Constrained Path planning with RRT*

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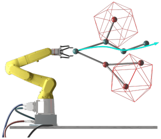
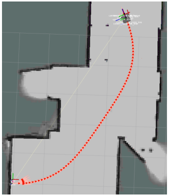
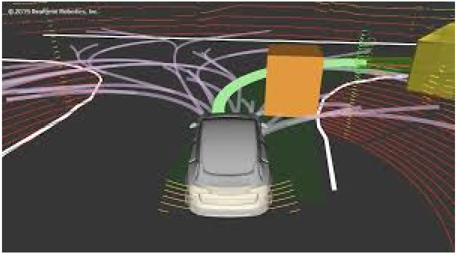
Introduction - Path Planning

Planning a path within a 2D or 3D space is fundamental in robotics.
A few major algorithms :

- Djikstra
- A*
- RRT

Introduction - Path planning

Limitations

Issues generally encountered :

- No pre-existing graph
- Convergence towards an optimal solution
- Account for complex path constraints

Proposition

A variant of the RRT algorithm, *RRT**

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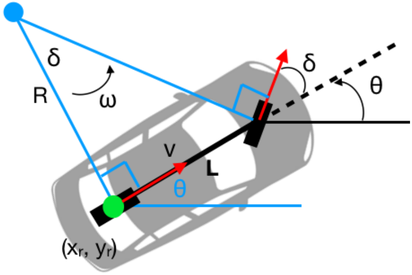
RRT* algorithm

Result: RRT* tree T
Initialization;
while *Not converged* **do**
    Sample random configuration q_{rand};
    Find nearest node q_{near} to q_{rand} in T;
    Steer towards q_{rand} from q_{near} to get q_{new};
    if q_{new} *is collision-free* **then**
        Find nearby nodes $N_{q_{\text{new}}}$ in T;
        Choose parent q_{min} from $N_{q_{\text{new}}}$ minimizing cost;
        Rewire T to q_{new} if it improves cost-to-come;
        Add q_{new} to T with q_{min} as parent;
    end
end

Algorithm 2: RRT* Algorithm

Kinematic model

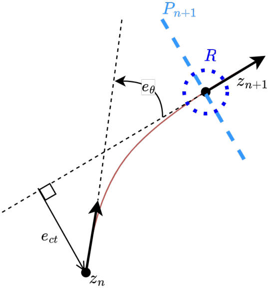


$$\begin{bmatrix} \dot{x} \\ \dot{y} \\ \dot{v} \\ \dot{\theta} \end{bmatrix} = \begin{bmatrix} v\cos(\theta) \\ v\sin(\theta) \\ a \\ \frac{v\tan(\delta)}{L} \end{bmatrix} = f(X, u) \quad \text{with } u = [a, \delta]^T \qquad (1)$$

Control strategy

$$a_c = \frac{v^2}{R} = \frac{v^2 \sin(\delta)}{L}$$

$$v_R = \min(v_{n+1}, \sqrt{\frac{a_{c_{max}} L}{\sin(\delta)}})$$



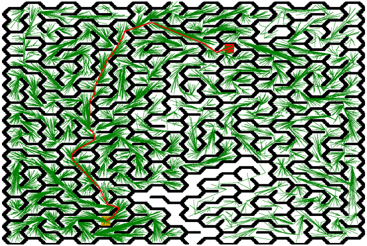
Commands

$$\begin{cases} a = clamp_{[-a_m, a_m]}(K_p(v_R - v)) \\ \delta = clamp_{[-\delta_m, \delta_m]}(K_{str} \arctan(K_{ct} e_{ct}) + K_{str} e_\theta) \end{cases} \quad (2)$$

1. RRT* algorithm
2. Kinematic constraints
3. Results
   - Without kinematic constraints
   - With kinematic constraints
4. Conclusion and perspectives

First results

(a) Path found on an urban map



(b) Tree graph (green) and path (red) in an hexagonal maze

FIGURE – Shortest paths using euclidean distance and no kinematic constraints

First results

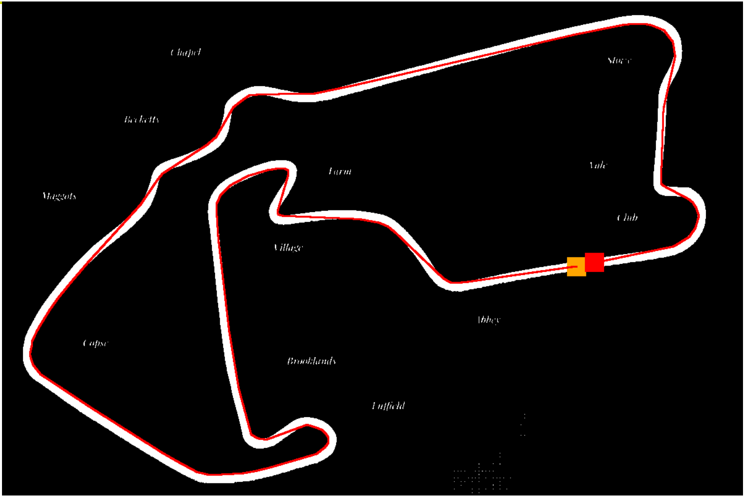


FIGURE – Shortest (but obviously not fastest) trajectory on the Silverstone racetrack

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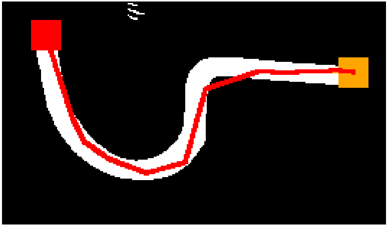
Choice of the *C Cost* function

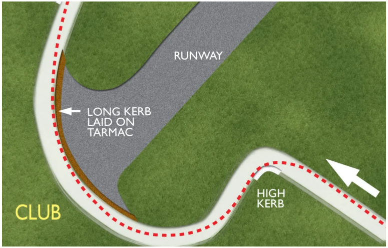
Different choices for $C(x, u)$

1. Path length : $C(x, u) = \int_0^{t_{end}} |v(t)| dt$
2. Total time : $C(x, u) = t_{end}$
3. Energy consumption, tire fatigue, ...

Finding the fastest path



(a) Simulation of the fastest path with 2114 nodes



(b) Reference race line on the Silverstone racetrack

FIGURE – Attempting to find the fastest path on the Silverstone racetrack

Conclusion

Limitations

- Implementation issues
- Optimization (ex : better node sampling)

Results

- Rather satisfactory results
- Many applications (ex : parking manoeuvers)

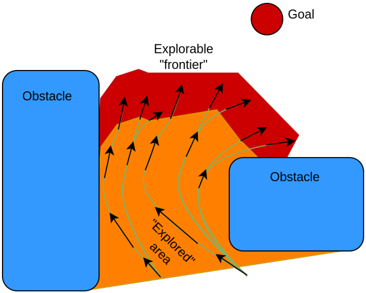


FIGURE – Proposition of a dynamic generation of nodes

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Conclusion

End of the presentation