A Mobile Robot Path Planning Algorithm Based on Improved A* Algorithm and Dynamic Window Approach

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November 29, 2025

Traditional Dynamic Window Approach (DWA)

System Model

$$\dot{x} = v\cos\theta, \quad \dot{y} = v\sin\theta, \quad \dot{\theta} = \omega$$

Dynamic Window

$$(v,\omega) \in \begin{cases} [v_{\text{cur}} - \dot{v}_{\max}\Delta t,\ v_{\text{cur}} + \dot{v}_{\max}\Delta t] \\ [\omega_{\text{cur}} - \dot{\omega}_{\max}\Delta t,\ \omega_{\text{cur}} + \dot{\omega}_{\max}\Delta t] \end{cases}$$

Trajectory Rollout

$$\mathbf{s}(t+\tau) = f(\mathbf{s}(t),(v,\omega)), \quad \tau \in [0,T]$$

Score Function

$$J = w_h H + w_c C + w_v V$$

- H: heading to goal
- C: clearance to obstacles
- V: forward velocity

Issues: weight tuning, short-horizon myopia, local minima.

RL to Improve DWA

Idea 1: Learn Weights

$$(w_h, w_c, w_v) = \pi_\theta(s_t)$$

Idea 2: Learn Sampling Distribution

$$(v, \omega) \sim \pi_\theta(v, \omega \mid s_t)$$

Idea 3: RL Overrides, DWA as Safety Filter

$$(v, \omega)_{\text{exec}} = \begin{cases} (v, \omega)_{\text{RL}}, & \text{if safe} \\ (v, \omega)_{\text{DWA}}, & \text{otherwise} \end{cases}$$

Benefits

- Avoid manual tuning
- Adapt to dynamic obstacles
- Multi-step reasoning beyond DWA rollout

Replacing DWA with Monte Carlo Tree Search (MCTS)

Action Set

$$\mathcal{A} = \{(v_i, \omega_j)\},\ i = 1..N_v,\ j = 1..N_\omega$$

Tree Expansion: rollout dynamics

$$s_{t+1} = f(s_t, a_t), \qquad a_t \in \mathcal{A}$$

UCT Selection

$$a^* = \arg\max_a \left[Q(s,a) + c\sqrt{\frac{\ln N(s)}{N(s,a)}} \right]$$

Advantages

- Multi-step lookahead instead of single-step rollout
- Naturally handles uncertainty & dynamic obstacles
- Eliminates hand-tuned weights entirely

Output

$$a_0^* = \text{best action at root}$$