Software Design Specifications of Perspective taking (ToM) and adaptive decision-making in HRI

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Advanced Agent Competition: Human Robot Collaboration and Teamwork – SS 17

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1. Introduction

1.1. Motivation and Problem Definition

The goal of the project is Human and Robot collaboration where Robot should observe human when he is not doing his task and do that task instead.

This project tries to solve the problem the factories facing in warehousing and the work assignment between Robot and Human. The project starts with receiving a command of “an object with an ID is ready to be picked by Human/Robot”. The ID information gives the specifications of the object including: the size, the storage conditions, time for delivery, delivery means (delivery on site or delivery to an external address) etc. Initially when object arrives for picking and packaging there will be decisions according to the object parameters (size, weight, temperature) in order to identify who should pick the object (Human or Robot). If object should be picked by Human and he is not paying attention or failed to pick it up then Robot should take over the assigned object. So, the technical problem is to find a suitable algorithm that assigns the most suitable decisions for the robot regarding to observing Human beside the task of picking up the object and packaging it so that the entire process consumes less time and faults.

1.2. Objectives

- Development of an interface to generate decisions according to the object parameters
- Animating and Modelling Human, Robot and convey avatar using MORSE
- Defining states and actions for Human using MDP (Markov Decision Process)
- Configuring and integrating human behaviour sensor using SPARK (Spatial Perspective- taking of Human)
- Robot decision making and collaboration with Human using POMDP (Partially Observable Markov Decision Process)

1.3.General Constraints

This project makes these assumptions:

- While the object in work is not finished, no other object will follow through on the conveyor band (this limits the number of objects that can be worked on by either human or robot to 1)
- Robot is capable of grasping objects that are only within its (arm-)range (i.e. robot can not move)
- System-, (some specified) human- or robot failure will lead into a STOP-State status while outputting an ERROR (i)
- (i) occurs, when
    - System is not capable to proceed in the way it is meant to be (i.e. conveyor Band Failure)
    - Human has recognisable health issues (might be sudden inappropriate behaviour of human, i.e. falling down without standing up)
    - Robot does not work accordingly (i.e. no power, or internal system break down
- While System is in ERROR-State, it will send a message to a 2nd person (outside of the person standing at conveyor band) who then needs to investigate the problem and solve it
- While System is in ERROR-State the process of object packaging is stopped and also, if not already stopped, the conveyor band will be stopped
- The ERROR-State has a tiny probability to be achieved, and may alter considering the fact which Human-Avatars, Roboters and hardware the system uses (probability may get even smaller)
- Robot shall not guide or control human actions, it can just estimate human is acting and it stays idle

2. State-of-the-Art

In the field of human robot interaction, finding proper methods for robots to understand humans behaviour has been in the central area. "The Theory of Mind"[5] hypothesis which illustrates the ability of robots to sense humans intentions, beliefs and desires, has been widely used in many HRI systems.

In the work of [6], Devin et al presented a system that allows to estimate and maintain mental states of other agents concerning not only the environment but also about the goals, plans and actions in the context of certain task and achieved quite good results in some predefined scenarios. In the work of [7], Görür et al proposed a system, where after each robot moves, the resulting human intention is estimated and compared to the desired goal. They trained an elastic network based on two modes which define human body mood: "confident mode" and "suspicious mode".

Some more complicated systems use a ACT-R(Adaptive Control of Thought-rational) architecture, which defines the basic cognitive operations of robots to simulate human and aims to figure out how human brain is organised to produce cognition. In [8], Trafton et al uses a variation of ACT-R and model the way to predict humans behaviour in different situations. Those models go into insights of the cognitive level of human's intention and are more difficult to integrate.

In the work of [9], Görür et al use a stochastic model to predict humans intentions and desires from the observed environment. A POMDP based human-robot shared planner is used to model the interaction between them. In our work, we basically follow the work of [9] and use two stochastic models, one for the modelling of humans behaviours, one for the robots to estimate human intentions. Also, we try to simulate the interaction in more difficult scenarios and build a general framework.

