14. TEB path planning algorithm

14.1. Introduction

The full English name of ted is Time Elastic Band. It performs subsequent modification on the initial trajectory generated by the global path planner to optimize the motion trajectory of the robot, which belongs to **local path planning**. During the trajectory optimization process, the algorithm has various optimization objectives, including but not limited to: **overall path length, trajectory running time, distance to obstacles, passing through intermediate path points and robot dynamics, kinematics and compliance with geometric constraints.**

The popular explanation is that the local trajectory generated by TEB is composed of a series of discrete poses with time information. The goal of g2o algorithm optimization is these discrete poses,So that the final trajectory composed of these discrete poses can achieve the goals of the shortest time, the shortest distance, and away from obstacles, etc.,At the same time, the speed and acceleration are limited so that the trajectory meets the kinematics of the robot.It should be pointed out that the results of g2o optimization do not necessarily meet the constraints, that is, they are actually soft constraints. **If the parameter settings are unreasonable or the environment is too harsh, teb may fail and plan a very strange trajectory**.Therefore, the conflict detection part is included in the teb algorithm. After the trajectory is generated, it is judged point by point whether the points on the trajectory conflict with the obstacle. This process takes **the actual outline of the robot** into consideration.

14.2. Comparison of teb algorithm and dwa algorithm

The DWA algorithm is commonly used, and the target robot model is a differential robot, or an omnidirectional robot, which can at least rotate in situ. However, R2 is a car model belonging to the Ackerman model, so the dwa algorithm does not apply to R2. The DWA algorithm has a contradictory point, that is, due to the mismatch of the target model, it is impossible to set the very important parameter of the steering radius.

teb will **adjust its own posture orientation** during the movement process. When it reaches the target point, usually the orientation of the robot is also the **target facing without needing to rotate**; dwa is **reaches the target coordinate point first** , then **rotate in place to the target facing**. This is where there is a clear difference between the two. For a two-wheel differential chassis, **teb adjusting the orientation in motion will make the motion path unsmooth****, and there will be **unnecessary backing** when starting and when it will reach the target point. This is not allowed in some application scenarios.

14.3. teb parameter adjustment

It can be seen from the above that if you want the path planned by teb to travel more smoothly, you need to adjust the parameters. There are still quite a few parameters for teb path planning. Here is the meaning of each parameter.

14.3.1. The parameters in the Trajectory section are used to adjust the trajectory

```
# Trajectory
teb_autosize: True
dt_ref: 0.3
dt_hysteresis: 0.1
max_samples: 500
global_plan_overwrite_orientation: True
allow_init_with_backwards_motion: True
max_global_plan_lookahead_dist: 6
global_plan_viapoint_sep: -1
global_plan_prune_distance: 1
exact_arc_length: False
feasibility_check_no_poses: 2
publish_feedback: False
```

Parameter	Meaning
dt_ref	Desired trajectory time resolution
dt_hysteresis	Automatically resize the phenomenon of hysteresis based on current time resolution
global_plan_overwrite_orientation	Overrides the orientation of local subgoals provided by the global planner
max_samples	Maximum number of samples
max_global_plan_lookahead_dist	Specifies the maximum length of a subset of global plans to consider for optimization
allow_init_with_backwards_motion	Whether to initialize before planning the path Including reversing action

Parameter	Meaning
global_plan_viapoint_sep	Minimum interval between every two consecutive passing points selected from the global path
publish_feedback	Publish planner feedback with full trajectory and active obstacle list
global_plan_prune_distance	This parameter determines to start cropping from a certain distance behind the current position of the robot
exact_arc_length	If true, the planner uses the exact arc length [increased CPU time] in velocity, acceleration and turn rate calculations, otherwise uses the Euclidean approximation.
feasibility_check_no_poses	It is used when judging whether the generated trajectory collides, and it is set to 3 at this time, that is, the 3 points on the trajectory are checked one by one from the starting point of the trajectory. If none of the three points collide, the trajectory is considered valid. If less than 0 all waypoints are checked.

14.3.2. The parameters of the Robot part set the structure parameters and speed parameters of the robot

```
 # Robot
 max_vel_x: 0.4
 max_vel_x_backwards: 0.4
 max_vel_y: 0.0
 max_vel_theta: 1.0 # the angular velocity is also bounded by min_turning_radius in case of a carlike robot (r = v / omega)
 acc_lim_x: 0.5
 acc_lim_theta: 0.5
 # ********************** Carlike robot parameters ********************
 min_turning_radius: 0.768        # Min turning radius of the carlike robot (compute value using a model or adjust with rqt_reconfigure manually)
 wheelbase: 0.25                 # Wheelbase of our robot
 cmd_angle_instead_rotvel: False # stage simulator takes the angle instead of the rotvel as input (twist message)
 # ********************************************************************
```

Parameter	Meaning
max_vel_x	Maximum speed in the x-axis direction
max_vel_x_backwards	Maximum reversing speed in the x-axis direction
acc_lim_x	Acceleration limited in the x-axis direction
max_vel_theta	Maximum turning speed
acc_lim_theta	Turning acceleration limit
min_turning_radius	Minimum turning radius (**experience value is 2.4* car length**)
wheelbase	Wheelbase

