1 handout: slides

You think you know when you can learn, are more sure when you can write, even more when you can teach, but certain when you can program.

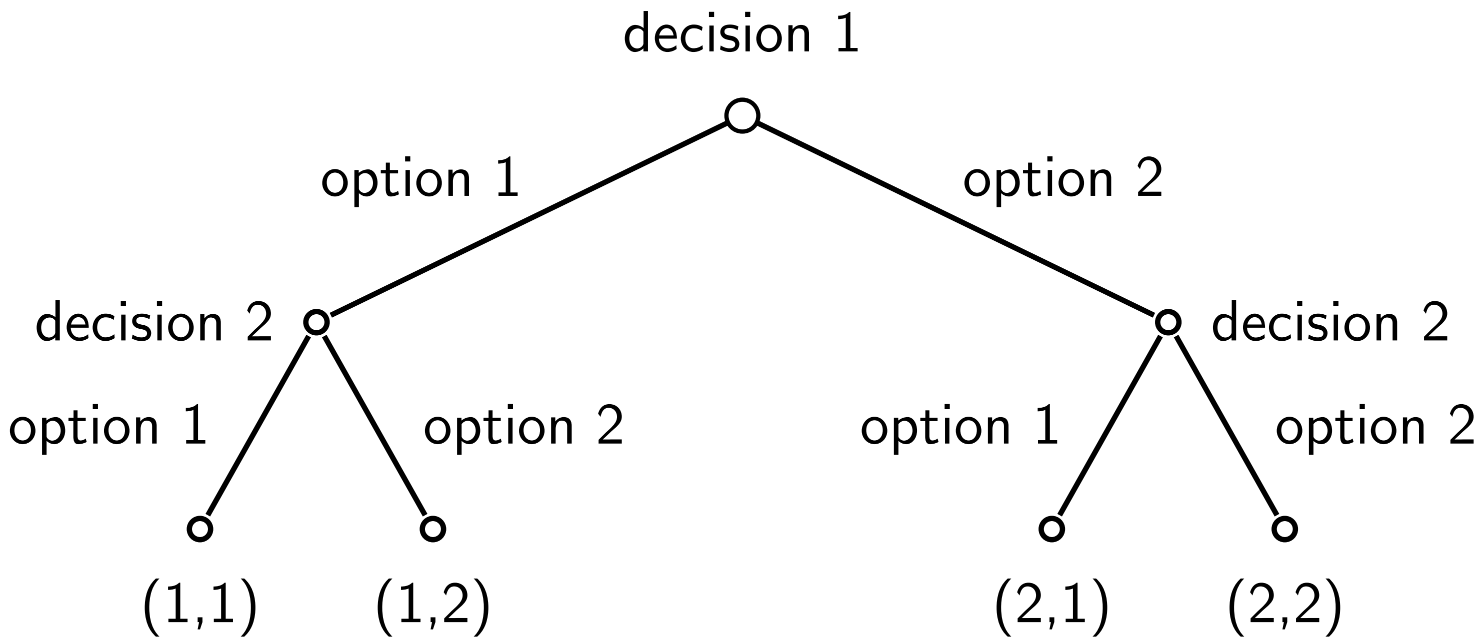
EOLQs

Combinatorial Optimization

Types of Search Problems

- Shortest-path (M&C, vacuum, tile puzzle)
  - want least-cost path to a goal
  - goal depth unknown
  - given operators and their costs
- Constraint satisfaction (map coloring, n-queens)
  - any goal is fine
  - maximum depth $=$ number of variables
  - given explicit constraints on variables
- Combinatorial optimization (TSP, max-CSP)
  - want least-cost goal
  - maximum depth $=$ number of variables
  - every leaf is a solution

Combinatorial Optimization



A tree representation of alternatives in a small combinatorial problem.

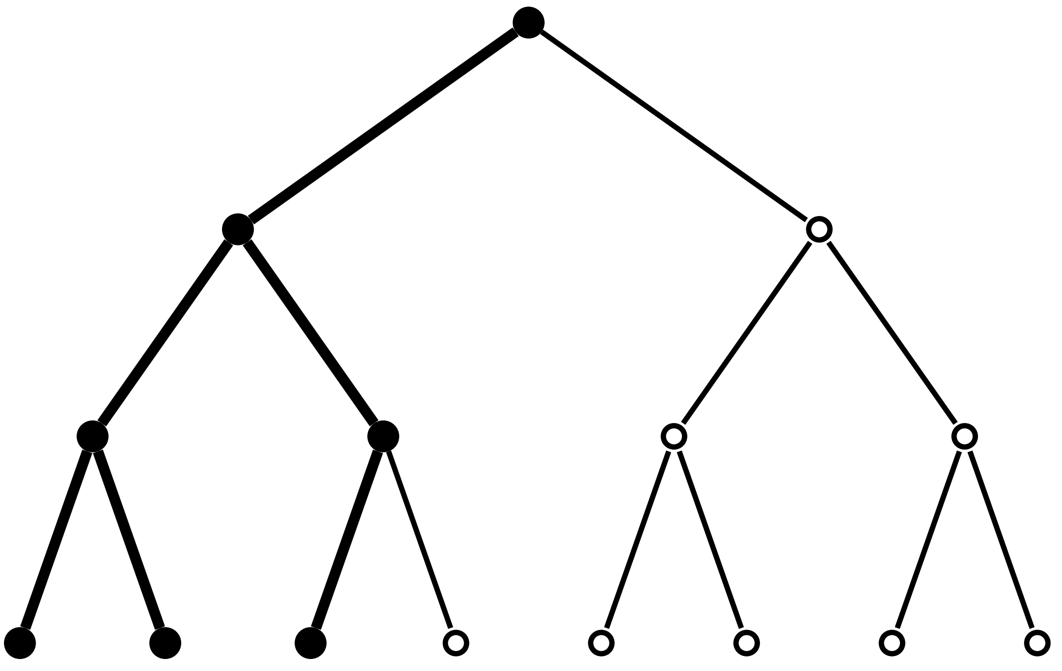
Backtracking

depth-first search
child ordering
lower bounds
branch-and-bound

Depth-first Search


```
DFS (node)
If is-leaf(node)
    Visit(node)
else
    For i from 0 to num-children
        DFS(child(node, i))
```

