Math Matters

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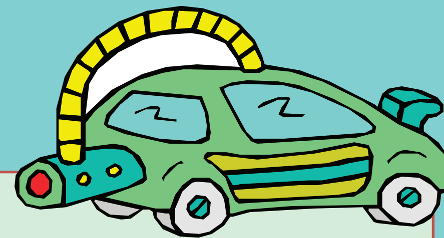


The math behind... Autonomous Vehicles

Technical terms used:
Localization, probability, Kalman filter, particle filter, path planning, control system

Uses and applications:
Robotics, manufacturing, signal fusion, motion planning

How it works:
Design of an autonomous vehicle aims at replacing humans in the driving loop. The autonomous vehicle should be able to understand the environment, estimate its location, and make driving decisions based on the known factors. Such a mobile robot observes its world through sensors such as GPS, SONAR, LIDAR, and Camera [1]. It incorporates each sensor data for localizing itself considering possibilities of errors in various sensors using probability-based tools. The robot thus creates a model of its surroundings by employing sensor data fusion. Kalman filtering is usually employed for including various sensor signals while considering the confidence in each signal. This method works best for linear motion and can be used to predict states of the vehicle, such as position and velocity. Another technique for sensor integration is the particle filtering approach. This method tests possible scenarios and chooses the best probable cluster representing vehicle states.

Once the current state of the autonomous vehicle has been estimated, the next challenges are motion planning and controls to ensure correct movement. Motion planning is conducted to calculate the path of a vehicle traversing from an estimated position to a desired location [2]. The most common algorithms are based on graph theory and dynamic programming. Control algorithms are designed for ensuring motion from start to end point with energy efficiency and robustness. Cruise control is one such algorithm that has been developed for maintaining constant speed [3]. Such algorithms can be employed to feed inputs such as throttle, transmission, and steering to ensure that the planned motion is followed effectively and precisely. This completes the entire driving loop by eliminating the need for a driver, thus giving us autonomous cars.

Interesting facts:
Tesla's autonomous cars are among the most popular in the current market [4]. The cars depend on a mix of global maps of surroundings and reactive responses to identified nearby objects. A global map is incorporated to augment long-term motion planning in the system. However, the storage capacity of its cars has been the main reason behind its dominance of the electric vehicle market. Competitions such as the DARPA Urban Challenge have propelled development of similar systems.

References:

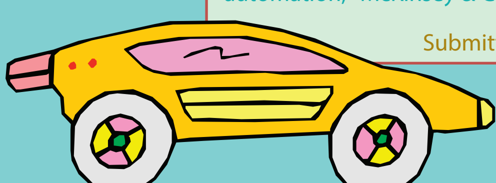
[1] M.W.M.G. Dissanayake, P. Newman, S. Clark, H.F. Durrant-Whyte, M. Csorba, A solution to the simultaneous localization and map building (SLAM) problem. IEEE Transactions on Robotics and Automation, 17, no.3, pp.229-241, Jun 2001

[2] A.P. Aguiar, J.P. Hespanha, Trajectory-Tracking and Path-Following of Underactuated Autonomous Vehicles with Parametric Modeling Uncertainty. IEEE Transactions on Automatic Control, 52, no.8, pp.1362-1379, Aug. 2007

[3] P.A. Ioannou, C.C. Chien, Autonomous intelligent cruise control. IEEE Transactions on Vehicular Technology, 42, no.4, pp.657-672, Nov 1993

[4] "Competing for the connected customer – perspectives on the opportunities created by car connectivity and automation," McKinsey & Company, Advanced Industries September 2015

Submitted by Parth Paritosh, Purdue University, USA, Math Matters, Apply it! Contest, February 2016



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