3. Requirements

- Project shall start / be triggered upon object parameters after the inspection
- Decision maker script shall decides task division according to inspected object parameters (size, weight, temperature)
- A timer shall be set to control object transfer speed and give time for both human and robot time to grasp and package the object

- Human and Robot shall be simulated using the existing human model of MORSE environment
- Human shall be able to be installed with different human types (e.g. expert, beginner, sleepy)
- The human types shall be modelled externally using a decision process (e.g. Markov Decision Process)
- Human shall have an interface allowing for external control of his actions (via a remote controller)
- External decision modeller for Human shall consider three main states of human in grasping and packaging the object; success, human-errors, non-human errors
- Success state of human shall lead project code in asking another task for execution
- Human error states shall lead project code in handing over grasping and packaging task to Robot
- Non-human error states shall lead project code in stopping decision maker script in sending tasks, conveyor band in moving objects toward human and robot, and restarting all stopped
- The human actions shall be sensed and observed externally using environment management and perspective taking (e.g. Spatial Reasoning and Knowledge Module)
- Human's sensed and observed actions shall be inferred and used in generating robot action decisions
- Usage of human mental states and generation of collaborative decision-making shall be done modelled under uncertainty (e.g. Partially Observable Markov Decision Process)
- Robot shall not guide or control human actions, it can just estimate human is acting and it stays idle

4. Use Cases / Scenarios

We start by defining our System inputs and outputs. In figure 1 we see that our system is defined through the Inputs of Object Parameters and will produce System outputs of a packaged object (final product) or an error. While the state of error will be tried to avoid naturally, it might not be avoidable all the time. In this case we will further describe situations, that might lead to an error state and how to work with them.

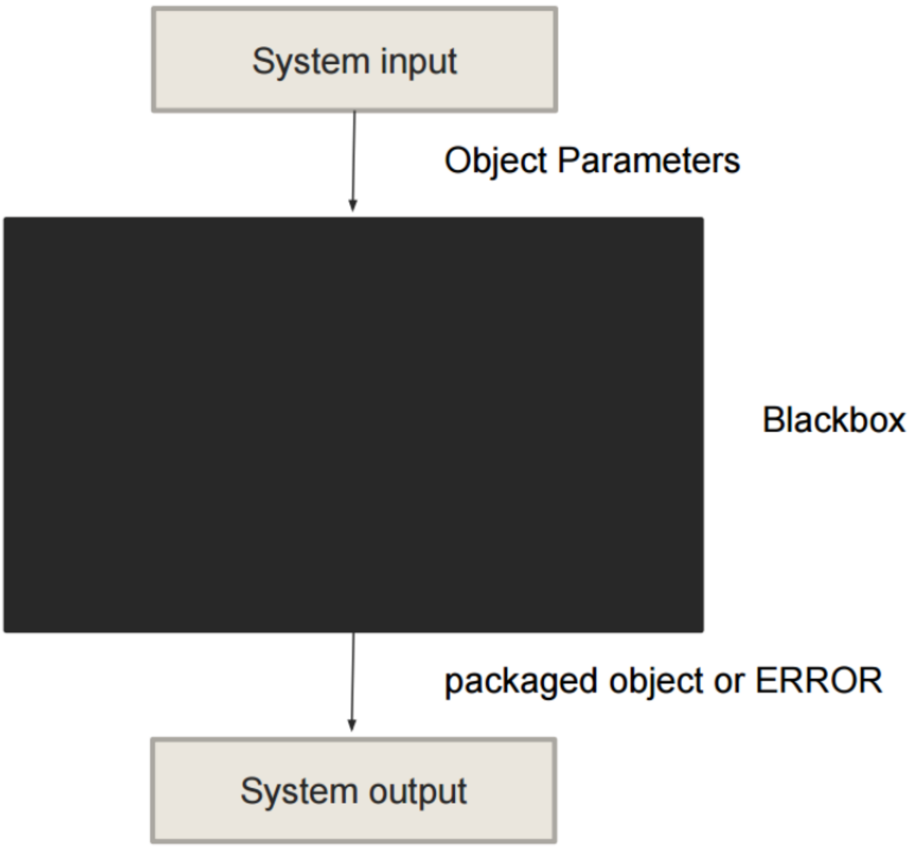


Figure 1: System overall input and output

Everything that happens in the blackbox will be part of our project. We want to try to cover all possible situations that might occur here in the following figures:

