IPSA

IN516 - Cursus Project S2D Cyber

Aéro 5

Project : Treasure Hunt with connected Robots

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1 Introduction

1.1 Presentation of the project

The *Unlock Boxes* project, developed as part of the IN512 course on Distributed and Intelligent Systems, focuses on designing strategies for autonomous robots operating in a constrained environment. The task requires robots to navigate a discrete grid, where their goal is to locate and retrieve color-coded keys and unlock their corresponding boxes, minimizing the number of cells visited. Each robot is assigned a specific color, and it must first find its unique key before proceeding to its associated box. The robots are "blind," meaning they can only sense information about the cell they currently occupy. However, they are capable of sharing crucial information with others when they discover a key or box belonging to another robot. This project emphasizes the development of efficient algorithms for collaboration, navigation, and task optimization while overcoming obstacles and visibility limitations, ensuring the robots achieve their objectives with minimal exploration.

1.2 Our strategy

Our strategy is carefully structured into several steps, each addressing a specific aspect of the problem. The steps are outlined as follows:

- **Establishing the Layout:** We begin by creating a layout for the grid. This involves dividing the map into distinct areas based on the number of robots and the grid's size, ensuring that each robot is allocated an equivalent exploration zone. This structured division allows for efficient navigation and minimizes overlaps in the search process.We also taking into account that objects (keys and boxes) have a detectable zone around them, we designed exploration bands with a spacing of four cells. These bands maximize the likelihood of detecting objects while ensuring comprehensive coverage of the grid.

- **Object Search Method:** Upon entering the detectable zone of an object, the robot transitions to an object search algorithm. This algorithm systematically prioritizes cells with the highest detection values, ensuring precise navigation toward the object while minimizing unnecessary movement.

- **Mode-Based Robot Behavior:** Each robot operates within a dual-mode framework:

  - *Discovery Mode:* The robot methodically explores its allocated area, identifying objects within its detectable range.
  - *Object Search Mode:* When an object is detected, the robot shifts focus to efficiently retrieve it.

  After successfully collecting the object, the robot resumes its layout exploration seamlessly.

- **Retrieving Keys and Boxes:** Once all objects are located, each robot proceeds to retrieve its assigned key and corresponding box. Using information exchanged via the server, the robots determine the precise locations of their targets. The A* algorithm is employed to optimize their paths, favoring previously traversed routes to ensure efficient task completion.

- **Dodge obstacle:** The obstacle avoidance strategy concludes our project. It allows, in the case of obstacles on the robot's path, to bypass them and return to its original layout. In our case we use ....

  In the following sections, we will present each step of the strategy in detail, explaining the underlying algorithms and design choices.

1.3 A-star Model

The A-star (A*) model is a pathfinding algorithm that finds an optimal path between two points by considering both the total cost of the path traveled and an estimate of the remaining cost to reach the destination. However, in our case, A-star is not used to find the shortest path in the traditional sense but to create an optimized list of robot movements. By following the dedicated layout matrix, the algorithm allows the robots to move efficiently while adhering to the predefined structure of the map. This approach is combined with a function that calculates the shortest path between point A and point B, ensuring that the robots' movements are as direct as possible while following the layout framework. The A-star model has thus been used throughout the project, integrated into the various functions that handle the robot's movements, enabling smooth and optimized coordination of their actions.

2 Establishing the Layout

The layout, as explained previously, represents our strategy for map exploration. The robots will divide the map into zones based on its dimensions, and scan each zone with a spacing of four cells. This method ensures that all chests and keys will be found. To achieve this, we designed a dedicated matrix for initialization, allowing the robots to know their exact movements. Additionally, we implemented a function that transforms the layout coordinates into coordinates on the map, accounting for the inverted reference system. This step was crucial to ensure that no objects, even those near the outer walls of the map, are missed.

