

## **I will provide the following lists for you**

### **LISTS**

1. The lists of the tasks for an inspection job (**list [1]**)
2. The lists of tasks for a repair job (**list [2]**)
3. The lists of tasks that are Mandatory for Human-MFH (**list [3]**)
4. The categorization for safe and unsafe tasks (**T<sub>safe</sub> and T<sub>unsafe</sub>**) (**list [4]**)
5. The categorization for safe and unsafe locations (**L<sub>safe</sub> and L<sub>unsafe</sub>**) (**list [5]**)
6. The lists of tasks the Robot can perform (**list [6]**)

The list should be stored in the planner.

The Planner should be able to automatically get info from the lists to make decisions when needed.

The Human should be able to access the list from the Planner UI to modify it before or if the plan is paused.

For this project, we will be concentrating on one compound job

### **INSPECTION AND REPAIR**

The Human can make three types of Job plan request [INPUT]

1. INSPECTION
2. REPAIR
3. INSPECTION + REPAIR

### **FIRST PHASE [INPUT TO THE PLANNER]**

1. The human through the UI, selects an INPUT ("INSPECTION" OR "REPAIR" OR "INSPECTION+REPAIR") to the Planner.
2. The Planner identifies this request and displays the lists of tasks for the Job selected.
3. This list will be used to generate the plan.
4. The Human can view the list, choose to modify it or not and if modified the changes are saved.
5. If the list was modified, the planner will use this new list for the planning.

### **SECOND PHASE [ PLAN GENERATION] [ALGORITHM]**

**There are 6 main Criteria**

**Each Task is passed through the algorithm, searching through it to determine which agent get allocated the task, starting from the first criteria, a task can get**

allocated to an agent (Robot or Human) at any step. For instance, if it gets allocated a task at the first step, the search to allocate the task to an agent stops for that task and it picks up the next task and starts the search to allocate that task to an agent for that task all over again.

## [INPUT 1/3] INSPECTION/INSPECTION +REPAIR JOB PLANNING

### ✓ THE FIRST CRITERIA [SAFETY]

- The planner uses the lists [4] and [5] it already has stored here to perform the identification.
- The planner at this step identifies if the task is  $T_{safe}$  or  $T_{unsafe}$ .
- It stores the result for this.
- It again identifies if that same task is  $L_{safe}$  or  $L_{unsafe}$ .

Task Safety	Location Safety	Overall Safety
$T_{safe}$	$L_{safe}$	SAFE
$T_{safe}$	$L_{unsafe}$	UNSAFE
$T_{unsafe}$	$L_{safe}$	UNSAFE
$T_{unsafe}$	$L_{unsafe}$	UNSAFE

- It stores the result for this.
- Then using both results the overall safety is deduced using the AND table below
- If the task is UNSAFE for either of the three cases above, assigned the task to the Robot.
- If the task is SAFE, use the next criteria.

### ✓ SECOND CRITERIA [OUTER SHELL INSPECTION]

If the task name is either "VISUAL INSPECTION [OUTER SHELL]" or "ULTRASONIC INSPECTION [OUTER SHELL]".

- The planner request for the:
  1. Height of human
  2. Height of the Tank
- The task should be assigned to both Agents (Human and Robot) based on a job distribution criterion (JDC)
- The height of the Tank is always way higher than that of the human.
- So, this task will be partitioned by this JDC
  1. Step 1: Assign the Area from the Human height (down) to the feet of the tank to the human.

2. Step 2: Assign the Area from the Height of the human (above) to the Top of the Tank to the Robot.

**NOTE > it should be stated in the plan that the human and robot will start work from TOP TO DOWN in the area portioned to them. So, the Human will start work from his/her height down to the feet of the tank while the Robot will start work from the top of the tank to the height of the human. This is done to avoid interference while the work is going on.**

- **If the task name is NOT** either “VISUAL INSPECTION [OUTER SHELL]” or “ULTRASONIC INSPECTION [OUTER SHELL]”.
- **Proceed to the next criteria.**

✓ **THIRD CRITERIA [MANDATORY FOR HUMAN]**

- If the task is identified as a task from the already defined list [3],
- The task is assigned to the Human.
- If it is NOT identified as a task from the already defined list [3]
- Proceed to next step.

✓ **FOURTH CRITERIA [COLLABORATIVE TASK]**

- The planner will first prompt a question to the human **“IS THE TASK COLLABORATIVE OR IS THERE NEED FOR COLLABORATION”**
- If the Human Selects **YES**
- The task is assigned to both and labelled on the plan **“COLLABORATIVE”**
- If the Human selects **NO**
- **Proceed to next Criteria.**

✓ **FIFTH CRITERIA [COST FUNCTION]**

- The planner request for the following info from the Human
  1. The estimated completion time  $\uparrow$  the task in mins (time must be between 0-60 mins) by each agent (Robot and human).
  2. The Level of operating costs ,  $O_{(w_i, a_j)}$  (HIGH, MID and LOW).
- The planner also gets the info of the task complexity ,  $T_{(w_i, a_j)}$  from the list [6].

