R2-D2 is a robot that is trying to escape from an m x n grid. The problem is that the robot’s only way out is a teleport laying on one of the cells of the grid which can send it back to it’s planet. Yet, it is not as easy as just finding that cell and use it to get back. The grid also consists of three more things; pressure pads, obstacles and rocks. In order for the robot to use the teleport cell, he has to push a rock over each pressure pad first. Still not an easy task giving that the robot has some limitations. The robot can not push more than one rock at a time in any given direction neither push any of the prison’s obstacles. After all the pressure pads have a rock over them, the teleport cell is finally activated and the robot can head directly to it, use it and go back to his home planet.

To make use of the OOP concepts, we used java to implement this project. The project consists of 5 packages:

1. Search Package:

This package contains all the general and abstract classes to solve any general problem. It has 5 classes:

* State Abstract Class:

The State object denotes the state of a given Node. Since each problem defines it’s own state, the State class is an empty Abstract class that has only one abstract method which is the *heuristic(int n) method.* We will talk about what that method does later on.

* Node Class:

It defines a Node object of a general search tree. The Node object has a 5 tuple instance variables; parent of type Node which indicates the parent of this node, currentState of type State which denotes the state of the node, depth of type int indicating the level of the node in a given search tree, pathCost of type int which is the summation of the nodes’ costs till reaching that node and operator of type String indicating the operator that was made by the parent node to reach that node. Then there is one final variable which is the order of type int, it is used to order the node in the priority queue in case of greedy or A\* algorithms.

* Problem Abstract Class:

The Problem Class defines the 5 tuple of any general search problem. It has three instance variables; an array of type String operators which consists of all the possible operators of the problem, an array of type State stateSpace which is the finite state space of the problem and finally the initState of type State which defines the first state of the problem. Then there are the two missing items of the 5 tuple which are two abstract methods, the *goalTest(Node node)* which returns a Boolean of whether the goal test is passed or not and the *pathCost(Node n)* which defines the pathCost of a given node. Finally, we have three important abstract methods; the Expand(Node node) which returns an ArrayList of type Node containing all the reachable nodes from the given node, pastState(Node node) which returns a Boolean denoting whether the given node has a state that has been explored before or not, this method enhances the search performance and speed by eliminating redundant states and lastly the clearPastState() which clears the ArrayList holding the past states for a purpose that would be explained later on in this report.

* QueuingFunction Enum: Enumerators that differentiate between the different search algorithms.
* GeneralSearch Class:

This class holds most of the logic in this project. The class is defined by four instance variables; the problem of type Problem, the qingFunc which is an enum of type QueuingFunction stating which queuing function will be used in the search and two data structures. The reason we used two data structures in the search is that we have different search algorithms that need different data structures, we divided the algorithms into two sets. BFS, DFS and IDS use a double ended queue which eases the process of adding the nodes in either side depending on the algorithm. UC, A\* and Greedy algorithms use a priority queue which also eases the process of sorting the nodes inside the queue. Then we have the search() method which either returns the node that passed the goal test or null indicating that no solution is found. Depending on the qingFunc, the search() calls one of the six different search methods to handle the tree traversing and returns back the solution. We will dig deeper into how each algorithm is implemented. Finally we have the main method of the class and the project which is the search(Grid grid, QueuingFunction strategy, boolean visualization) method; as shown, the method takes a grid object of type Grid which defines the initial grid of the problem, a queuing function, and visualization of type Boolean which indicates of the user wants to visualize the problem or not.

2. Assignment1 Package:

* MyState Class:

This class extends the State class and defines the HelpR2-D2 problem’s state. The state here keeps track of the things that usually change with the problem’s operations. It has currentPosition of type Cell which denotes the position of the droid, unactivatedPads denoting the number of the pads that still does not have a rock above them, an array of type Cell rocksPositions that holds the positions of rocks in the grid in a given state and finally an int expandedNodes which records the number of nodes expanded to reach this node. The class also implements the heuristic method of the State abstract class. The heuristic(int n) takes an n as an input denoting which heuristic function will be used since we have two functions, 0 indicates using the first function and 1 indicates using the second. We will explain both functions later on in this report.

