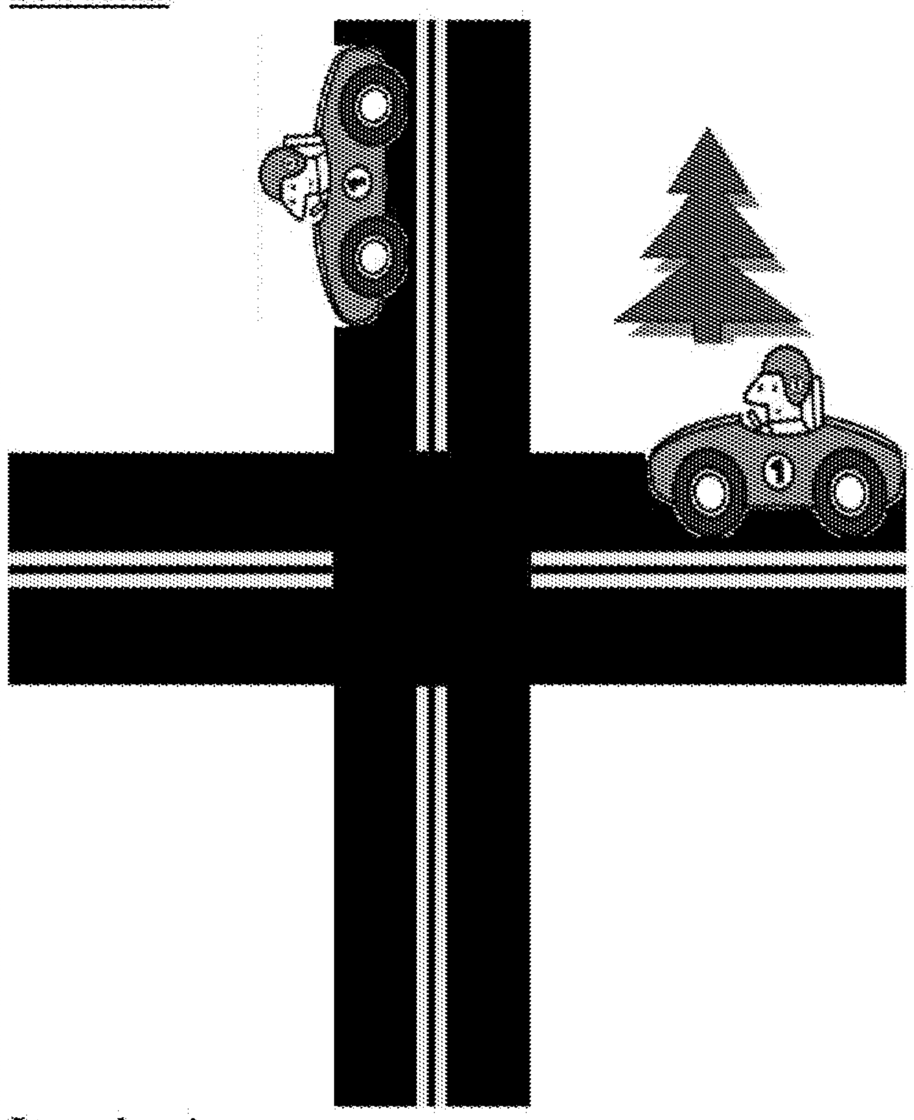
Cooperative decentralized intersection collision avoidance using Extended Kalman Filtering

A. Farahmand and L. Mili

Virginia Tech-NVC, USA

We propose an adaptive, decentralized, cooperative collision avoidance (CCA) system that optimizes each vehicle's controls subject to the constraint that no collisions occur. The system contributes a nonlinear 5-state variable vehicle model, a set of constrained, coupled EKFs, and a vehicular network based on the new WAVE standard. The system is compared to today's common control devices.

Problem



Introduction

•Stop signs and traffic signals are:

•Unsafe – fail during disasters, power outages

•Inefficient – cause excessive delays, waste fuel

•Costly – installation, maintenance, electricity

•Researchers have primarily focused on radar, optical [2], [3], or cooperative systems [4], [5] but these have limitations

Solution

•A cooperative, decentralized intersection collision avoidance system comprising:

•nonlinear 5-state variable vehicle model

•set of coupled, constrained EKFs

•wireless network for vehicular control

Vehicle Model

•We expand the model developed in [1]

