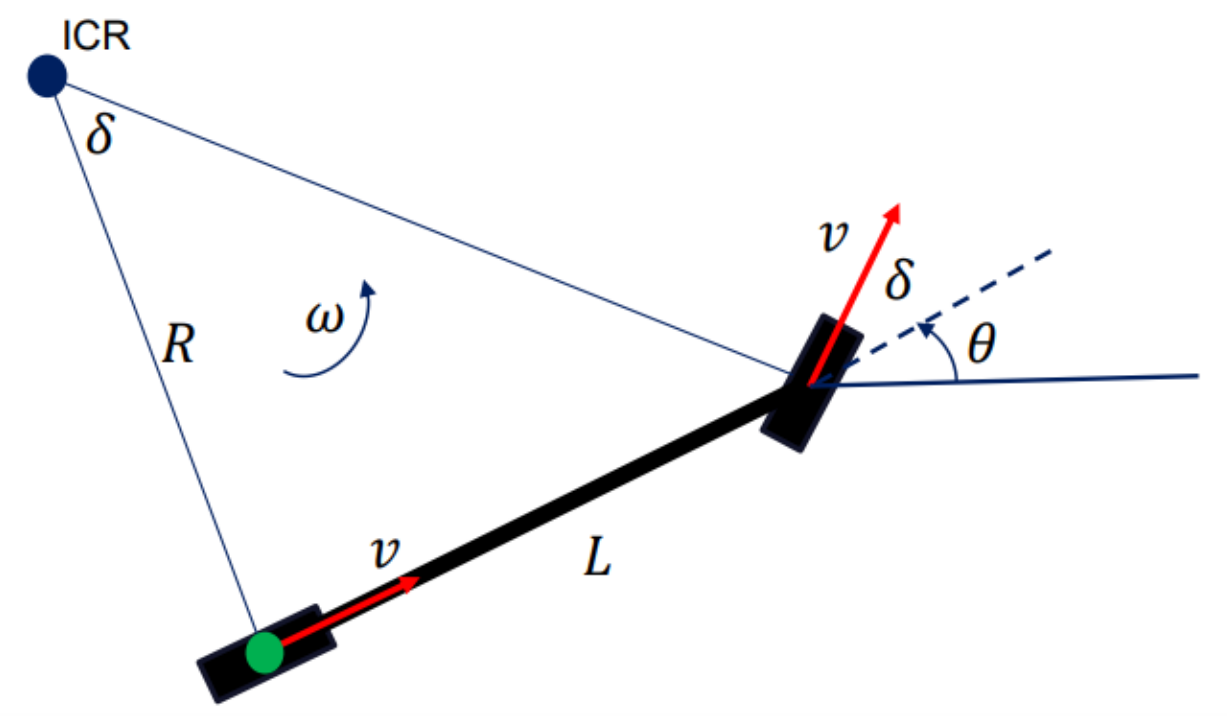
运动学模型关注线速度和角速度 偶尔将其导数作为输入

动力学模型关注力和扭矩作为输入



$$\dot{x} = v\cos(\theta)$$
$$\dot{y} = v\sin(\theta)$$
$$\dot{\theta} = \frac{v\tan(\delta)}{L}$$
$$\delta_{min} \le \delta \le \delta_{max}$$
$$v_{min} \le v \le v_{max}$$

这些方程离散化的结果

↓

可以递归地实现序列中所有更新 → 迭代地为给定的输入序列建立完整的轨迹

Kinematic Model Discretization

- Discretization of differential equations allows for efficient computation of trajectories
- Recursive definition saves computation time

$$x_n = \sum_{i=0}^{n-1} v_i\cos(\theta_i)\Delta t = x_{n-1} + v_{n-1}\cos(\theta_{n-1})\,\Delta t$$

$$y_n = \sum_{i=0}^{n-1} v_i\sin(\theta_i)\Delta t = x_{n-1} + v_{n-1}\sin(\theta_{n-1})\,\Delta t$$

$$\theta_n = \sum_{i=0}^{n-1} \frac{v_i\tan(\delta_i)}{L}\Delta t = \theta_{n-1} + \frac{v_{n-1}\tan(\delta_{n-1})}{L}\Delta t$$

两种碰撞方法

基于条纹的碰撞检查

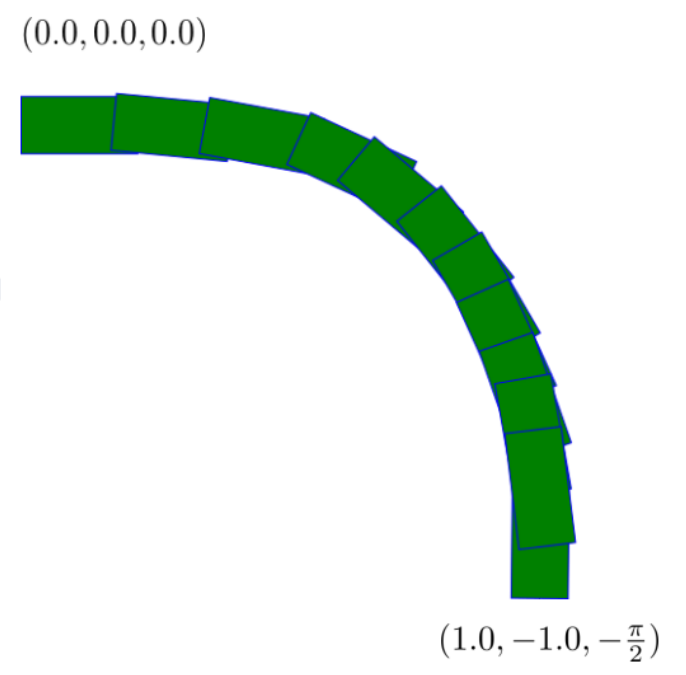
基于圆圈的碰撞检查

碰撞检测 → 具有挑战性的计算密集型的问题

- Area occupied by car along path generated by rotating the car's footprint by each x, y, θ along the path
- Swath along path is the union of each rotated and translated footprint
- Swath can then be checked for collisions