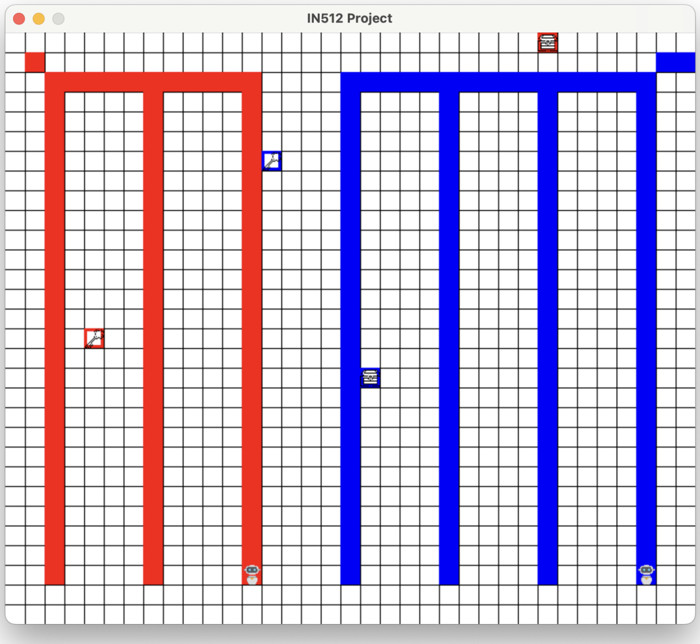

Figure 1: Image of complete layout for two robots

3 Retrieving the positions of treasures and keys using a search mode

When an object enters the robot's detectable zone, it activates an object search algorithm. This algorithm systematically prioritizes cells with the highest detection values, ensuring precise navigation toward the object while minimizing unnecessary movement. To achieve this, we opt for a simple method: when the robot encounters a key or chest on its scanning path, it immediately moves toward the object. To do so, we have the robot perform crosses. Once the cross is applied, the robot analyzes the obtained values and heads toward the highest one. If two values are equal and the highest, the robot moves diagonally, indicating that it is positioned in a corner of the object's emission zone. Once the object is reached and value 1 is detected, the information is sent to the server to be stored, specifying the object's owner and its position. Finally, the robot initiates a reverse movement to exit the object's emission zone and return to its scanning path.

4 Different robots mode

As briefly mentioned earlier, the robots have several operating modes, allowing them to act differently depending on the situation. Four modes can be identified:

– **First mode:** This occurs when the robots head towards the starting point of their scanning path. This ensures that the robots do not start searching for an object before beginning the exploration, thus avoiding conflicts when multiple robots might search for the same object at the same time.

– **Second mode:** This is the classic mode, where the robots move according to the layout matrix to explore the map.

– **Third mode:** The search mode, which is activated when a robot enters the emission zone of an object. In search mode, at each step, the cell is analyzed, and as soon as it is no longer equal to zero, the robot remains in search mode.

– **Final mode:** The object retrieval mode, which is based on the return of server information and the layout path, allowing the robot to retrieve keys and chests.

5 Data transfer to map server

For the server part, it comes into play when a robot finds an object. Once the robot positions itself on the object, it initiates a request to the server. The server then transmits information about the ownership of the object and its type (chest or key). At this point, we have chosen a simple method: the robot broadcasts the object information and its position to the other robots. This way, each robot has a list containing information about all the chests and keys found by all the robots. The object retrieval mode will be activated only once all the objects have been found and, consequently, when each robot's list is filled.

6 Retrieving their keys and chests

For the retrieval part, each robot uses the index in the list of found objects to head towards the key and chest assigned to it. To achieve this, it follows the layout previously mapped out, using the A-star algorithm, which has been employed throughout the various stages to optimize movement. Using the lists of keys and chests recorded in the previous step, the robot will first target the key and then transport it to the corresponding chest. This process enables each robot to perform a precise and efficient retrieval task. Once this step is completed, the robots stop, and the mission is considered finished.

7 Obstacle avoidance

To conclude, we have implemented an obstacle avoidance system. To achieve this, it was necessary to create walls on the map. These walls also have an emission zone, allowing the robots to detect the edges of the walls and avoid them. To facilitate this process, we decided to create a final mode. This mode enables the robot to move to the top right corner whenever it encounters a cell with a value of 0.35 (emission zone). This allows it to circumvent the obstacle on the right side and then attempt to return to the original path corresponding to the layout. Additionally, this mode directly modifies the original path. Therefore, whenever another robot needs to pass along the path of a robot that has avoided an obstacle, it will follow the new path. The robot exits this mode only when it returns to the original layout, ensuring a smooth transition.

This real-time modification of the layout effectively avoids walls while maintaining a complete map sweep. We assumed that this method would be sufficient because walls would never be too close to an object, and no wall would be directly adjacent to the right wall, allowing them to be avoided on that side. This approach ensures an efficient balance between obstacle avoidance and full coverage of the exploration area without compromising the accuracy of the sweep.

8 Conclusion

In conclusion, through the implementation of different modes and the A-star algorithm, we successfully optimized the robots' movement costs while ensuring a complete map exploration. The obstacle avoidance system allowed the robots to circumvent walls without disrupting the original path, ensuring smooth exploration. The use of various movement strategies and object management techniques maximized the overall system's efficiency, with constant control over the path taken. This project thus demonstrates that optimizing movement in a dynamic environment is not only possible but also crucial to ensure full and accurate coverage of the exploration area.