SAE Paper Outline

Abstract:

“Vehicle autonomy is critically dependent on an accurate identification and mathematical representation of road and lane geometries. Many road lane identification systems are ad hoc (e.g., machine vision and lane keeping systems) or rely on polynomial approximations of road data and GPS positioning. A novel system is proposed in which geodetic road data is parsed along road directions and digitally stored in a road data matrix. Using mapping algorithms, the road data is converted to a smooth, differentiable path which connects critical road coordinates with curvature vectors and changes to road tangent angles. Different road data sources such as GPS or geographical scans were evaluated with this method and compared to current road design standards as per the American Association of State Highway and Transportation Officials. This approach takes advantage of standard roadway design practices, which rely on speed limit, superelevation, and empirical data for maximum lateral acceleration tolerance to determine acceptable radii of curvature for different classes of roadways. Successful implementation of this technology could accelerate autonomous vehicle’s navigation research and development for new guidance paradigms in addition to traditional machine vision-based systems.”

Introduction:

* Fundamentals of AI vehicles
  + Vision
  + Objectives
  + Techniques
    - Sensors used
    - Data collected (needed)
* Creation of Target Paths
  + Vehicle Equations of Motion
    - Normal/tangential coordinates
    - Longitudinal & lateral accelerations (turning)
    - Ackerman steering & relationships
    - Tire-pavement friction limits
    - Yaw stability & rotational inertia
    - Effect of road crowning & superelevation
  + Path construction
    - Criteria for constructing (mathematically forming) path
    - Types of boundary conditions (holonomic vs non-holonomic, soft vs. hard, etc)
    - Characteristics of closed-form solutions to path generation problems0
  + Literature review of other techniques – how are paths currently generated/estimated
    - Polynomial
    - Clothoid
    - Euler-Lagrange
* Concept: Curvature-Based Path Generation
  + Objective
    - Mathematically prescribe target path using unique combination of non-holonomic constraints: position (X,Y,Z) at end points; tangent angle (theta); and curvature
  + Parametric equation representation (separable x(t), y(t))

Formulation

* Your setup is fine. No changes needed.

Implementation (revise to Application to Roadway Path Generation)

* PATH SMOOTHING/FILTERING (add this section!!!)
  + Take noisy data points and smooth them
  + Average over number of segments? Discuss “oversampling” due to errors?
  + Segment lengths? Do you have a suggestion for what it should be – or can you refer that to future work?
* Theoretical Design by AASHTO Green Book standards
  + Explain road layout, limits, background
  + See \\mwrsf-poweredge\Department of State\TO-0054 2015-2016 Friction-Vehicle Perf Limits Phase I\Report 1 - Coefficient testing\ TRP-03-341-16 -- Coefficients for Calculator.pdf for extensive background on friction testing, AASHTO guidelines, lit review, etc – good usable material there which could augment your writeup if necessary
* Aerial or Satellite Photography
  + “Maps” technique: manually select points on roadway with high precision
  + May be augmented / accelerated using machine learning, photo recognition techniques
  + WARNINGS: high tree density (forested locations) or obscured; data may be old and new road construction or environmental effects (flood washout, earthquake) may alter path
* Survey, LIDAR, or Photogrammetry Point Clouds (UAV)
  + Highest priority: identify every lane edge from among data. Have to accurately identify preferred travel corridors from background or adjacent noise.
  + Can be affected by other vehicles or obstructions in area and may have variable precision (sometimes very good, sometimes poor)
* GPS travel log
  + Lowest overall accuracy but if collected from many, many vehicles can be very precisely determined
  + Bulk collection is essentially mandatory
  + May require a minimum number of trips to be considered “accurate enough”
  + THIS IS NOT AN ACCEPTABLE METHOD FOR RURAL, LOW-TRAFFIC ROADS
    - Unmarked/unpaved roads vehicles will *generally* travel in the center of the road – doesn’t tell you where road edges are.
    - Deviations will be related to what vehicles are there: if you are passing a stopped motorist, you may pass by very closely. If motorist from opposite direction, you may pass by further away and even slow down. If farm/ag equipment, you are going to give them a WIDE berth because combines & tractors (et al) are very wide vehicles.

Discussion and Future Work

* The way this paper was written, it is all about ground vehicles – which is perfectly fine. This is when you can denote that it is a simple extrapolation to include a Z-axis component and apply the same conditions for flight paths, such as for UAVs, air taxis (future), etc.
* More future work: implement this into a system which relays road geometrical details to vehicles wirelessly. Note that other automotive companies are then free to use the same technique described here to do the same thing if they choose – or Google too. (Google is pretty closed-house, so not sure they would even try no matter how good this technique is. Uber on other hand has shown a willingness to implement a new technology in whole. See Google’s recent successful lawsuit from a former tech who went to Uber and developed a car using primarily Google tech.)
* Data population technique: this approach is critically dependent on good information, transmitted to vehicles consistently. Has scalability to be used in “real-time” changes such as lane closures due to work zones or crashes, EMS response, etc. May require a dedicated entity (business?) to monitor and maintain road data and update in real time. This process is set up to enlist assistance from state DOTs at least initially, but could be long-term partnership too. Still, may not actually require long-term commitment from state DOTs and could be independently monitored by business/non-profit/gov entity in real time.