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R&D Project Proposal

Robot motion planning in dynamic environment: A comparative study

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1. Introduction

The topic for this R&D is motion planning for dynamic environment. By solving this problem, we can ensure

- Safe environment for humans and for robots
- Cost effective transportation of goods

Motion planning in dynamic environment needs to perform the following task

- Reach the desired target position
- Avoid static and moving obstacle
- Consider actuator constraints
- Consider geometry of robot

It needs to perform these tasks in *fast* and *efficient* manner. The *fast* nature of planner dictates that the planning of motion should be at least performed in real time for the robot to react to its environment. An approach is *efficient* if the planner

- does not collide
- takes minimal time to reach goal position
- does not require a large amount of sensor data
- does not require a lot of computational resources

1.1. Problem Statement

- Current approaches are not generalised for all types of robot. They work best for circular holonomic robots. Velocity based approaches, which perform very well, are mostly tested on point sized robots.
- Some approaches are defined and tested for non-holonomic vehicles, but they either lack in terms of computation speed or they do not guarantee a solution.
- Most of the approaches do not even address how the objects needs to be perceived. They do not address how errors from perception and control would influence the planner's efficiency.
- This work will provide a comparative study on existing approaches for motion planning in time varying environment.

2. Related Work

- All the existing approaches have tested their efficiency on different robots and in different test environment.
- As the measuring criterion for each of them is different, it becomes an impossible task to determine a clear winner.
- There are several existing survey article:
  - Mohanan et al.[1] covers 101 research papers that were published between 1985 and 2016 in the field of motion planning in dynamic environment. They have addressed all the approaches but a comparative analysis of all the approaches with their contributions and deficiencies is left to be desired.
  - Hoy et al.[2] provides a survey for algorithms which provide collision free navigation for robots. This survey is not only detailed but also quite broad as it covers obstacle avoidance algorithm as well. Even though it provides a comparison between main approaches based on numerous criterion, it still does not evaluate these approaches on a standard uniform test.
  - Keshmiri et al.[3] provides a survey specifically for motion planning in dynamic environment. It covers all the approaches presented in research papers published between 1986 and 2008 totalling up to 150 papers. They have provided a comparison on how much contribution has been made in motion planning field based on different approach but regarding the actual approaches itself, only a summary of at most 23 sentences for each approach is provided.
  - Approaches [4] and [5] are quite dated and does not cover any state of the art approaches in motion planning for dynamic environment.
- Existing approaches generally provide critique and deficiencies on their previous works. These are generally helpful but they mostly compare their approach with the existing solutions and only point out the deficiencies that they have addressed. Therefore, though these comparisons are helpful, they might not be completely reliable.

2.1. Approaches in motion planning for dynamic environment

2.1.1. Velocity based

- *Dynamic window approach*: Fox et al.[6] proposed the original idea for simply optimizing a function which balances robot's distance from goal, distance from nearest obstacle and current velocity. This approach, despite being robust, simple and fast did not work for dynamic environment. Later, Brock et al.[7] extended this approach for global path planning and for dynamic environments by combining it with NF1 algorithm. This eradicated the problem of local minima. It has been since extended in [8] and [9]

- *Velocity obstacle (VO)*: Originally developed by Fiorini et al.[10], this approach proposes to avoid obstacles by choosing velocity outside *collision cone*. This approach unifies the representation for avoiding static and dynamic obstacles. This idea has since been transformed to incorporate many scenarios[11][12][13][14]. For multi robot systems, Van den berg et al.[15][16][17] have extended VO approach.

- *ICS based approach*: Inevitable collision states (ICS)[18][19][20] have proposed a solution to avoid states that has no outcome other than collision. They propose that this states if avoided will ensure that the robot will never collide. They have approached this problem in a mathematical way. They provide a very fast and almost infinite look ahead option[1].

2.1.2. Roadmap based

- *Randomized kinodynamic planning*: Hsu et al.[21] provides an extension of probabilistic roadmap approach by considering kinodynamics of the robot before choosing a motion control.

- Van den berg et al.[22] provides an extension on roadmap based motion planning for static and dynamic obstacles.

2.1.3. Other

- *Nearness diagram*: [23] proposes a *divide and conquer* strategy for motion planning in dynamic environment using a geometry based approach for their implementation.

