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R&D Project Proposal

Robot motion planning in dynamic environment: A comparative study

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1. Introduction

- Mobile robot needs a plan to reach to its desired goal. This plan is provided by motion planning algorithms.
- Robot motion planning (RMP) for static environment is not sufficient for most of the applications.
- Take for example, a robotic wheel chair or robot carrying hospital bed. These robots needs to tackle moving obstacle like patients, other wheel chairs, hospital beds, etcwhile safely moving towards its goal in a structured environment containing hallways, rooms and corridors.
- This type of problem applications need RMP for dynamic environment.
- By solving this problem, we can ensure
 - Safe environment for humans and for robots
 - Cost effective transportation of goods
- RMP in dynamic environment needs to perform the following task
 - Reach the desired target
 - Avoid static and moving obstacle
- It needs to perform these tasks in *fast* and *efficient* manner.
- The *fast* nature of planner dictates that the planning of motion should be atleast performed in real time for the robot to react to its environment.
- *Efficiency* of the planner can be defined on the basis of
 - Amount of information needed about the environment
 - Computation limits
 - Time to reach goal position
 - Number of collisions encountered (should be 0)

1.1. Problem Statement

- Current approaches solves these problems. Though they 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 lack in terms of speed.
- 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 RMP in dynamic environment.
- This comparative study will include
 - An in depth literature review of existing approaches
 - Identifying top solutions
 - Evaluating these candidates on various practical test on a real and simulated environment
 - Identifying the best solution based on performance measure

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.[12] covers 101 research papers that were published between 1985 and 2016 in the field of RMP 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.[7] 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.[9] provides a survey specifically for RMP 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 RMP 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 [5] and [19] are quite dated and does not cover any state of the art approaches in RMP 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 RMP for dynamic environment

2.1.1. Velocity based

- *Dynamic window approach*: Fox et al.[3] 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.[1] 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 [17] and [13]
- *Velocity obstacle (VO)*: Originally developed by Fiorini et al.[2], 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[18][15][14][6]. For multi robot systems, Van den berg et al.[22][21][20] have extended VO approach.
- *ICS based approach*: Inevitable collision states (ICS)[4][16][10] 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[12].

2.1.2. Roadmap based

- *Randomized kinodynamic planning*: Hsu et al.[8] provides an extension of probabilistic roadmap approach by considering kinodynamics of the robot before choosing a motion control.
- Van den berg et al.[23] provides an extension on roadmap based motion planning for static and dynamic obstacles.

2.1.3. Other

- *Nearness diagram*: [11] proposes a *divide and conquer* strategy for RMP in dynamic environment using a geometry based implementation of their approach.

3. Project Plan

3.1. Work Packages and milestones

The bare minimum will include the following packages:

Work packages	Milestones
Literature review	Gather literature on RMP 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
Experiments	Define performance metrics to test approaches Choose top 5 RMP approaches to test based on use case Implement top 3 RMP approaches Test 3 approaches on use case and gather results Analyse results and provide conclusion
Documentation	Document conclusion and review Refine report for better readability

Table 3.1: Work packages and milestones

3.2. Project Schedule

DELETE BEFORE FINAL

literature review: till end of july

Experiment: till end of mid December

Documentation: parallel with literature review and experimentation, refining report
till january 1st week

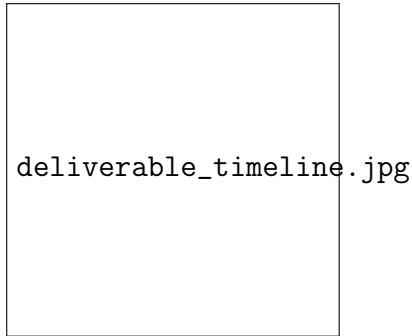


Figure 3.1: Gantt chart of milestones

3.3. Deliverables

3.3.1. Minimum

- Annotated bibliography on RMP for dynamic environment
- Analysis of state of the art
- Description of review criteria
- Demonstration of 3 approaches in simulation
- Demonstration of 3 approaches on a real robot
- R & D report

3.3.2. Expected

- All items in minimum deliverable
- Description of use cases
- Demonstration of 1 additional approach in simulation

3.3.3. Desired

- All items in expected deliverable
- Detailed analysis of the result
- Demonstration of 1 additional approach in simulation

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