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.

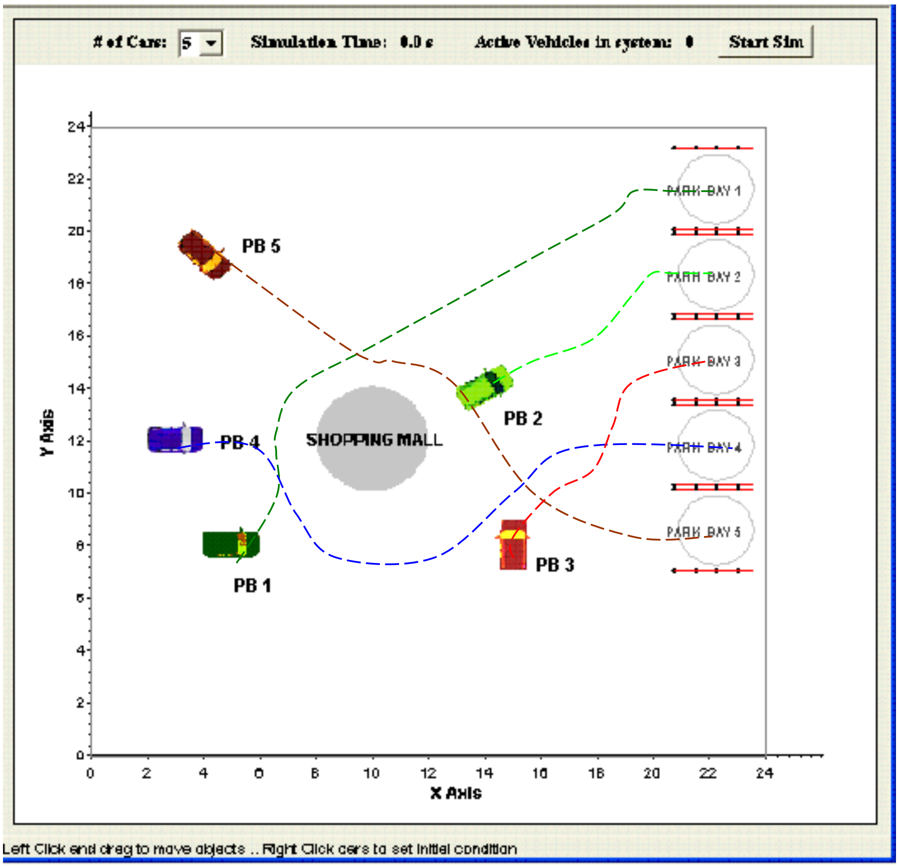
… (B N Sharma & J Vanualailai , 2005) proposed a single Lyapunov function and continuous control laws for navigation, steering and posture stability for a single non-holonomic car-like vehicle.

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 …

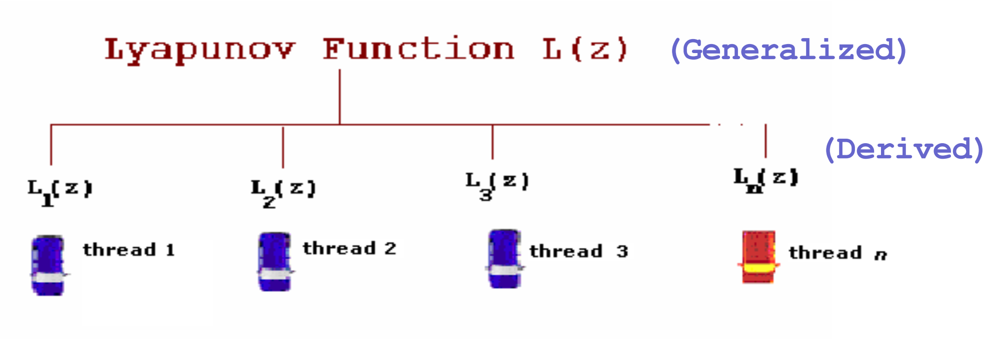
System Description

- 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

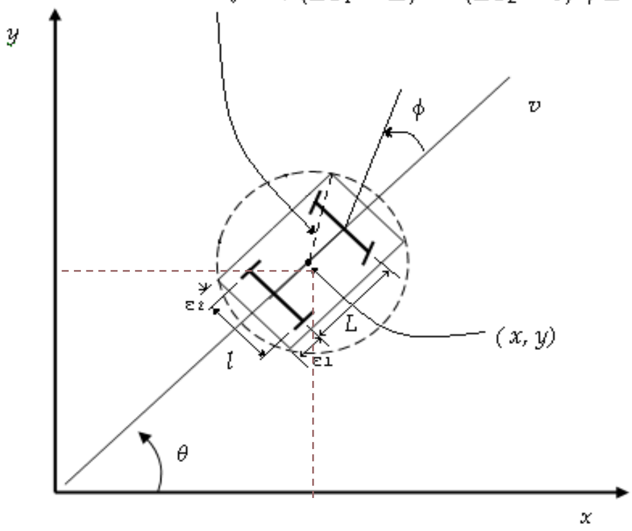


Each autonomous entity will derive its independent self-governing control scheme and acceleration