These values for this three variables time, operating costs and task complexity will be used to calculate a cost function.

### **COST FUNCTION CALCULATION**

$$C_F = \beta_t T_{(w_i, a_j)} + \beta_c C_{(w_i, a_j)} + \beta_o O_{(w_i, a_j)}$$

#### **Task complexity**

$$T_{(w_i, a_j)} = \begin{cases} 0, & \text{if the task is identified as a task the robot can perform} \\ \infty, & \text{otherwise} \end{cases}$$

#### **Level of operating costs**

$$O_{(w_i, a_j)} = \begin{cases} 1, & \text{if high} \\ 0.5, & \text{if mid} \\ 0, & \text{if low} \end{cases}$$

#### **completion time**

$$C_{(w_i, a_j)} = t/n \quad \text{where } n = 60$$

#### **Beta Values (weights) are constant**

$$\beta_t = 0.1$$

$$\beta_c = 0.3$$

$$\beta_o = 0.6$$

- This Cost function will be calculated for each agent.
- The agent with the lower cost will be allocated the task.
- If both agents have the same cost
- Proceed to next criteria

### **SIXTH CRITERIA [ITERATIVE RANDOM ALLOCATION]**

- In the first instance of the random allocation.
- Randomly allocate the task at random to any of the agent.
- In the 2nd instance
- The planner allocates the task to the opposite agent

- If there's a third instance it allocates a task to the first agent that was randomly allocated a task at the first instance.
- If there's a fourth instance, it allocates to agent as in the second instance.
- It follows the iterative process for all other future instances.

### **THIRD PHASE [SHARED PLAN: OUTPUT OF THE PLANNER]**

- The Plan is then displayed and stored on the UI, so the human can view it.
- The planner asks the human to authorise the inspection plan.
- OKAY OR NOT OKAY
- If the human selects OKAY
- The Planner displays THE JOB STARTS
- If the human selects NOT OKAY
- The planner asks the human to tick the tasks it wants it to reallocate
- The Planner recalls the Criteria that was used to allocate the task initially
- The only tasks that were assigned with criteria 2, 4, 5 and 6 can be changed. Tasks allocated based on Criteria 1 and Criteria 3 can't be changed.
- If any of the task was selected by Criteria 6, it will change the agent assigned to the opposite agent.
- If any of the tasks ticked is based on Criteria 1, the planner prompts the human that it can't change it since it's a safety concern.
- If any of the tasks ticked is based on Criteria 3, the planner prompts the human that this job is mandatory for the human to do it.
- If any other task is ticked, the Planner reallocates the task after asking for new info based on the Initial Criteria used to allocate the task.
- The Planner goes ahead to reallocate it based on the new info.
- The Planner then displays a new plan again.

### **FOURTH PHASE [REPLANNING]**

- As the job has been carried out if there is a need to replan {The human becomes unavailable}
- For this project, this unavailability will be triggered by a Human from the input.
- The planner will replan the entire job based on the next Criteria.

### **SEVENTH CRITERIA [AVAILABILITY]**

- The Planner will allocate the remaining tasks yet to be done that were not assigned based on criteria 1 to the Robot.

- A new plan is generated.
- The new plan is displayed on the UI.
- Then JOB CONTINUES is displayed.

When the inspection Job is done [for this purpose of this project a trigger from the human is used].

The planner asks the human whether it should make a new plan for repair or not if the job plan request selected at the beginning was for INSPECTION + REPAIR.

If the human selects YES

The planner generates a plan for repair job

- Using Criteria 1,3,4,5,6
- The Planner allocates task to either robot or human.
- A new plan for the repair job is displayed.
- Then JOB STARTS is displayed
- At the end of the Repair Job.
- JOB ENDED is displayed. (For this project this is triggered by an input).

**Else if the human selected only INSPECTION at the beginning, it ends the planning phase.**

If the human selects YES

The planner generates a plan for repair job

- Using Criteria 1,3,4,5,6
- The Planner allocates task to either robot or human.
- A new plan for the repair job is displayed.
- Then JOB STARTS is displayed
- At the end of the Repair Job.
- JOB ENDED is displayed. (For this project this is triggered by an input).

## **[INPUT 2] REPAIR JOB PLANNING**

If the human selects only REPAIR

The planner generates a plan for just repair job

- Using Criteria 1,3,4,5,6
- The Planner allocates task to either robot or human.
- A plan for the repair job is displayed.
- Then JOB STARTS is displayed

- At the end of the Repair Job.
- JOB ENDED is displayed. (For this project, this is triggered by an input).