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PRACTICAL WORK 1: AUTONOMOUS VEHICLE CONTROL WITH CLIPS

In 2013, the US Department of Transportation's National Highway Traffic Safety Administration (NHTSA) defined five different levels of autonomous driving. In October 2016, the NHTSA updated their policy to reflect that they have officially adopted the levels of autonomy outlined in the "SAE International's J3016 document" (http://standards.sae.org/j3016_201609/). These 0-5 levels correspond to:

Level 0 – Driver Full Control: The driver (human) controls it all, such as steering, brakes, throttle, power.

Level 1 – Function-specific Automation: Automation of specific control functions, such as cruise control, lane guidance and automated parallel parking. Drivers are fully engaged and responsible for overall vehicle control.

Level 2 - Combined Function Automation: Automation of multiple and integrated control functions, such as adaptive cruise control with lane centering. Drivers are responsible for monitoring the roadway and are expected to be available for control at all times, but under certain conditions can disengage from vehicle operation (e.g., hands off the steering wheel and foot off pedal simultaneously).

Level 3 - Limited Self-Driving Automation: Drivers can cede all safety-critical functions under certain conditions and rely on the vehicle to monitor for changes in those conditions that will require transition back to driver control. Drivers are not expected to constantly monitor the roadway.

Level 4 - Full Self-Driving Automation in some Environments: Vehicles can perform all driving functions and monitor roadway conditions for an entire trip under predefined environments specified in the operational design domain (ODD).

Level 5 - Full Self-Driving Automation: Vehicles can perform all driving functions and monitor roadway conditions for an entire trip, and so may operate with occupants who cannot drive and without human occupants.

In this practical work we will develop the knowledge required for the autonomous speed control of vehicles. Knowledge will be progressively modified to reach level 5 (in a simplified manner). Knowledge should be expressed as CLISP rules. Notice than, in order to implement superior levels of autonomy, previous level rules might require redefinition.

Separate knowledge bases are expected for each level. Knowledge levels 0 and 1 carry 1 point each of the final mark, the rest of levels, 2 points each. Knowledge levels must be provided in order (if one level is not implemented, the following levels will not be evaluated).

The expected documentation includes one CLISP file for each one of the levels implemented. File names should be Level1.clp, Level2.clp, Level3.clp, Level4.clp, and Level5.clp.

Knowledge Level-0: The driver can press (throttle X) and (brakes X) being X intensity low, medium, or high. The car can be on/off (car on)/(car off) and its speed (speed X) known in Km/h. As the system receives throttle/brakes/on/off signals, the electronic control system controls the speed by means of (increment) and (decrement) signals, each one producing a 5 Km/h increment/decrement of the current speed. Signals on/off are only attended if speed is 0 km/h. For low/medium/high throttle/brakes intensities, speed is expected to increase/decrease 5/10/15 Km/h (approximately) the current speed by means of (increment) or (decrement) signals. Speed must always be between 0 and 200 Km/h.

Knowledge Level-1: The driver can activate/deactivate a cruise control system with (control on)/(control off). Cruise control cannot get activated if the care speed is below 50 Km/h, and it deactivates automatically if these low speeds are reached. With the cruise control activated, the driver can press (fix-speed) button, which means that the current speed is fixed to be the cruise speed (cruise-speed X). If the driver pushes throttle/brakes or the (pause) button, the cruise control is paused and the system starts behaving at level-0 control. From a paused situation, the driver can recover cruise control by pushing the button (recover), then the cruise control will start working to increase/decrease the current speed to reach the cruise speed by means of instructions (increment)/(decrement). Notice that if the speed goes below 50 Km/h in paused mode, the cruise control should be automatically deactivated. While the cruise control is activated, the user can increase/decrease speed by 5 Km/h after pushing (increase)/(decrease) buttons.

Knowledge Level-2: Two additional issues affect the automatic speed control system: speed limit signals and obstacles in the road. For this purpose, the car has a front camera, radar, and ultrasonic sensor. The camera has a maximum distance detection of 80m, and it's able to identify speed limit signals (speed-limit X) with X=10, 20, 30, 40, …, 110, 120, 130 Km/h. The car is expected to always respect the road signals, for this reason as new speed-limits are detected, if the car speed is larger than the speed limit, the cruise control has to be paused (if speed $\geq$ 50 Km/h) or deactivated (if speed < 50 Km/h) and the control is given back to the driver after printing out a (beep) message.

Radar, camera, and ultrasonic devices also detect obstacles (i.e., other vehicles, people, rocks, etc.) that may show up in front of the car. Radar/camera/ultrasound devices detect objects that are closer than 160/80/8 meters, respectively: (obstacle X), with X the distance of the car to the obstacle, in meters. Notice that these devices can produced several simultaneous (obstacle X) messages with different X's. If several (obstacle X) messages exist, the system discards those with a larger X, and it reacts only the one with the lower X. If driving is under the cruise control, and an (obstacle X) with minimal distance X is detected closer than 100 m (i.e., X<100.0), then the cruise control is paused (if speed $\geq$ 50 Km/h) or deactivated (if speed < 50 Km/h) and the control is given to the driver, who is informed with a print out of the message (beep).

Knowledge Level-3: Under the cruise control, if a (speed-limit X) signal is detected with X lower than the current speed, the cruise control gets paused and it orders (decrement)s till the car speed is equal or lower than the speed limit. While paused because of this automatic speed reduction, new speed limit signals may be detected (speed-limit X) and the speed automatically regulated with (decrement)/(increment) instructions. If the speed limit goes below 50 Km/h, the cruise control is deactivated and the control is left to the driver, after printing out a (beep) message. If paused, and the speed limit in a new signal goes above the cruise speed, then the cruise control is automatically recovered, and it takes control to reach the corresponding cruise speed by means of speed (increment)s.

Under the cruise control, if an (obstacle X) is detected, X being the minimal distance of all the detected obstacles, and X lower than 100 m, then the cruise control pauses and the car speed is regulated with (decrement)s so that the car could get stopped in the distance X, according to the current car speed S. When the speed goes below 50 Km/h the cruise control deactivates, but the speed control remains responsible to stop the car before crashing with (decrement)s.

Knowledge Level-4: The cruise control is able to go from active to paused, and to deactivated (as in Level-3), but also back to paused and then to activated when the (speed-limit X) increase above 50 Km/h, or above the fixed cruise speed, respectively. When an obstacle is detected it causes the cruise control to pause or deactivate (as in Level-3), but if the object gets more distant (e.g., the car in front moves away) or disappear the automatic speed control reacts to reach speed control whenever there's not a crash risk. Cruise control will pass from deactivated to paused, and finally to activated as speed goes above 50 Km/h or above the cruise speed, respectively. In Level-4, cruise control only deactivates without a possible later recovery when the car stops or when the driver pushes the (control off) button.

Knowledge Level-5: The cruise control and the speed control are the same thing. Every time the car is started up (car on), a cruise speed is demanded and the automatic control starts. From there on out, the car is fully automatic to decide the right speed in terms of the speed-limit signals, obstacles, and cruise speed. The system will try to keep as close as possible to the cruise speed, but always respecting the speed-limit signals, and avoiding the risk of crash. Since there's not a cruise control separated from the speed control, there's no need to activate/deactivate/pause the system. While the car is on, the automatic speed control system cannot be stopped. The car can be stopped (car off) only if the current speed is 0 Km/h.