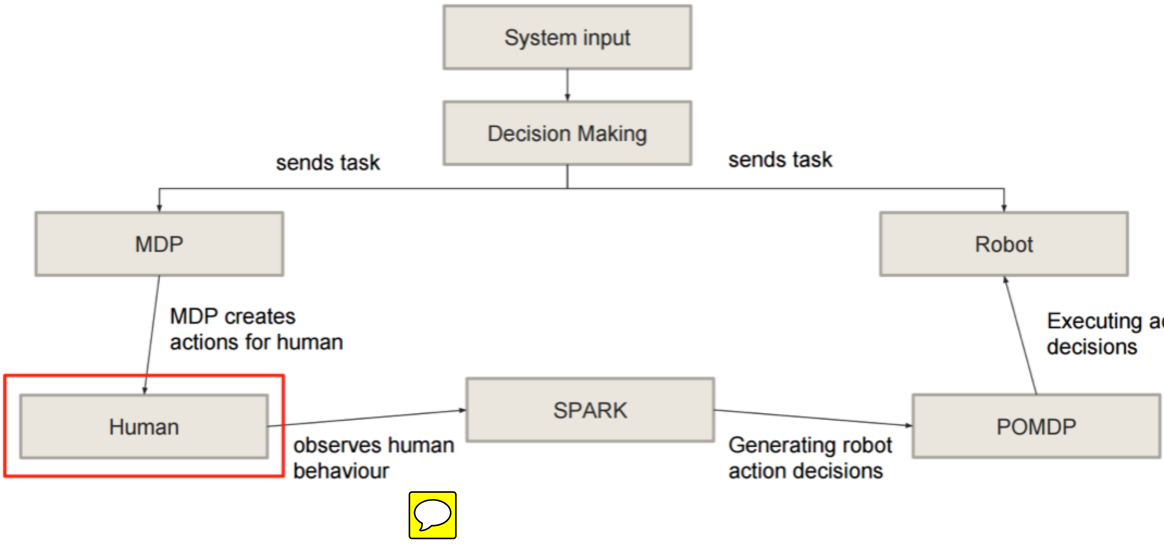


Figure 2: System input processing

Figure 2 shows the outline of processing the System input. It will tell the "Decision maker" on whom to assign the task of picking up the object and package it, based on the criteria which project group 2 (Object identification) identified. While the object assigned to the robot will most probably always follow a default procedure (excluding errors), the part of the human assignment will be much more difficult and complex to simulate. Because of the reason that human produce errors while maintaining long, monotonous, dull work, which also grow proportionally with the time spend on doing that work, many uncertain states may be created. While we can cover discrete states for human actions using MDP, there will also be non-discrete states using POMDP while the robot observes human behaviour. Using probabilistic calculus the robot will make an assumption on which state the human might be in and act accordingly.

To describe certain states that might occur during the whole procedure we will have a deeper look into the Human part first. Figure 3 shows the most general use case scenario while human being assigned to the task.