Depth-first Search Order

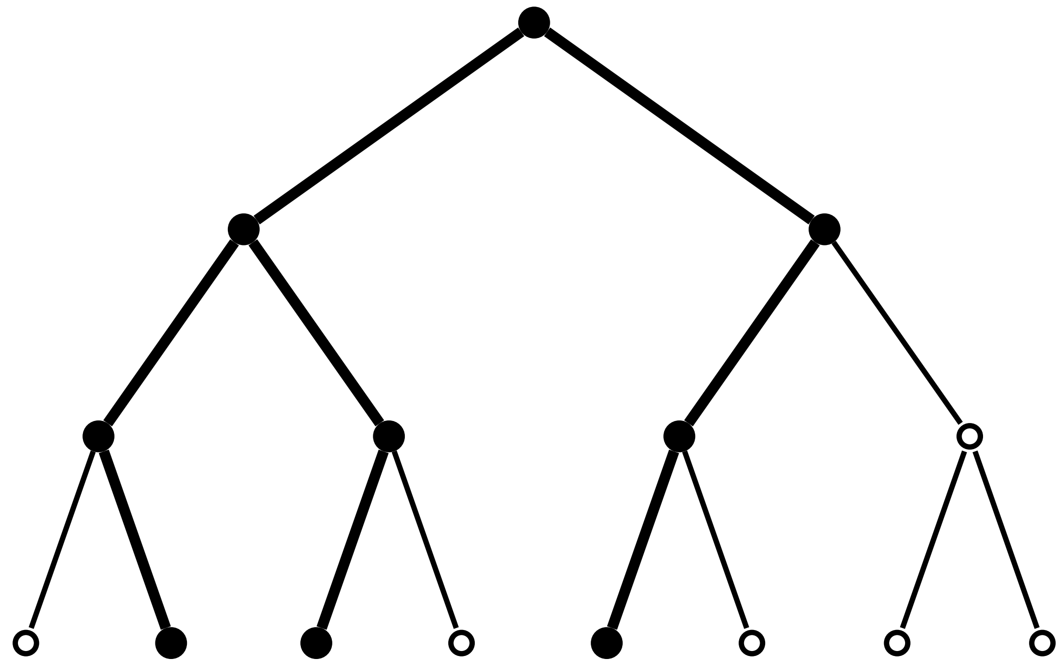


Improved Discrepancy Search


```
ILDS (node, allowance, remaining)
    If is-leaf(node)
        Visit(node)
    else
        If allowance > 0
            ILDS(child(node, 1), allowance − 1, remaining − 1)
        If remaining > allowance
            ILDS(child(node, 0), allowance, remaining − 1)
```

start with ILDS(root, *iteration*, *max-depth*)

Discrepancy Search Order



The second pass of ILDS visits all leaves with one discrepancy in their path from the root.

Break

- asst 4
- projects

Hill-Climbing

Sol $\leftarrow$ some random solution (probably poor quality).
Do *limit* times
  New $\leftarrow$ random **neighbor** of *Sol*.
  If *New* better than *Sol*,
    then *Sol* $\leftarrow$ *New*.

Hill-Climbing

Sol ← some random solution (probably poor quality).
Do *limit* times
    New ← random **neighbor** of *Sol*.
    If *New* better than *Sol*,
        then *Sol* ← *New*.

Elaborations: best neighbor (aka gradient-descent)
restarts
simulated annealing
population (GAs, 'go with the winners')

search space (genotype) vs solution space (phenotype)

Continuous Optimization

Types of Optimization Problems

- Discrete
  - finite (often small) set of values per choice
  - planning, CSPs, combinatorial optimization
  - constraints can be implicit or explicit
- Continuous
  - real values
  - constraints can be linear, quadratic, . . . , non-linear
  - objective can be linear, quadratic, . . . , non-linear
- Mixed discrete / continuous
  - eg, MIPs, MILPs, ...
  - planning for ‘hybrid systems’

real variables, linear constraints, linear objective

- cheapest diet that meets nutrition guidelines
  - $y_{vitaminA} = 2.3x_{broccoli} + 1.7x_{carrots} \ldots$
  - $cost = 4.99x_{broccoli} + 2.67x_{carrots} \ldots$
  - minimize $cost$ subject to $y_{vitaminA} > 500 \ldots$
- max flow through network with capacity constraints
- earliest finish time subject to job durations

polynomial time (ellipsoid, Karmarkar's), but simplex method is popular
CPLEX, Gurobi, lpsolve

Beyond Linear Programming

convex programming: constraints and objective are convex
polynomial time

quadratic programming: constraints and objective are quadratic
some forms are polynomial time

0-1 LP: 0-1 variables, linear constraints, linear objective
NP-complete

integer linear programming: integer variables, linear constraints and objective
NP-complete

combinatorial optimization: variables are discrete

EOLQs

Please write down the most pressing question you have about the course material covered so far and put it in the box on your way out.

Thanks!