•Mass of air in the intake manifold m_a

•Engine angular velocity ω_e

•Brake torque T_b

•Throttle angle α

•Brake angle β

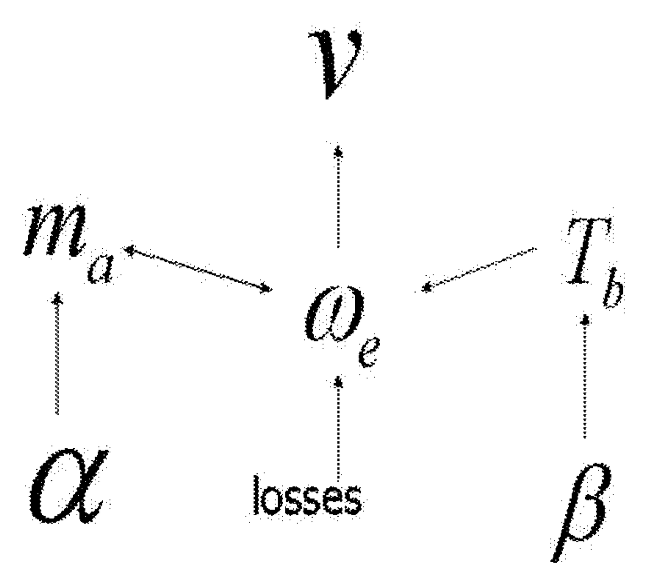
Coupled, Constrained EKFs

•State equation

$$\underline{\dot{x}}(t) = \underline{f}(\underline{x}(t), \underline{u}(t), t) + \underline{w}(t)$$

•Observation equation

$$\underline{z}(t) = \underline{h}(\underline{x}(t), \underline{u}(t), t) + \underline{e}(t) \quad t = t_i \quad i = 1,2\ldots$$



Interdependencies of vehicular dynamics

Vehicular Network

•uses WAVE\DSRC (IEEE 1609 and 802.11p)

•Low latency (50 ms), low interference

•High range (1 km) and high rate (6-27 Mbps)

How Does System Work?

•Observe vehicle states using GPS and sensors

•Share control information among vehicles

•Estimate states using coupled, constrained EKFs

•Optimize vehicular controls

•Automate controls according to optimization

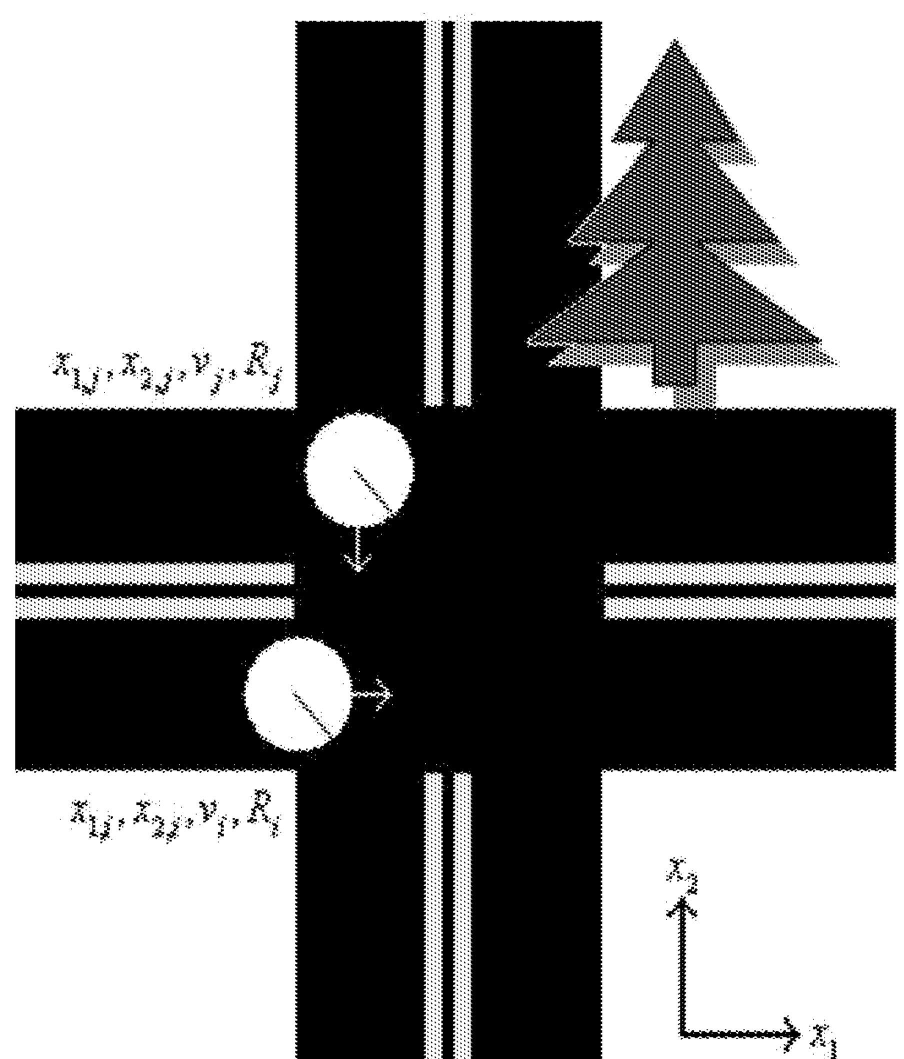
Sparse Traffic Optimization Algorithm

•Objective function:

$$\arg\min \tau = \frac{1}{n}\sum_{k=1}^{n}(t_{o,k} - t_{a,k})$$

•Constraints:

