Robot motion planning in dynamic environment: A comparative study

Dharmin Bakaraniya
Advisors:
Prof. Erwin Prassler
Dr. Cesar Lopez

Hochschule Bonn-Rhein-Sieg

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Introduction

What is it?

- A mobile robot needs to
  - Reach goal in **minimal** time
  - Avoid **static** *and* **moving** obstacle
  - Consider **kinematics** *and* **dynamic** constraints
- **Our aim**: Find out the "best" planner

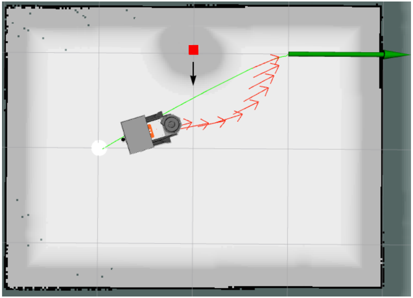

Figure: Robot motion planning in dynamic environment

Introduction Cont.

What are the benefits?

- **Safer** environment for humans *and* for robots
- **Cost effective** transportation of goods

State of the art

Survey of motion planning in dynamic environment (2018)[1]

- Covers 101 research papers published between 1985 and 2016
- Only introduces approaches. Virtually no comparison.

Motion planning algorithm survey (2015)[2]

- Compares collision avoiding algorithms in detail.
- Does not validate the comparison with common experiments.

[1] Mohanan and Salgoankar, "A survey of robotic motion planning in dynamic environments".

[2] Hoy, Matveev, and Savkin, "Algorithms for collision-free navigation of mobile robots in complex cluttered environments: a survey".

State of the art cont.

Field contribution survey (2009)[3]

- Introduces 150 papers from 1986 to 2008. Compares contribution in different area of motion planning
- Only states. Does not compare the approaches at all.

Dated comparison (1992)[4]

- Surveys papers from 1979 to 1989 for all types of motion planning.

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[3] Keshmiri and Payandeh, "An overview of mobile robotic agents motion planning in dynamic environments".

[4] Hwang and Ahuja, "Gross motion planning–a survey".

What is lacking?

- The surveys do not test the approaches.
- The approaches test themselves
  - on <u>different</u> robots
  - with <u>different</u> kinodynamic constraints[5]
  - with <u>different</u> assumptions
  - in <u>different</u> environments
  - to optimize <u>different</u> parameters

[5] Hoy, Matveev, and Savkin, "Algorithms for collision-free navigation of mobile robots in complex cluttered environments: a survey".

Qualitative Comparison

We qualitatively compare 30+ planners based on

Vehicle type

Holonomic, unicycle or bicycle

Restrictions on obstacle

- Constant or varying direction
- Constant or varying velocity

Obstacle shape

Circular or polygonal

Experiment environment

Simulated and/or real

Experimental setup

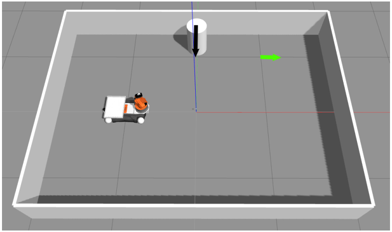
Setup

- **Robot**: KUKA youbot with 2 laser rangefinder
- **Environment**: Gazebo simulator
- **Obstacle**: Cylinders with varying velocity and varying direction

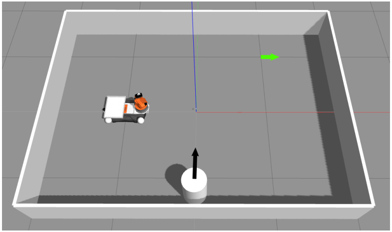
Measured values

- Travel time
- Number of collisions
- Number of re-plans

Test case 1



(a) t=0.0s

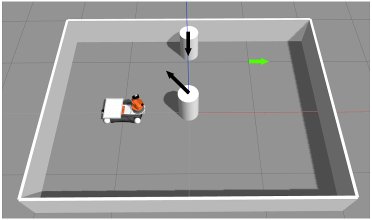


(b) t=10.0s

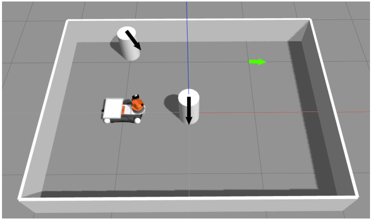
Description

- Room size: 4 meters x 3 meters
- Starting position: `x=-1.0, y=0.0, theta=0.0`
- Goal position: `x=1.0, y=1.0, theta=0.0`