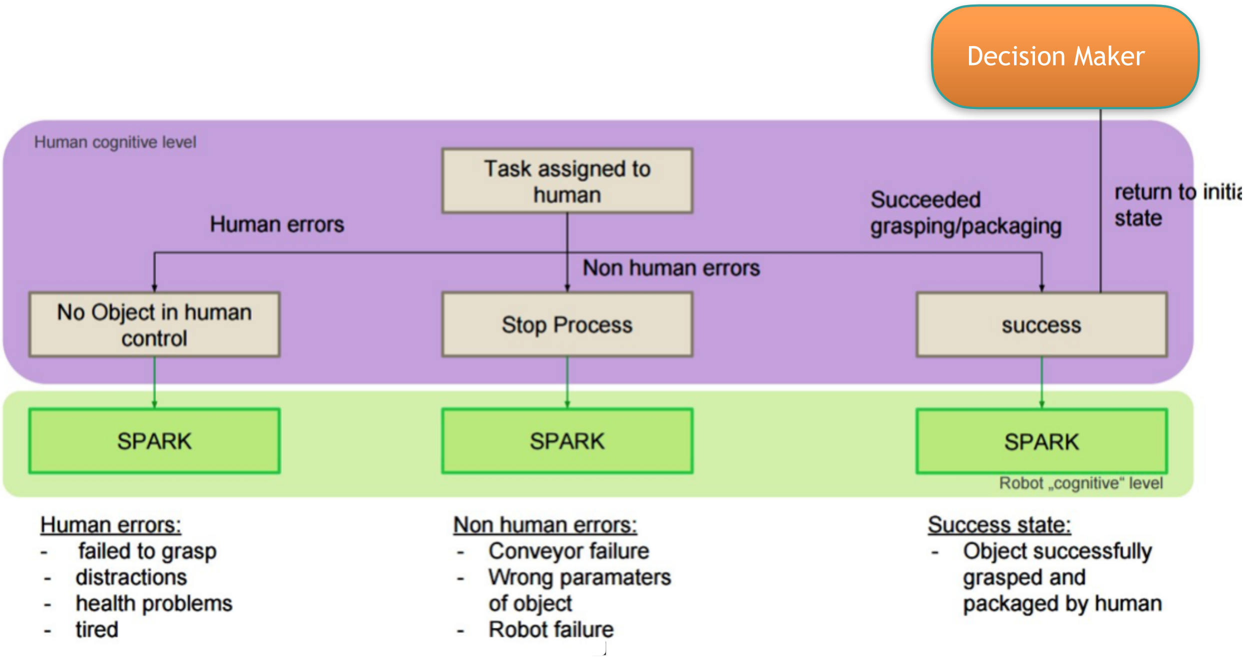


Figure 3: General Use-case scenario

As we can see in figure 3, states are categorised into 3 major topics: The object which shall be packaged is not in human control, the process is stopped due to non-human errors or we entered the success state. While these states cover the basic use-case scenarios, there may also be plenty of misuse cases which lead into uncertain states for the robot (it may face following questions, which need to be answered by its implemented models: Which current state does the human have? Does he continue working? Is the human still able to work? When does the robot interfere?). A Misuse case as an example: The Human is an absolute beginner (first day worker, trainee etc.) and is trying to grab the object. He fails. Since the conveyor band does not stop the human might a) give up on trying to grasp the object because it is too far away already or b) try to grab the object again or c) look to the robot (waiting for the robot to grab it) because of uncertainty of the current situation. Another example: The object is assigned to the human although it is too heavy (wrong system input). The human tries to grab it and realises that he is not able to carry it. Another situation of uncertainty is created and the human may a) stop the conveyor band, even if there is no need to, or b) lift the object while destroying it (using too much force or object is falling down) or even c) do typical human reactions like pointing at the object to “tell” the robot to pick it. SPARK needs to sense these situations and cover them by creating adequate reactions from the robot based on POMDP model and "hidden" states of the human (state of human will be assumed by robot).