$$S = \cup_{p\in P} F\big(x(p), y(p), \theta(p)\big)$$

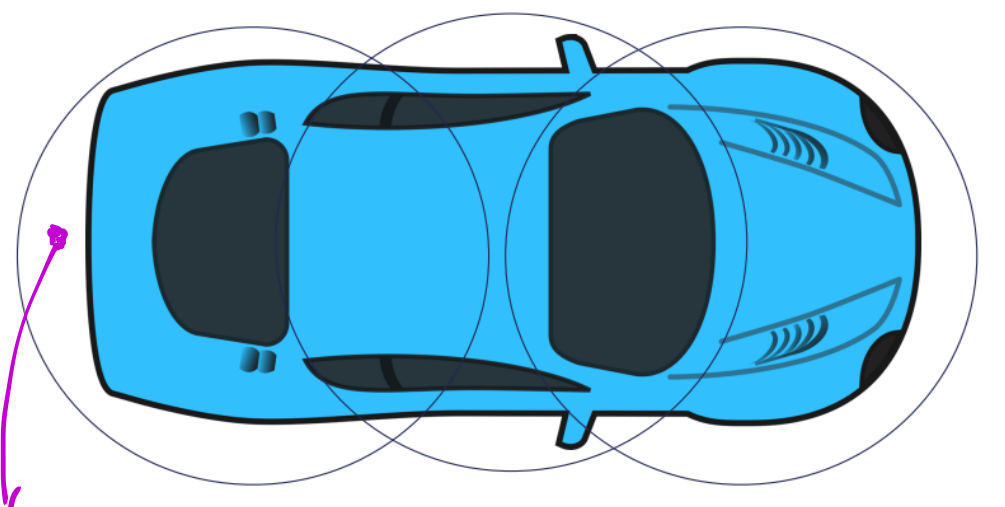
检查集合是否有障碍物



碰撞检测相当于沿着给定路径的每点旋转和平移车辆的足迹

碰撞检测的保守近似

- Conservative approximations may report a collision even if there isn't one, but will never miss a collision if it were to actually happen
- The car can be completely encapsulated by three circles



障碍物（即使不会碰撞 但还是会报告）

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冲突检查器可能会包含一些假阳性冲突 但不会包含假阴性

(Trajectory Rollout Algorithm)

轨迹展开算法

→ 轨迹传播 (Trajectory propagation)

→ 碰撞检查 (Collision checking)

→ 路径选择 (Path selection)

选择符合目标函数的最优

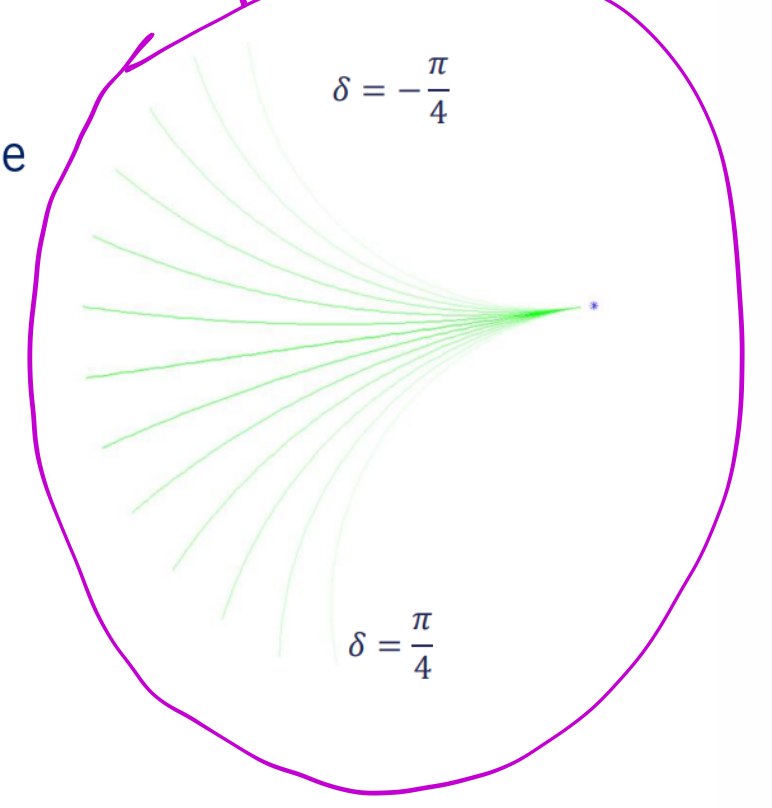
Trajectory Propagation

- Holding the velocity constant and varying the steering angle gives candidate set of trajectories

$$x_n = \sum_{i=0}^{n-1} v_i\cos(\theta_i)\,\Delta t = x_{n-1} + v_{n-1}\cos(\theta_{n-1})\Delta t$$

$$y_n = \sum_{i=0}^{n-1} v_i\sin(\theta_i)\,\Delta t = y_{n-1} + v_{n-1}\sin(\theta_{n-1})\Delta t$$

$$\theta_n = \sum_{i=0}^{n-1} \frac{v_i\tan(\delta_i)}{L}\Delta t = \theta_{n-1} + \frac{v_i\tan(\delta_i)}{L}\Delta t$$



保持速度不变 改变方向角度

→ 得到一组弧线作为候选弧

动态窗口 (Dynamic Windowing) 允许在车辆轨迹上设置约束

通常动态窗口方法允许合并更多方法