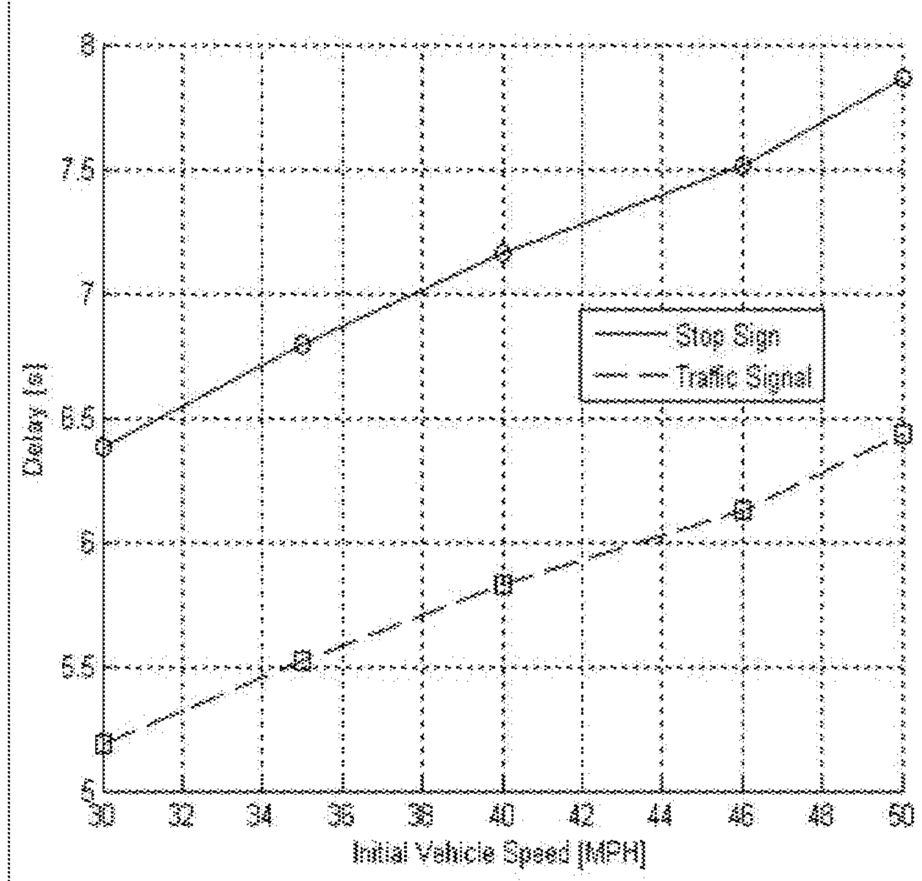
$$(x_{1,j} - x_{1,i})^2 + (x_{2,j} - x_{2,i})^2 > (R_i + R_j + m_s)^2$$



Simulation Results

•We determine the average additional delay caused by stop signs and traffic signals under sparse traffic conditions in comparison to the Sparse Traffic Optimization Algorithm at various velocities

Velocity	Delay for Stop Sign	Delay for Traffic Signal
30 MPH	6.38 s	5.19 s
35 MPH	6.79 s	5.52 s
40 MPH	7.16 s	5.83 s
46 MPH	7.51 s	6.13 s
50 MPH	7.86 s	6.43 s



Conclusions

•The system is superior at minimizing average delay in comparison to current collision avoidance technologies

•The system is more safe, efficient, and inexpensive than current devices

References

[1] J.K. Hedrick, D.H. McMahon, and D. Swaroop, "Vehicle modeling and control for automated highway systems". California PATH Program, UC Berkeley, November 1993.

[2] P.N. Pathirana, A.E.K. Lim, A.V. Savkin, and P.D. Hodgson, "Robust video/ultrasonic fusion-based estimation for automotive applications". *IEEE Transactions on Vehicular Technology*, Vol. 56, No. 4, pp. 1631-1639, July 2007.

[3] S. Quinlan and O. Khatib, "Elastic bands: connecting path planning and control". *Proceedings of IEEE International Conference on Robotics and Automation*, Vol. 2, pp. 802-807, May 1993.

[4] L. Li and F.Y. Wang, "Cooperative driving at blind crossings using intervehicle communication". *IEEE Transactions on Vehicular Technology*, Vol. 55, No. 6, pp. 1712-1724, November 2006.

[5] K. Sung, J. Yoo, and D. Kim, "Collision warning system on a curved road using wireless sensor networks". *IEEE Vehicular Technology Conference*, pp. 1942-1946, September 2007.