5. System Architecture and Specifications

5.1. System Architecture

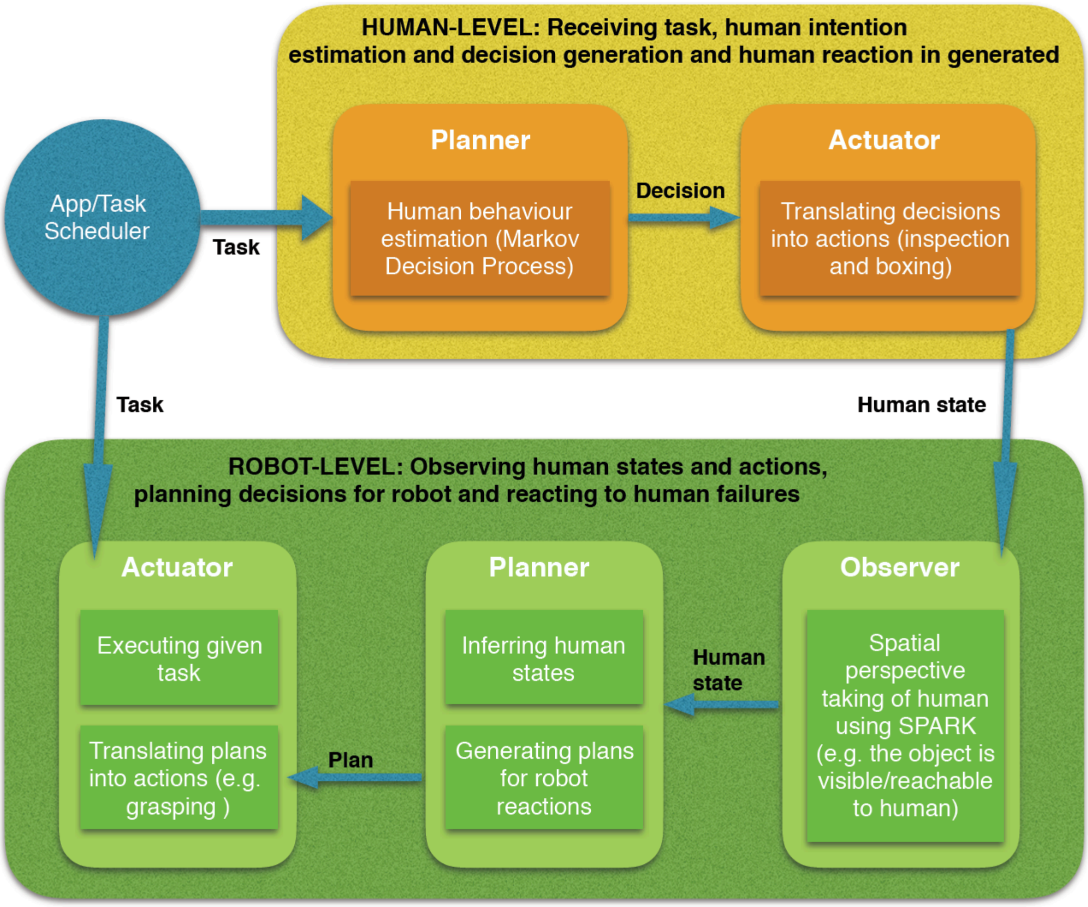
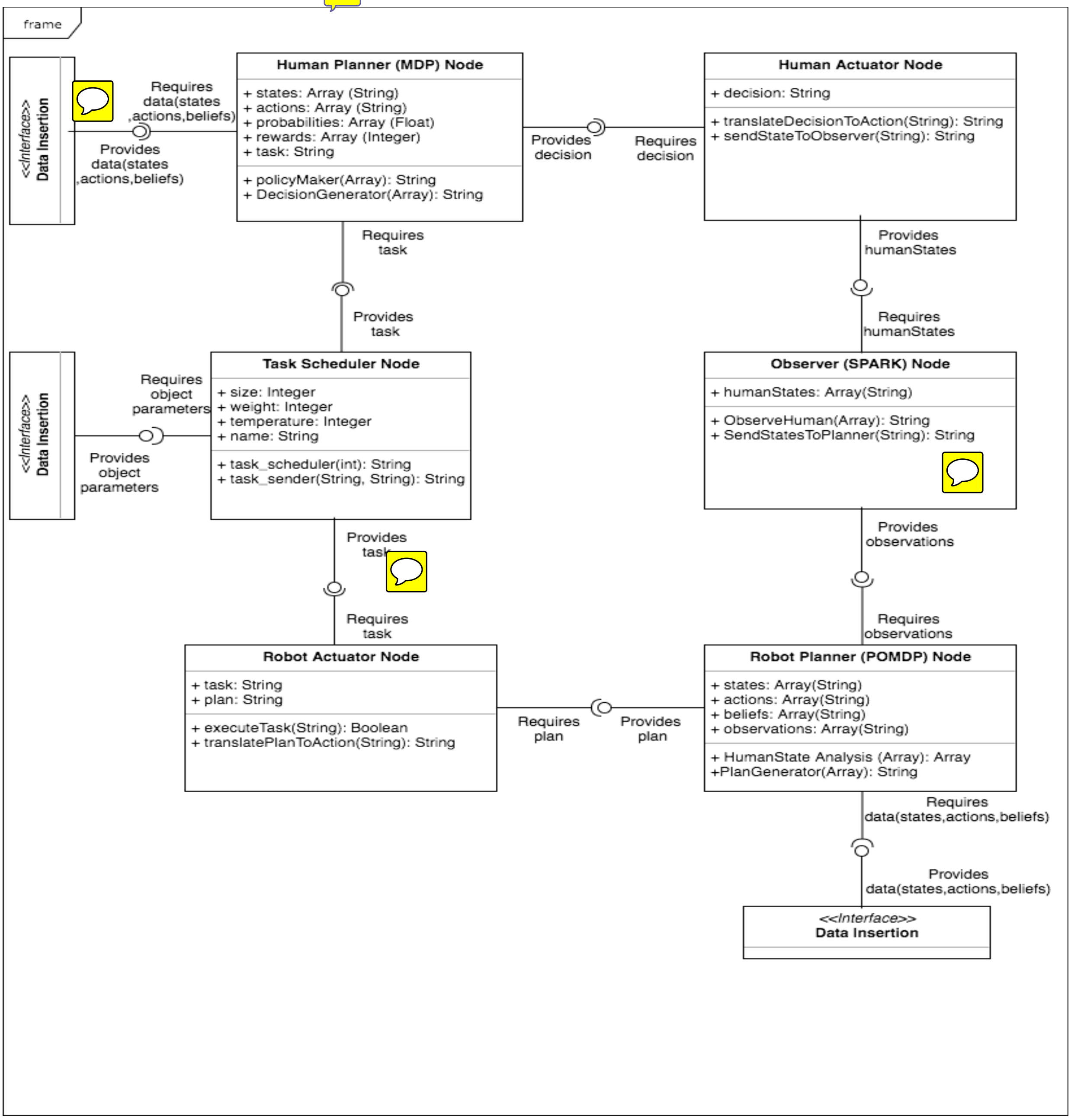


