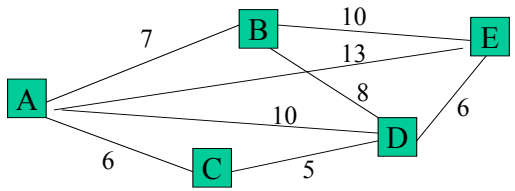
# Exercise 1

Traveling salesman problem (TSP)




Initial state: (A)

A circuit: (A B E D C A) (A C D E B A) ...

States: (A C) (A D) (A B) (A E ) (A C D) (A C D E) (A C D E B) ...

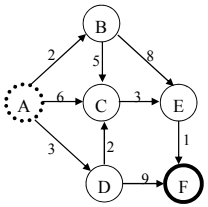
Operators: travel(<From>,<To>)

GOAL: Circuit in which all cities (except the original one) are visited exactly once.

# Exercise 2

The initial state is A.

The goal state is F.




What is the search tree with the different strategies? Repeated states are not eliminated.

- Breadth-first search
- Depth-first search
- Uniform-cost search.

# Exercise 3

- We have a 5-liter jug filled up with water and an empty 2-liter jug. How can we fill the 2-liter jug with exactly one liter of water?
- We can transfer the contents of a given jug to fill the other jug, throw water away, but we only have the original 5 liters.
- This problem can be formulated as a search problem
  - What are the states?
  - What is the initial state?
  - What are the goal states?
  - What are the actions?
- Assuming all actions have the same cost, write down the search tree with uniform cost (use elimination of repeated states) Specify the order in which the nodes are being expanded.

# Exercise 4

We have two water jugs: a 4-liter jug and a 3-liter jug.
We also have a water source.
When we fill up or empty a jug, we do it completely.
Initially both jugs are empty.
Our goal is to have the 4-liter jug with 2 liters of water and the 3-liter jug empty.

- This problem can be formulated as a search problem
- Use bidirectional breadth-first search.
- Assuming all actions have the same cost, write down the search tree with uniform cost (use elimination of repeated states).
- Specify the order in which the nodes are being expanded.

# Exercise 5

Formalize these brain teasers as search problems (i.e., defining states, operators, etc.)

- Crossing a river: Of zombies and humans.
  - There are 3 zombies and 3 humans trying to cross a river on a boat. The problem is that if at any time there are more zombies than humans, the humans will also become living dead. The boat is small may transport at most two people at a time.

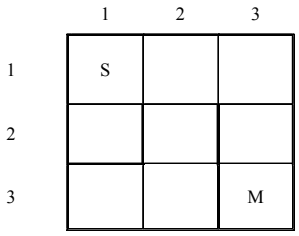
- Crossing a river (revisited): A peasant traveling with a wolf, a sheep and a cauliflower needs to cross a river with a boat. The boat can take only the peasant and one of the three companions. The wolf and the sheep cannot stay alone, nor can the sheep and the cauliflower. How can the peasant cross the river without having any "accidents"?

# Exercise 6

Given the set of integers I = {i1 , i2 , i3, ... , iN}, find the non-empty subset $S \subset I$ whose elements add up to zero. The cost of the solution is the sum of the squares of the elements in S.

- Give a formalization for this problem, defining precisely:
  - State.
  - Initial state.
  - Goal function.
  - Successor function.
  - Cost function for each action.
- Solve the problem for the set I = {-3, 1, 2, 3} by searching with graph-search (elimination of repeated states)
  - UCS (uniform cost search)
  - DL-DFS (depth-limited depth first search). Specify the limit for the search that guarantees finding a solution.
  - For each of these strategies,
    - Draw the search tree.
    - Indicate on the tree the order in which the search algorithm expands the different nodes.
    - Indicate the path to the solution.
  - Which of these strategies guarantees optimality, independently of I?

# Exercise 7




Consider the 3 by 3 labyrinth.

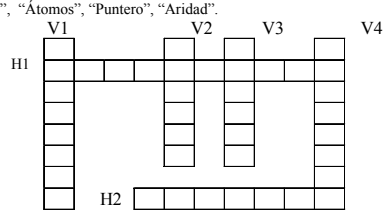
- Double lines in the figure indicate a wall (no way through).
- Each position in the labyrinth is indicated by a pair of coordinates *(x,y)*, where *x* is the column, *y* is the row,
- The goal is to reach M (3,3) from the initial position S (1,1).

- One can move in the labyrinth one step at a time by taking the following actions: U,R,D,L.
- When searching, this actions are applied always in the same order.
- All actions have unit cost.

1.- U: move up
2.- R: move right
3.- D: move down
4.- L: move left

# Exercise 8

We wish to solve a crossword puzzle filling the horizontal and vertical entries of the puzzle with the words: "Esfuerzo", "Algoritmos", "Paralelo", "Átomos", "Puntero", "Aridad".




This problem can be seen as a *Constraint Satisfaction Problem (CSP)*. CPS's can be solved by searching. The successors of a given search node are generated by considering all possible assignments for a single variable that is not yet instantiated in that node. An assignment to an uninstantiated variable can be made if this assignment does not lead to a conflict with the value of other instantiated variables.

Answer the following questions in detail for the crossword puzzle problem:

1.1. Variables y values
- Indicate which are the variables in the problem.
- Indicate the domain of each variable (i.e., the range of values these variables can take).
- What is the depth of the search tree in this problem. Why?

1.2. Indicate the restrictions in this problem (suggestion: for every pair of values search for a common letter and mark it. Indicate only the combinations that are possible).

1.3. Indicate the initial and the final states in the problem.

1.4. Make a list of the criteria (heuristic rules) that you will use to determine without ambiguity the selection order for the variables in the search problem. The order of application of these criteria should be chosen so that the search process is as efficient as possible.

1.5. Following your answers to the previous questions draw the search tree, indicating at each step the criterion used to select which variable is instantiated at each step in the search process. To build the tree use depth-first search with the following improvements:
- Eliminate branches where the restrictions cannot be satisfied.
- Propagate the restrictions. I.e., owing to the restrictions identified, the value assigned to a variable may limit the range of values the other variables may take.

1.6. Finally, use the solution given by the search tree to solve the crossword puzzle.