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Automated Vehicle Algorithm for Pedestrian Collision Avoidance Function

Customer: Mr. Chris Capaldi, Project Manager, Dataspeed

Overview of Need:
Autonomous or Highly Automated driving is an area of intense interest by the public and the auto industry. It is obvious that a self-driving car must be able to stay in it's lane, brake at intersections, & remain under control during maneuvers, in other words exhibit basic driving skills. But another fundamental aspect of the driving function is **avoiding collisions** (in this case with pedestrians) **in emergency situations**. Human drivers do this by:

1) Recognizing & responding to potential hazardous situations (identifying a risk and adjusting driving situation to reduce it)
2) Recognizing & responding to immediate hazards (identifying an imminent collision and executing strong avoidance maneuver)

Performance Targets:

Background for Performance Target 1: For human drivers, a measure of collision avoidance performance can be seen by comparing one's collision rate (assessed after many miles/years of driving) with the population's "normal" collision rate (gathered by groups such as the IIHS and NHTSA).

Performance Target 1: Safety Effectiveness
There shall be zero vehicle/pedestrian collisions for each of the scenarios defined in this specification.

Background for performance target 2: As with many decisions within a system, a trade-off consideration is often present when deciding course of action for dealing with hazards. It can be argued that human drivers continuously deal with this as between productivity (getting the trip done) and safety (taking precautions to avoid hazards). Consider an extreme example: Safety could be greatly increased if we all decided to drive only at very slow speeds (say 10 mph), but in this case it's easy to see that there is another target in play (efficiency, productivity, etc.) in addition to our need for safety (the posted speed limits we use can be looked at as a resulting trade-off choice). This leads to the second performance target, "Efficiency". Cybersecurity is another important factor with regards to effectiveness. Consider a multilayer approach to ensure effectiveness is not impacted by a breach in security.

Performance Target 2: Efficiency (minimization of lost time)
For this project, the efficiency performance target is to minimize any lost time experienced by the vehicle (and it's occupant(s) due to safety maneuvers.

System Definition for "Automated Pedestrian Collision Avoidance" (APCA)

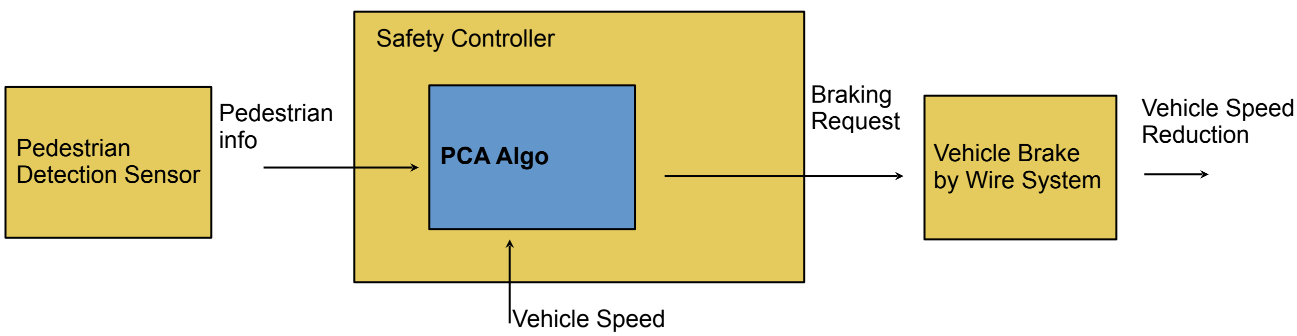
General:

APCA is fitted to an autonomous vehicle for the purpose of avoiding pedestrians automatically (without human driver intervention).

System Functional Behavior:

Monitor path in front of vehicle while driving, looking for pedestrians and identifying potential collisions with them. Determine potential collisions by analyzing collision path between vehicle and pedestrian. Take action to avoid pedestrians by executing velocity reduction commands (automatic braking) which override the current steady state velocity of the vehicle. The braking command will activate the brake by wire system in the vehicle to reduce velocity as requested by the system. When the command is ended (hazard no longer exists), vehicle velocity will automatically return to steady state velocity. Identify and mitigate opportunities in which a security breach of the system endangers a pedestrian.

System Architecture:



Sub-systems and Interfaces:

Pedestrian Sensor:

The pedestrian sensor is a stereo camera with following properties:

Output:

- -Pedestrian recognition and tracking
- -Pedestrian location (x,y)relative to car with accuracy +/- .5 m
- -Pedestrian velocity (speed & direction). Speed +/- .2 m/s. Direction +/- 5 deg
- -Cycle time: Above signals are sent as a packet every 100 ms

Brake-by-Wire Actuator

The BBW sub-system responds to deceleration requests by interrupting the steady state velocity control (cruise control) and then applying brake torque via elctro-mechanical actuators at all four wheels of the vehicle, and sensing the actual vehicle decel for closed loop control. The BBW system can respond to these brake requests about as fast as a human driver is capable, exhibiting the following properties:

-Deceleration accuracy: +/- 2%
-Response time to reach requested decel: 200 ms
-Release time: 100 ms
-Maximum deceleration: 0.7 g (1g = 9.81 m/s^2)

Vehicle:

The autonomous vehicle for this application will have the following properties:

-Normal steady state speed: 50 kph (13.9 m/s)
-Acceleration to steady state speed (after auto brake apply): .25 g
-Vehicle Width (collision zone): 2 m