Components/Objects

- **Vehicle Model**

$$r_v = \sqrt{(2\varepsilon_1 + L)^2 + (2\varepsilon_2 + l)^2} / 2$$



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, υ and ω 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 :

$$\mathbf{z}^* = (p_1, p_2, \theta_f, 0, 0)$$

Obstacle Avoidance

For obstacle avoidance, we use the following functions :

- **Boundary obstacles (4)**

$$W_1(\mathbf{z}) = x - r_v$$
$$W_2(\mathbf{z}) = n_2 - (y + r_v)$$
$$W_3(\mathbf{z}) = n_1 - (x + r_v)$$
$$W_4(\mathbf{z}) = y - r_v$$

- **Obstacle in Workspace (1)**

$$W_5(\mathbf{z}) = \frac{1}{2}\left\{(x - o_1)^2 + (y - o_2)^2 - (ro_5 + r_v)^2\right\}$$

Obstacle Avoidance

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

$$W_6(\mathbf{z}) = \frac{1}{2}\left\{[x - (p_1 - a/2)]^2 + [y - (p_2 + b/2)]^2 - (ro_6 + r_v)^2\right\},$$

$$W_7(\mathbf{z}) = \frac{1}{2}\left\{[x - (p_1 - a/4)]^2 + [y - (p_2 + b/2)]^2 - (ro_7 + r_v)^2\right\},$$

$$W_8(\mathbf{z}) = \frac{1}{2}\left\{(x - p_1)^2 + [y - (p_2 + b/2)]^2 - (ro_8 + r_v)^2\right\},$$

$$W_9(\mathbf{z}) = \frac{1}{2}\left\{[x - (p_1 + a/4)]^2 + [y - (p_2 + b/2)]^2 - (ro_9 + r_v)^2\right\},$$

$$W_{10}(\mathbf{z}) = \frac{1}{2}\left\{[x - (p_1 - a/2)]^2 + [y - (p_2 - b/2)]^2 - (ro_{10} + r_v)^2\right\},$$

$$W_{11}(\mathbf{z}) = \frac{1}{2}\left\{[x - (p_1 - a/4)]^2 + [y - (p_2 - b/2)]^2 - (ro_{11} + r_v)^2\right\},$$

$$W_{12}(\mathbf{z}) = \frac{1}{2}\left\{(x - p_1)^2 + [y - (p_2 - b/2)]^2 - (ro_{12} + r_v)^2\right\},$$

$$W_{13}(\mathbf{z}) = \frac{1}{2}\left\{[x - (p_1 + a/4)]^2 + [y - (p_2 - b/2)]^2 - (ro_{13} + r_v)^2\right\}.$$

where a and b are the bays length and width respectively .

$a = 2\,(r_v + \gamma_1)$ and $b = 2\,(r_v + \gamma_2)$

Obstacle Avoidance Technique

We employ some constants $\alpha_i > 0,\ i = 1, .., 13$

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.

Lyapunov Function

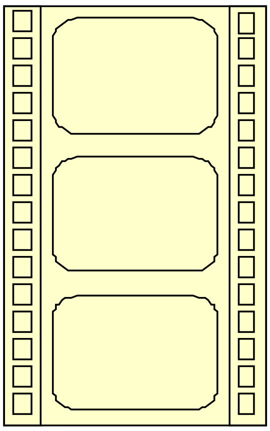
The tentative Lyapunov function :

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

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

$$G(\mathbf{z}) = \frac{1}{2} \left\{ (x - p_1)^2 + (y - p_2)^2 + (\theta - \theta_f)^2 \right\} \geq 0.$$

Simulation



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

$$U_1(\mathbf{z}) = \frac{1}{2}\left\{(v_{max} - v) + (v_{max} + v)\right\},$$

$$U_2(\mathbf{z}) = \frac{1}{2}\left\{\left(\frac{v_{max}}{|\rho_{min}|} - \omega\right) + \left(\frac{v_{max}}{|\rho_{min}|} + \omega\right)\right\},$$

- Acceleration are of the form

$$\dot{\delta}_1 = -(\delta_1 + f_1 \cos\theta + f_2 \sin\theta)/f_4 \quad , \quad (Translational\ velocity)$$

$$\dot{\delta}_2 = -\left(\delta_2\omega + \frac{L}{2} f_2 \cos\theta + f_3 - \frac{L}{2} f_1 \sin\theta\right)/f_5 \quad , \quad (Rotational\ velocity)$$