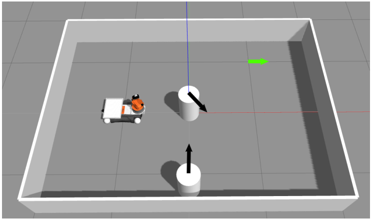
Test case 2



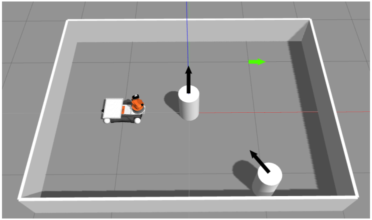
(a) t=0.0s



(b) t=5.0s

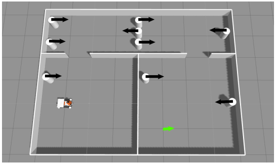


(c) t=10.0s

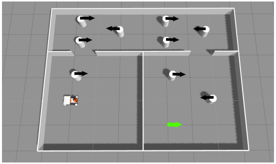


(d) t=15.0s

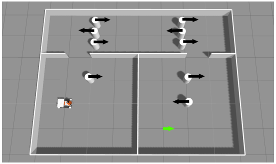
Test case 3



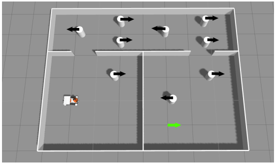
(a) t=0.0s



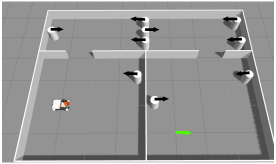
(b) t=5.0s



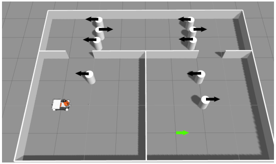
(c) t=7.5s



(d) t=10.0s



(e) t=15.0s



(f) t=22.5s

Figure: Test case 3 (Total size: 8m x 6m)

Planners

- Timed elastic band planner (TEB)[6]
- Spline based planner[7].
- Elastic band approach (EBand)[8].
- Eband* (EBand2)
- Dynamic window approach* (DWA)[9]

* with obstacle position look ahead of 3 seconds

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[6] Rosmann, Hoffmann, and Bertram, "Planning of multiple robot trajectories in distinctive topologies".

[7] Mercy, Van Parys, and Pipeleers, "Spline-based motion planning for autonomous guided vehicles in a dynamic environment".

[8] Quinlan and Khatib, "Elastic bands: Connecting path planning and control".

[9] Fox, Burgard, and Thrun, "The dynamic window approach to collision avoidance".

Results (travel time)

Planner	Static single room	Test case 1	Test case 2	Static double room	Test case 3
TEB	**5.205**	5.972	6.083	**27.139**	**35.330**
Spline based	5.421	**5.574**	**5.819**	-	-
DWA	19.526	17.625	17.114	39.004	-
EBand	6.270	6.570	6.240	30.862	71.968
EBand2	6.270	6.025	6.234	30.862	-

Table: Average time of travel for planners for different test cases

Results (re-plans)

Planner	Static single room	Test case 1	Test case 2	Static double room	Test case 3
TEB	0	0	1	0	4
Spline based	0	0	0	Fail	Fail
DWA	0	0	2	0	Fail
EBand	0	1	Fail	0	Fail
EBand2	0	1	1	0	Fail

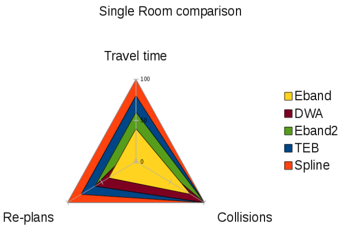
Table: Maximum re-plan attempts of planners for different test cases

Results (collisions)

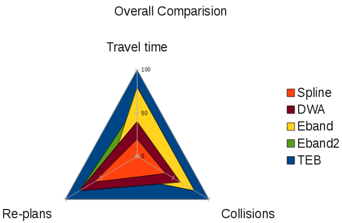
Planner	Static single room	Test case 1	Test case 2	Static double room	Test case 3
TEB	0	0	0	0	0.75
Spline based	0	0	0	-	-
DWA	0	0	0	0	-
EBand	0	0.25	0.5	0	4
EBand2	0	0	0	0	-

Table: Average collisions of planners for different test cases

Results visualised



(a) Ranking comparison for test case 1 and 2



(b) Ranking comparison for all test cases

Verdict

TEB planner performs best for our experiments out of 5 planners.

Conclusion and future work

Conclusion

- Qualitative comparison of motion planning approaches for dynamic environments.
- Develop an open source framework to test motion planners
- TEB planner performs “best” for given scenario out of 5 planners

Future work

- Test more planners with this framework.
- Test with humans as obstacles for real robots.
- Test with different models of robots.

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