Adaptive Fuzzy Control for Inter-Vehicle Gap Keeping

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What is Adaptive Cruise Control?

- Adaptation of the speed of the car to a predefined one
- Keeping a safe gap between the controlled car and the preceding vehicle on the road
Outline

- Intelligent Transportation Systems
- Fuzzy Controls
  - A. Application of a Fuzzy Coprocessor to the Automatic Vehicle Driving
  - B. Longitudinal Control
    - Fuzzy Cruise Control System
    - Adaptive Fuzzy Cruise Control System
- Conclusion
Intelligent Transportation System

- Application of robotic techniques to achieve safe and efficient driving
- Used of sensors (give information to the driver, connected to computer that performs some guiding actions, attempting to minimize injuries and to prevent collisions)
- Providing assistance to the control of some of the vehicle elements, like the throttle pedal and the speed-control assistance
How to achieve ACC?

- **Conventional Method**
  - Based on analytical control, gives good results but with high design and computational costs since the object, car is nonlinear element.

- **Artificial Intelligence Techniques**
  - Fuzzy Control, which allows an approximate human reasoning and an intuitive control structure.
Stop&Go

- Stop&Go systems
  - Being developed in order to automate problems such as stop and go, which happens during the busy hours of traffic jams.
  - The combination of ACC and Stop&Go increases driving comfort, smooths traffic speed and allows queues to discharge faster from bottlenecks.
A. Application of a Fuzzy Coprocessor to the Automatic Vehicle Driving

1. Represent the human approximate reasoning.

2. Determine the fuzzy values, according to the main car parameters.

3. Two mass-produced cars were instrumented in order to permit automatic fuzzy control on the steering and the accelerator-brake set.
ORBEX

- Experimental fuzzy coprocessor which allows writing fuzzy rules as sentences in almost natural language.
- The rules are IF... THEN fuzzy sentences where the original input granules, or others derived from them, are fuzzy AND/OR combined in the IF part of the rule to produce a fuzzy output.

- Ex. IF crossing VERY near OR lane occupied THEN braking strong
Controls Architecture

- Human Driving – three controls (mechanical layer, an actuation layer, knowledge reasoning layer)

- Automated Driving – three layers (mechanical layer, electronic layer, control layer) control layer is made up of fuzzy control and a knowledge base.
Fuzzy Controller

A) The Fuzzy Cruise Control System:

\[ Speed \_Error = \text{Current \_Speed} - \text{Pre-set \_Speed} \]

\[ \text{Acceleration}_t = \frac{\text{Current \_Speed}_t - \text{Current \_Speed}_{t-1}}{\Delta t} \]
Speed Error Membership Functions

Speed Error membership function after applying MORE THAN and LESS THAN modifiers

FUZZY RULES:
- IF Speed_Error MORE THAN null THEN Accelerator up
- IF Acceleration LESS THAN null THEN Acceleration down
B. Adaptive Cruise Control System

ACC Controller Schematic

VPursued
XPursued
XPursuer
Target Time-Gap
Target Speed

Speed Error
Time-Gap
δTime-Gap
Acceleration Estimation

Fuzzy Controller

Accelerator pedal Pressure signal

Automobile

Real Speed
Membership Functions

Time-Gap_Error membership function

Derivative of Time-Gap membership function
Modified Acceleration Rules

- IF Speed_Error LESS THAN null AND Time_Gap_Error MORE THAN near THEN Accelerator down
- IF Acceleration LESS THAN null AND Time_Gap_Error far THEN Accelerator down
- IF Time_Gap_Error near AND d_Time_Gap negative THEN Accelerator up
Conclusion

- The combination of ACC and Stop&Go is a good solution in order to achieve a safer driving, from high workload roads to traffic jams.
- The used of Fuzzy Logic is vital in designing a system controller used in both CC and ACC.
- The full automatic driving is not yet developed but this application serves as the building block and a starting point for future uses.