Pedestrian:

The pedestrian for this application will be modeled/characterized as follows:

-Can be static or in motion (speed = 0 or 6 kph)
-Can change velocity with infinite acceleration (assumption)
-The size of the pedestrian in the x-y plane shall be considered a circle with .5 m diameter
-When moving, only moves at right angle to vehicle path
-Pedestrian behavior for system development & test is defined in the below "scenarios"

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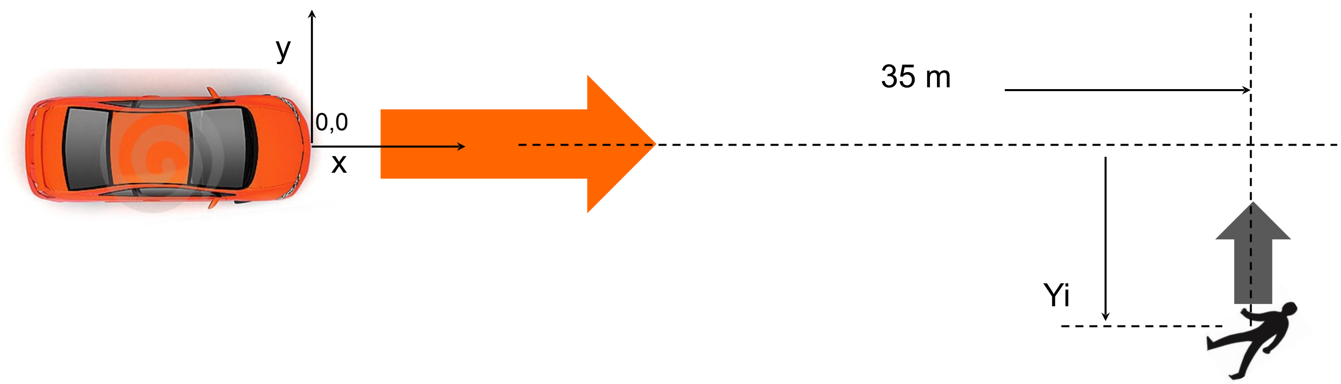
Scenarios

Vehicle:
Speed: Always initially at steady state velocity, controllable with brake-by-wire system
Heading: Always straight along +x axis
Initial Position: Always at x,y = 0,0

Pedestrian:
Speed: static or constant (per spec)
Heading: Always parallel to y axis
Initial Position: x= 35 m, y= -7m



Reference: potential collision at 2.5 sec

Pedestrian Motion Scenarios:

Moving then stopped				
Scen #	Initial Position, Yi	End Position, Yf	Initial Speed	Final Speed
	(m)	(m)	(kph)	(kph)
1	-7	0	10	0
2	-7	-2	10	0
3	-7	-3	10	0
4	-7	-5	10	0

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Static then moving				
Scen #	Initial Position, Yi	Delay before moving	Initial Speed	Final Speed
	(m)	(s)	(kph)	(kph)
5	0	1.5	0	10
6	-2	1.8	0	10
7	-4	1.1	0	10

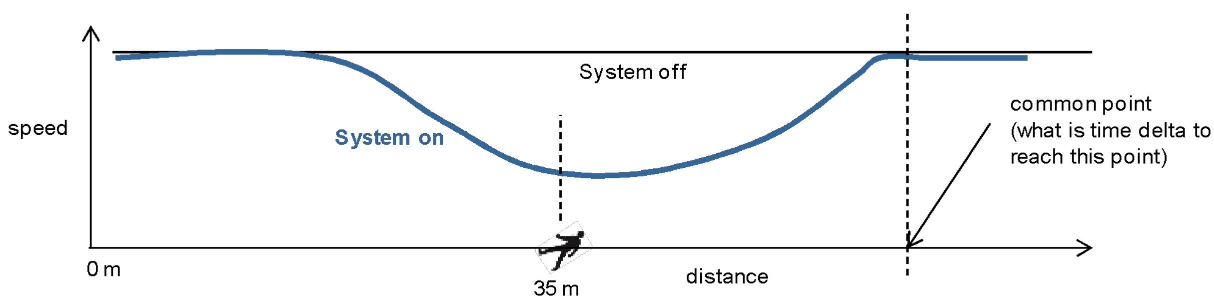
Static				
	(m)		(kph)	(kph)
8	0	NA	0	0
9	-2	NA	0	0
10	-4	NA	0	0

System (Algorithm) Performance Requirements:

1) Effectiveness: Zero collisions allowed under all 10 scenarios

2) Efficiency: "Lost time" shall be minimized for all non-collision scenarios
(lost time should be reported during simulations)

Definition of "lost time":
Time difference (in seconds) between system on and system off to reach a common point beyond the pedestrian with controlled vehicle back again at steady state velocity.



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Fail Safe Requirements:

1) A fail operational mode for the brake system increases the "response time to reach requested decel" from 200 ms to 900 ms. In this mode, the algorithm should adjust to maintain zero collisions in trade for increased lost time

This mode should be simulated and verified.

Notes:

1) One algorithm (system) must be used for measuring performance against all 10 scenarios

2) The system algorithm should be constructed assuming it does not know which scenario is occurring. The only pedestrian information available comes from the sensor.

3) Consider how to determine if system is optimized. Are you competing with other systems?