Figure 4: System Architecture

This is a general overview of system that is going to solve the problem the factories facing in warehousing. In following architecture three main nodes considered which will be divided into smaller nodes. First node is "Task Scheduler" which gets object's parameters and schedules tasks according to those parameters and finally sends a task whether to human or robot. Second node is "Human Level" where human action of a given task will be estimated according to human behaviour in sub-node "Planner" using MDP modelling algorithms and a decision will be generated to next sub-node "Actuator" which will translate given decision into action and will execute it using MORSE simulator.

Third node is “Robot Level” which consists of three sub-nodes, “Observer” which observes human actions and states using SPARK, then sends those observations to next sub-node called “Planner”. “Planner” will use those states to infer and generate plans for robot to act upon those plans. “Planner” node will use POMDP modelling algorithm since human states are uncertain each time. “Actuator” will receive both tasks from “Task Scheduler” and will execute those tasks and it will receive plans from “Planner” node to take actions by translating those plans into appropriate actions, this node will use MORSE simulator to do mentioned tasks.

5.2.System Specifications



6. Timeline

Our project will be completed in three milestones:

1. Information gathering, planning and documentation (one week)
2. Environment setup using MORSE simulator which includes simulation of human, robot and conveyor band, integrating these object to work with each other (basic workflow) and testing with some basic tasks like generating a random task, setting a random state and action to human, giving grasping command via external controllers, etc. (3 weeks)
3. Implementation, integration and testing of nodes which specified in system specification section which includes:
    - Defining Human status using MDP for “Human Planner” node and integrating it with “Human Actuator” node in Morse
    - Integrating “Observer” node to “Human Actuator” node in MORSE using SPAR to observe human actions and send observations to “Robot Planner” node
    - Defining uncertain situations for “Robot Planner” node using POMDP according to observations received from “Observer” node, to generate plans for Robot in order to act upon those plans
    - Integrating “Robot Planner” node to “Robot Actuator” node in MORSE to send plans for robot and “Robot Actuator” node will translate plans and execute them

ACTIVITY	ESTIMATED BEGIN	ESTIMATED DURATION
PRESENTATION	1	1
FINISH SDS	1	5
MILESTONE 1	1	7
Methology Research	2	15
Setting up Environment	5	15
Create Human/Robot Object	6	7
Integrate and Test	10	12
MILESTONE 2	25	7
MDP 1: library set up	8	32
MDP 2: modelling human	24	14
POMDP 1: library setup	6	32
POMDP 2: modelling robot	10	38
Test and improvement	31	25
MILESTONE 3	57	7
Finalize Presentation	62	5
Edit Feedback	62	8
FINAL PRESENTATION	TBD	TBD

Table 1: Project Timeline

7. Frameworks and Tools

- MORSE and ROS for simulation of “Human Actuator” and “Robot Actuator” nodes and environment which includes conveyor band for moving the object toward human and robot, human and robot avatars [1]
- Markov Decision Making (MDM),a ROS library for robot decision-making based on MDPs for implementation of “Human Planner” node[2]
- SPARK - Spatial Reasoning and Knowledge Module for implementing “Observer” node, human state observation[3]
- Approximate POMDP planning toolkit for modelling “Robot Planner” node [4]

8. References

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