An interactive window for multi-agent simulation

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Introduction

Navigation of non-holonomic vehicles is an active area of research, involving finding feasible trajectory, obstacle avoidance, steering, point and posture stabilization ...

... previous methods (J. Xu .., 2000), (H. Tanner .., 2001) provided discontinuous and/or time-varying control laws.

... (B N Sharma & J Vanualailai , 2005) proposed a single Lyapunov function and continuous control laws for navigation, steering and posture stability for a single non-holonomic car-like vehicle.

In this paper, the generalized control laws are refined and implemented using the object oriented programming paradigm and deployed using a multithreaded, multi-process synchronized solution enabling a smoothly running interactive system ...
System Description

- interactive window to illustrate collision avoidance schemes for mobile car-like multi-agents
- multi-agents are required to traverse their paths amongst fixed and moving obstacles in a fully known workspace
- multi-agents to reach their respective destinations with predefined postures
- The problem is addressed for a group of car-like vehicles within a potential field framework
- use the programming concept of multi-threading to enable simultaneous execution
- each autonomous entity will derive its independent self-governing control scheme to find a feasible trajectory

System Snapshot
Concept – Multithreading & OOP

Lyapunov Function \( L(z) \) (Generalized)

Each autonomous entity will derive its independent self-governing control scheme and acceleration

Components/Objects

- **Vehicle Model**

\[ r_y = \sqrt{(2\xi_1 + L)^2 + (2\xi_2 + 1)^2} / 2 \]
Target Attraction

To attract the vehicle to the target, we shall utilize, in the Lyapunov function to be proposed, the function:

\[ V(z) = \frac{1}{2} \left\{ (x - p_1)^2 + (y - p_2)^2 + v^2 + \omega^2 \right\}, \]

**At the target center, \( v \) and \( \omega \) will be zero**

Equilibrium point, \( V = 0; \)

Role of \( V \) in the Lyapunov function is to ensure the system trajectories start and remain close to:

\[ z^* = (p_1, p_2, \theta_f, 0, 0) \]

Obstacle Avoidance

For obstacle avoidance, we use the following functions:

- **Boundary obstacles (4)**

\[
\begin{align*}
W_1(x) &= x - r_v \\
W_2(x) &= r_2 - (y + r_v) \\
W_3(x) &= r_3 - (x + r_v) \\
W_4(x) &= y - r_v
\end{align*}
\]

- **Obstacle in Workspace (1)**

\[
W_5(x) = \frac{1}{2} \left\{ (x - o_1)^2 + (y - o_2)^2 - (r_0 + r_v)^2 \right\}
\]
Obstacle Avoidance

- **Parking Bay Fixed Obstacles (8)**

\[
W_6(x) = \frac{1}{2} \left\{ [x - (p_2 + a/2)]^2 + [y - (p_2 + b/2)]^2 - (r_{o6} + r_v)^2 \right\},
\]

\[
W_7(x) = \frac{1}{2} \left\{ [x - (p_2 + a/2)]^2 + [y - (p_2 + b/2)]^2 - (r_{o7} + r_v)^2 \right\},
\]

\[
W_8(x) = \frac{1}{2} \left\{ (x - p_2)^2 + [y - (p_2 + b/2)]^2 - (r_{o8} + r_v)^2 \right\},
\]

\[
W_9(x) = \frac{1}{2} \left\{ [x - (p_2 + a/4)]^2 + [y - (p_2 + b/2)]^2 - (r_{o9} + r_v)^2 \right\},
\]

\[
W_{10}(x) = \frac{1}{2} \left\{ [x - (p_2 + a/4)]^2 + [y - (p_2 + b/2)]^2 - (r_{o10} + r_v)^2 \right\},
\]

\[
W_{11}(x) = \frac{1}{2} \left\{ [x - (p_2 + a/4)]^2 + [y - (p_2 + b/2)]^2 - (r_{o11} + r_v)^2 \right\},
\]

\[
W_{12}(x) = \frac{1}{2} \left\{ (x - p_2)^2 + [y - (p_2 + b/2)]^2 - (r_{o12} + r_v)^2 \right\},
\]

\[
W_{13}(x) = \frac{1}{2} \left\{ [x - (p_2 + a/4)]^2 + [y - (p_2 + b/2)]^2 - (r_{o13} + r_v)^2 \right\},
\]

where \( a \) and \( b \) are the bays length and width respectively.

\[ a = 2 \left( r_v + r_i \right) \text{ and } b = 2 \left( r_v + r_i \right) \]

Obstacle Avoidance Technique

We employ some constants \( \alpha_i > 0, \ i = 1, \ldots, 13 \)

Considering the ratios :

\[
\frac{\alpha_1}{W_1}, \frac{\alpha_2}{W_2}, \frac{\alpha_3}{W_3}, \ldots, \frac{\alpha_n}{W_n}, \quad n = 13
\]

* Ratios are added appropriately to the Lyapunov function.

Vehicle approaches the boundary, or the obstacles, the ratio will increase and vice-versa. This increased activity directs the vehicle towards equilibrium point.
The tentative Lyapunov function:

\[ L(z) = V(z) + G(z) \left\{ \sum_{j=1}^{13} \frac{\alpha_j}{W_j(z)} + \sum_{j=1}^{2} \frac{\beta_j}{U_j(z)} \right\} \]

where constants \( \alpha_j, \beta_j > 0, j \in N \), are used as control parameters and

\[ G(z) = \frac{1}{2} \left( (x - y_1)^2 + (y - y_2)^2 + (y - y_3)^2 \right) \geq 0. \]
Conclusion

- Applied direct method of Lyapunov
- Algorithm – obtain the desired trajectory within constrained environment
- Generalized algorithm for multiple task including, motion planning, collision avoidance, and parking maneuverability of multiple cars

Future Work

- Modifying the proposed control algorithm for motion planning in dynamic environment, which include multiple moving obstacles.
Dynamic Constraints

- Modulus bounds on the velocity

\[ U_1(z) = \frac{1}{2} \left\{ \left( v_{\text{max}} - v \right) + \left( v_{\text{max}} + v \right) \right\}, \]

\[ U_2(z) = \frac{1}{2} \left\{ \left( \frac{v_{\text{max}}}{\theta_{\text{min}}} - \omega \right) + \left( \frac{v_{\text{max}}}{\theta_{\text{min}}} + \omega \right) \right\}, \]

- Acceleration are of the form

\[ \delta_1 = - \left( \theta + f_1 \cos \theta + f_2 \sin \theta / f_4 \right) \quad \text{ (Translational velocity)} \]

\[ \delta_2 = - \left( \theta \omega + \frac{f_2}{2} \cos \theta + \frac{f_3}{2} - \frac{f_1}{2} \sin \theta \right) / f_5 \quad \text{ (Rotational velocity)} \]