3. Project Plan

3.1. Work Packages and milestones

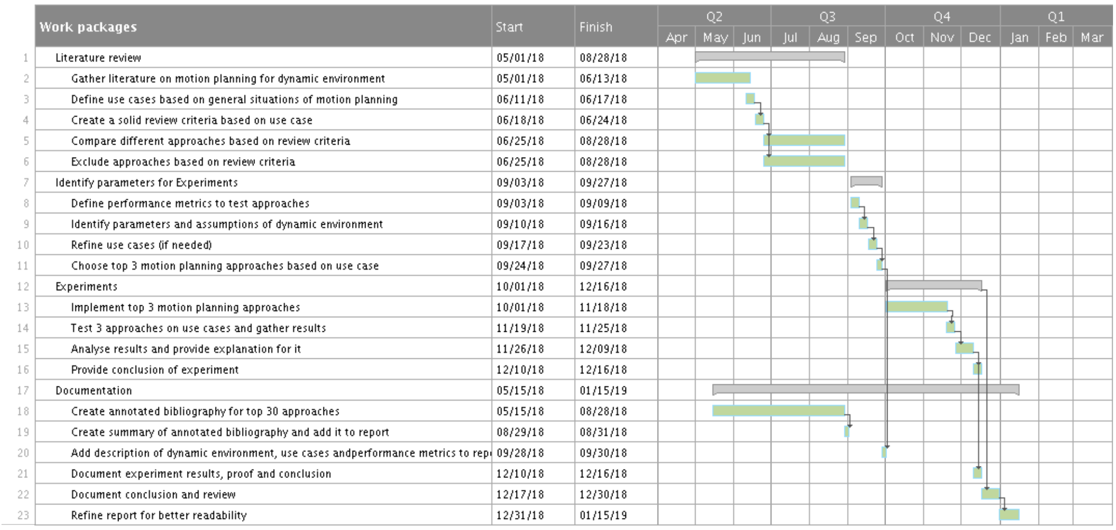
The bare minimum will include the following packages:

Work packages	**Tasks**
Literature review	Gather literature on motion planning for dynamic environment Define use cases based on general situations of motion planning Create a solid review criteria based on use case Compare different approaches based on review criteria Exclude approaches based on review criteria Create annotated bibliography for top 30 approaches Create summary of annotated bibliography and add it to report
Identify parameters for Experiments	Define performance metrics to test approaches Identify parameters and assumptions of dynamic environment which will be used for experiments Refine use cases (if needed) Choose top 3 motion planning approaches based on use case Add description of dynamic environment, use cases and performance metrics to report
Experiments	Implement top 3 motion planning approaches Test 3 approaches on use cases and gather results Analyse results and provide explanation for it Provide conclusion of experiment Document experiment results, proof and conclusion
Documentation	Document conclusion and review Refine report for better readability

Table 3.1: Work packages and milestones

3.2. Project Schedule

Please see Figure 3.1



	Work packages	Start	Finish
1	Literature review	05/01/18	08/28/18
2	Gather literature on motion planning for dynamic environment	05/01/18	06/13/18
3	Define use cases based on general situations of motion planning	06/11/18	06/17/18
4	Create a solid review criteria based on use case	06/18/18	06/24/18
5	Compare different approaches based on review criteria	06/25/18	08/28/18
6	Exclude approaches based on review criteria	06/25/18	08/28/18
7	Identify parameters for Experiments	09/03/18	09/27/18
8	Define performance metrics to test approaches	09/03/18	09/09/18
9	Identify parameters and assumptions of dynamic environment	09/10/18	09/16/18
10	Refine use cases (if needed)	09/17/18	09/23/18
11	Choose top 3 motion planning approaches based on use case	09/24/18	09/27/18
12	Experiments	10/01/18	12/16/18
13	Implement top 3 motion planning approaches	10/01/18	11/18/18
14	Test 3 approaches on use cases and gather results	11/19/18	11/25/18
15	Analyse results and provide explanation for it	11/26/18	12/09/18
16	Provide conclusion of experiment	12/10/18	12/16/18
17	Documentation	05/15/18	01/15/19
18	Create annotated bibliography for top 30 approaches	05/15/18	08/28/18
19	Create summary of annotated bibliography and add it to report	08/29/18	08/31/18
20	Add description of dynamic environment, use cases andperformance metrics to rep	09/28/18	09/30/18
21	Document experiment results, proof and conclusion	12/10/18	12/16/18
22	Document conclusion and review	12/17/18	12/30/18
23	Refine report for better readability	12/31/18	01/15/19

Figure 3.1: Gannt chart for workpackages

3.3. Deliverables

3.3.1. Minimum

- Annotated bibliography on top 30 approaches for motion planning in dynamic environment
- Description of review criteria, use cases, performance metrics
- Comparison of 3 approaches of motion planning in dynamic environment in simulation
- Proof of these 3 approaches being best based on experiment results and analysis
- R & D report

3.3.2. Expected

- All items in minimum deliverable
- Comparison of 3 approaches of motion planning in dynamic environment on actual robot

3.3.3. Desired

- All items in expected deliverable
- Experiment results of 3 approaches on more use cases and complex scenarios
- Comparison of an additional algorithm

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