14.3.3. GoalTolerance part of the parameter setting target error

```
 # GoalTolerance
 xy_goal_tolerance: 0.2
 yaw_goal_tolerance: 0.2
 free_goal_vel: False
```

Parameter	Meaning
xy_goal_tolerance	Allowable distance error of target position
yaw_goal_tolerance	Allowable angular error of target position
free_goal_vel	Whether to remove the constraint of target speed

14.3.4. The parameter setting of the Obstacles part of the obstacle processing

```
 # Obstacles
 min_obstacle_dist: 0.2 # This value must also include our robot's expansion, since footprint_model is set to "line".
 inflation_dist: 0.5
 include_costmap_obstacles: True
 costmap_obstacles_behind_robot_dist: 1.0
 obstacle_poses_affected: 20
 dynamic_obstacle_inflation_dist: 0.6
 include_dynamic_obstacles: True
 costmap_converter_plugin: ""
 costmap_converter_spin_thread: True
 costmap_converter_rate: 8
```

Parameter	Meaning
min_obstacle_dist	Minimum expected distance to obstacles
inflation_dist	Buffer zone around obstacles
include_costmap_obstacles	Whether to take into account the obstacles of the local costmap
costmap_obstacles_behind_robot_dist	Consider obstacles within n meters behind
costmap_converter_spin_thread	If true, the costmap converter will call its callback queue in a different thread,
costmap_converter_rate	The frequency with which the costmap_converter plugin processes the current costmap
obstacle_poses_affected	Obstacle attitude affected degree 0-30
dynamic_obstacle_inflation_dist	Expansion range of dynamic obstacles
include_dynamic_obstacles	Whether to predict dynamic obstacles as a speed model

14.3.5.Optimization part of the parameters set the weight size in the path planning

```
# Optimization
no_inner_iterations: 5
no_outer_iterations: 4
optimization_activate: True
optimization_verbose: False
penalty_epsilon: 0.1
obstacle_cost_exponent: 4
weight_max_vel_x: 2
weight_max_vel_theta: 1
weight_acc_lim_x: 1
weight_acc_lim_theta: 1
weight_kinematics_nh: 1000
weight_kinematics_forward_drive: 1
weight_kinematics_turning_radius: 1
weight_optimaltime: 1 # must be > 0
weight_shortest_path: 0
weight_obstacle: 100
weight_inflation: 0.2
weight_dynamic_obstacle: 10 # not in use yet
weight_dynamic_obstacle_inflation: 0.2
```

```
weight_viapoint: 1
weight_adapt_factor: 2
```

Parameter	Meaning
no_inner_iterations	Number of times the inner loop performs optimization after being called by the outer loop
no_outer_iterations	The number of optimizations of the outer loop executed The number of optimizations of the outer loop executed
optimization_activate	whether to activate the optimization
optimization_verbose	Whether to print the optimization process details
penalty_epsilon	*For hard-constrained approximations, add a safety margin to the penalty function*
weight_max_vel_x	Maximum x speed weight 0~2
weight_max_vel_theta	Maximum angular speed weight 0~1
weight_acc_lim_x	Maximum x acceleration weight 0~1
weight_acc_lim_theta	Maximum angular speed weight 0~1
weight_kinematics_nh	Optimal weights to satisfy non-holographic kinematics
weight_kinematics_forward_drive	In the optimization process, the robot is forced to choose only the forward direction, and the differential wheel is suitable
weight_kinematics_turning_radius	During the optimization process, the weight of the minimum turning radius of the model robot
weight_optimaltime	Trajectory-based temporal weights during optimization
weight_obstacle	During the optimization process, the weight of the minimum distance from the obstacle is 0~50
weight_inflation	During the optimization process, the weight of the inflated region
weight_dynamic_obstacle	During the optimization process, the weight of the minimum distance from the dynamic obstacle
weight_dynamic_obstacle_inflation	During the optimization process, the weight of the dynamic obstacle expansion area is 0~50.
weight_viapoint	During the optimization process, the weight of the distance from the global path sampling point

14.3.6, Homotopy Class Planner some parameters

```
enable_homotopy_class_planning: True
enable_multithreading: True
roadmap_graph_no_samples: 15
roadmap_graph_area_width: 5
h_signature_prescaler: 0.5
h_signature_threshold: 0.1
obstacle_heading_threshold: 0.45
switching_blocking_period: 0.0
visualize_hc_graph: False
visualize_with_time_as_z_axis_scale: False
```