* HelpR2D2 class:

The class extends the Problem class. The HelpR2D2 class holds the instances that does not change with the change of the state, in other words, those which are static and problem specific. It takes a grid of Type Grid and initializes those instances from that grid. It has telePosition of type Cell which holds the teleport position cell, two Cell array s obstaclesPositions and padsPositions that defines both obstacles cells and pads cells respectively, the height and width of the grid, the numberOfExpandedNodes which keeps track of how many nodes have been expanded so far and finally an array list expandedStates of type MyState that keeps track of the already expanded states so as not to go through the same state twice in some of the algorithms. The main method in the class is the *Expand(Node node)*, the method takes the node to be expanded and calls four methods for four operations on that node; up(Node node), down(Node node), right(Node node) and left(Node node). Each method checks if the operation can be applied on that node, if so it will apply the operation and returns the result node after that operation. The four methods checks all the possible cases when the droid tries to move in any of the four directions. All the checks are well documented inside the source code.

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**The Grid Package**

The grid package includes the classes that represent the physical components of the grid. These physical components are the Cell class which represents a single cell in the grid, the grid class with includes the grid of cells and the enumeration of the cell status (whether it is an obstacle, pressure pad, teleport or a free cell).

**The Cell Class and the CellStatus Enum:**

The cell class describes the cell. It includes the horizontal position (x), the vertical position (y), the cell name, a boolean that represents whether it has a rock on top of it and an enum that represents its status. The status was implemented as an enum because it independent of whether it has a rock or not. An obstacle cell is the only status that does not allow to have a rock.

**The Grid Class:**

The grid class represents a grid as data structure independent of the search algorithm, it does not have any search strategies implemented. It contains a 2D array of cells and two integers representing the width and the height of the grid. A grid object can be initialized either randomly or with specific width and height.

The obstacle and pad cells in the grid are randomly distributed in the grid as well as the rocks such that the number of pads equals to the number of rocks and the both the pad and obstacle counts is less than the number of cells divided by 7. Such constraints are implemented to provide an estimation of a grid that is realistic for the agent to traverse.

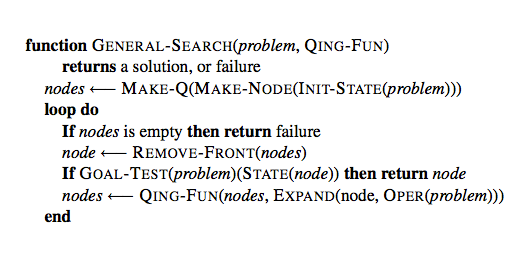
**Discussion**

**The Search Algorithm:**

The algorithm is executed by running a test file in the Test package. This test files instantiates a Grid object and calling the method GeneralSearch.search. The Grid object is passed to the method object along with a QueuingFunction enumeration and a boolean that indicates whether is is required to visualize the agent steps after finding a solution or not.

The GeneralSearch.search method checks the queuing function and calls a subroutine for each queuing function. BFS, DFS and IDS use a double ended queue to execute the search on the other hand, UC, Greedy and A\* use a priority queue.

Each subroutine follow the generic search algorithm presented in Lecture 2 slide 11.



The tricky part of the algorithm is the expand function which is handled by an instance of the Problem Class which is a parameter of the GeneralSearch class. In this project, an instance of HelpR2D2 is passed to the GeneralSearch class which expands a node to a list of nodes in the semantics of the specific problem of R2D2.

In the HelpR2D2 class, a node is expanded based on the given operators (UP, DOWN, LEFT, RIGHT) with respect to the given grid. The expand function checks all the cases that allows of disallows R2D2 to go from a cell to an adjacent cell with respect to some factors like the obstacles, borders and rock positions. Such factors are extracted from the grid in the form of arrays of Cell objects for the obstacles and pads and rocks, and single Cell object for each the Agent position and the teleport position. The HelpR2D2 class is equipped with a goalTest function that indicates whether a given node is a goal node or not. A node is a goal node if the specific state MyState contains an agent standing on the teleport position and the number of unactivated pad is 0. A pad is said to be unactivated if there is no rock on top of it.