (larger means better for me). Starred nodes would be chosen.
- I always choose child (next position) with maximum value; opponent chooses minimum value ("Minimax algorithm")

Alpha-Beta Pruning

- We can *prune* this tree as we search it.



- At the '≥ 5' position, I know that the opponent will not choose to move here (since he already has a -5 move).
- At the '≤ -20' position, my opponent knows that I will never choose to move here (since I already have a -5 move).

Cutting off the Search

- If you could traverse game tree to the bottom, you'd be able to force a win (if it's possible).
- Sometimes possible near the end of a game.
- Unfortunately, game trees tend to be either infinite or impossibly large.
- So, we choose a maximum *depth*, and use a heuristic value computed on the position alone (called a *static valuation*) as the value at that depth.
- Or we might use *iterative deepening* (kind of breadth-first search), and repeat the search at increasing depths until time is up.
- Much more sophisticated searches are possible, however (take CS188).

Some Pseudocode for Searching

```
/** A legal move for WHO that either has an estimated value >= CUTOFF
 *  or that has the best estimated value for player WHO, starting from
 *  position START, and looking up to DEPTH moves ahead.   */
Move findBestMove (Player who, Position start, int depth, double cutoff)
{
  if (start is a won position for who) return CANT_MOVE;
  else if (start is a lost position for who) return CANT_MOVE;
  else if (depth == 0) return guessBestMove (who, start, cutoff);

  Move bestSoFar = REALLY_BAD_MOVE;
  for (each legal move, M, for who from position start) {
    Position next = start.makeMove (M);
    Move response =  findBestMove (who.opponent (), next,
                               depth-1, -bestSoFar.value ());
    if (-response.value () > bestSoFar.value ()) {
      Set M's value to -response.value (); //  Value for who = - Value for opponent
      bestSoFar = M;
      if (M.value () >= cutoff) break;
    }
  }
  return bestSoFar;
}
```


Static Evaluation

- This leaves static evaluation, which looks just at the next possible move:

```
Move guessBestMove (Player who, Position start, double cutoff)
{
  Move bestSoFar;
  bestSoFar = Move.REALLY_BAD_MOVE;
  for (each legal move, M, for who from position start) {
    Position next = start.makeMove (M);
    Set M's value to heuristic guess of value to who of next;
    if (M.value () > bestSoFar.value ()) {
      bestSoFar = M;
      if (M.value () >= cutoff)
        break;
    }
  }
  return bestSoFar;
}
```