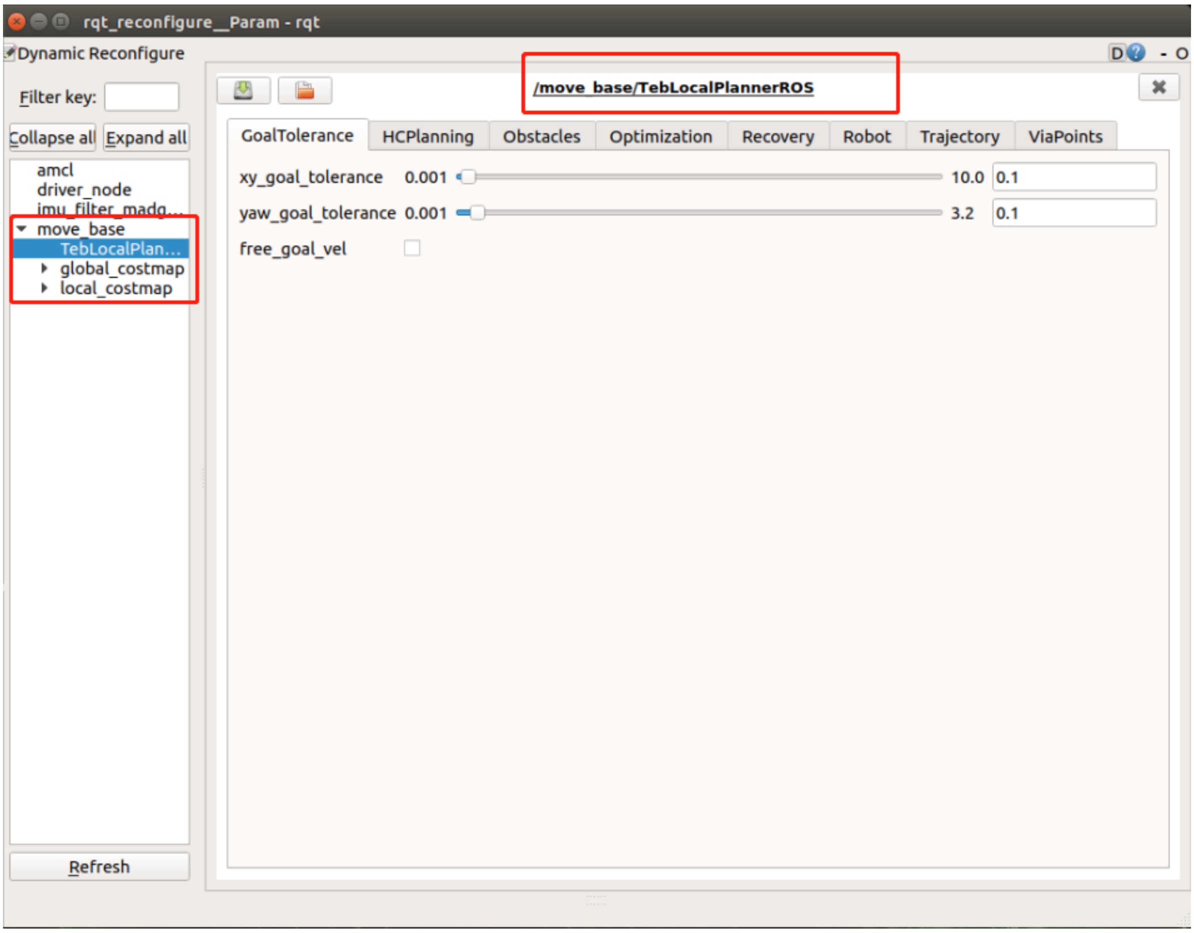
Parameter	Meaning
enable_homotopy_class_planning	Whether to activate parallel planning
enable_multithreading	Whether to allow multi-threaded parallel processing
roadmap_graph_no_samples	*Specify the number of samples to generate for roadmap creation*
roadmap_graph_area_width	Specifies the width of the area
h_signature_prescaler	Scaling the internal parameters used to differentiate homotopy classes

Parameter	Meaning
h_signature_threshold	Two h signatures are assumed to be equal if the difference between the real and complex parts are both below a specified threshold
obstacle_heading_threshold	Specifies the value of the scalar product between the obstacle heading and the target heading to explore taking the obstacle into account
switching_blocking_period	Duration that needs to be terminated before switching to a new equivalent class is allowed
visualize_hc_graph	Whether to visualize created graphs for exploring different trajectories
visualize_with_time_as_z_axis_scale	Whether you can see the optimized graph in rviz

14.4. Use the parameter adjuster to debug teb parameters

After the navigation is turned on, if we are not satisfied with the effect of the navigation, we can use the parameter adjuster to dynamically debug the parameters, input the terminal,

```
rosrun rqt_reconfigure rqt_reconfigure
```



xy_goal_tolerance 0.001 10.0 0.1

yaw_goal_tolerance 0.001 3.2 0.1

free_goal_vel □

Generally speaking, the minimum turning radius of **min_turning_radius is 2.4 times the length of the vehicle**;**The wheelbase parameter needs to be actually calibrated, the distance between the drive shaft and the rotating shaft**.Other parameters are debugged according to the actual situation.The parameters in this part of Optimization are aimed at optimizing the navigation effect,Among them, the weight value of **weight_kinematics_forward_drive** is to force the car to move forward without reversing.Experience tells us that when this value is adjusted to the maximum, **there is no way to completely prohibit the effect of reversing**.Whether the car can move forward is determined by combining other parameters.

For more explanation of parameters, you can refer to the official documentation reference:

teb_local_planner - ROS Wiki