Duckietown Traffic Code

1. General principles

- Unless specifically mentioned otherwise, Massachusetts traffic laws apply in Duckietown.
- Whenever a crash happens in Duckietown, *all* involved parties are considered guilty, so drive carefully!

2. Intersection with Traffic Lights

- During the red light, vehicles must fully stop before stop lines.
- During the green light, vehicles on the corresponding lane can cross the intersection. The green light implies that vehicles can go straight or make left or right turns as shown in Figure 2.
- When a traffic light turns from green to red, a vehicle is allowed to cross the intersection if it already passes a stop line. Otherwise, a vehicle must brake and stop.
- Traffic lights are operated such that at every instant at most one lane has a green light.
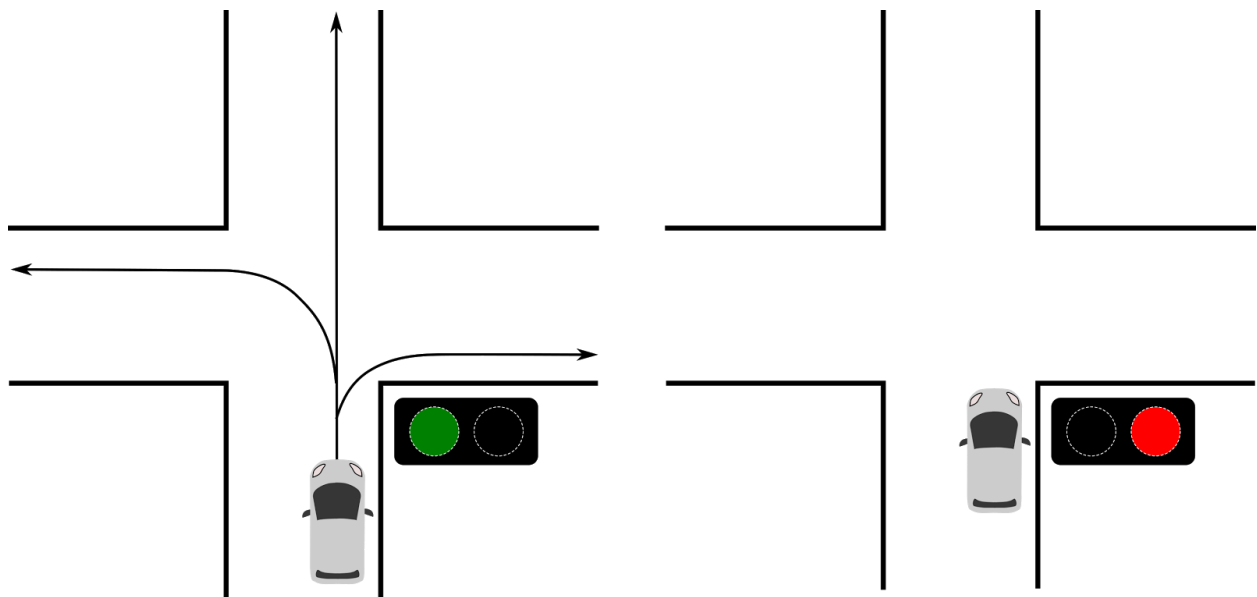
See Figure 2 for an illustration.

Figure 2: Signalized intersection.

3. Intersection with Stop Signs

- Drivers in Duckietown communicate at intersections using their own signal lights.
- *At an intersection, each vehicle can see other vehicles on the right (hereafter named right vehicle) and front (hereafter named opposing vehicle), but not on the left.*

Reminder of stop line specific traffic rules:
1. Full stop at the stop sign is mandatory
2. When trying to negotiate an intersection the LED light must be on and display either yellow, green or red color.
3. While crossing the intersection the yellow LED needs to be switched on
4. No vehicle can occupy the intersection longer than P seconds
5. In the absence of a vehicle coming from the opposing direction one has to yield to the right.
6. If one detects a vehicle crossing and nobody else has acknowledged this by showing a red light, one has to show a red light at least until that vehicle crossed the intersection
7. Before crossing an intersection one has to show its intention by displaying the yellow light for a time t**

Super simplified summary of the rules:
- If the only visible car is on the right, I must yield.
- Otherwise, I must wait (light green or red) or cross (blinking yellow light).

Intersection mitigation algorithm
Required Inputs
- Color of the LED of the opposing vehicle or 0 if there is no opposing vehicle at the stop line
- Color of the LED of the right vehicle or 0 when no light on but visible. -1 if no right vehicle is visible
- Binary variable indicating whether there is currently a visible vehicle on the intersection.

Required Actuation Capabilities
- Capability to make the LED display the colors red, green, yellow and off.
- Communication with motion planner to update the driving mode from lane following to coordination and from coordination to intersection driving.
- Internal clock to manage the waiting times.

Other requirements
- Need for an upper bound on the time it takes to cross the intersection.

1. Bring ego vehicle to full stop at stop line and switch on green LED. Go to 2.
2. Go through the following cases:
   a. If there is at least one car showing a red LED. Wait until that LED is turned green and then go back to 2.
   b. If there is at least one car in the field of view with its yellow light on:

- Wait for at least t**
- Check if yellow light is still on:
  - If yes, turn on red LED and wait for P seconds. Then turn on green LED and go back to 2.
  - Otherwise, go back to 2.

c. If no vehicle is on the right, no opposing vehicle is present or has a green light, and no vehicle is currently on the intersection / both the opposing vehicle and the right vehicle have green LED / only the opposing vehicle is present, switch on yellow LED and wait for t**
- If during t** all visible cars have green LED or LED Off, then go to 3.
- Otherwise change LED color to green, choose a random waiting time t* in [0.2, 1] s (This interval should be calibrated) and go to 2.

d. If only the right vehicle is present and has either no light or green light, do nothing and go back to 2.

3. Change to intersection driving mode, keep light on until the exit of the intersection
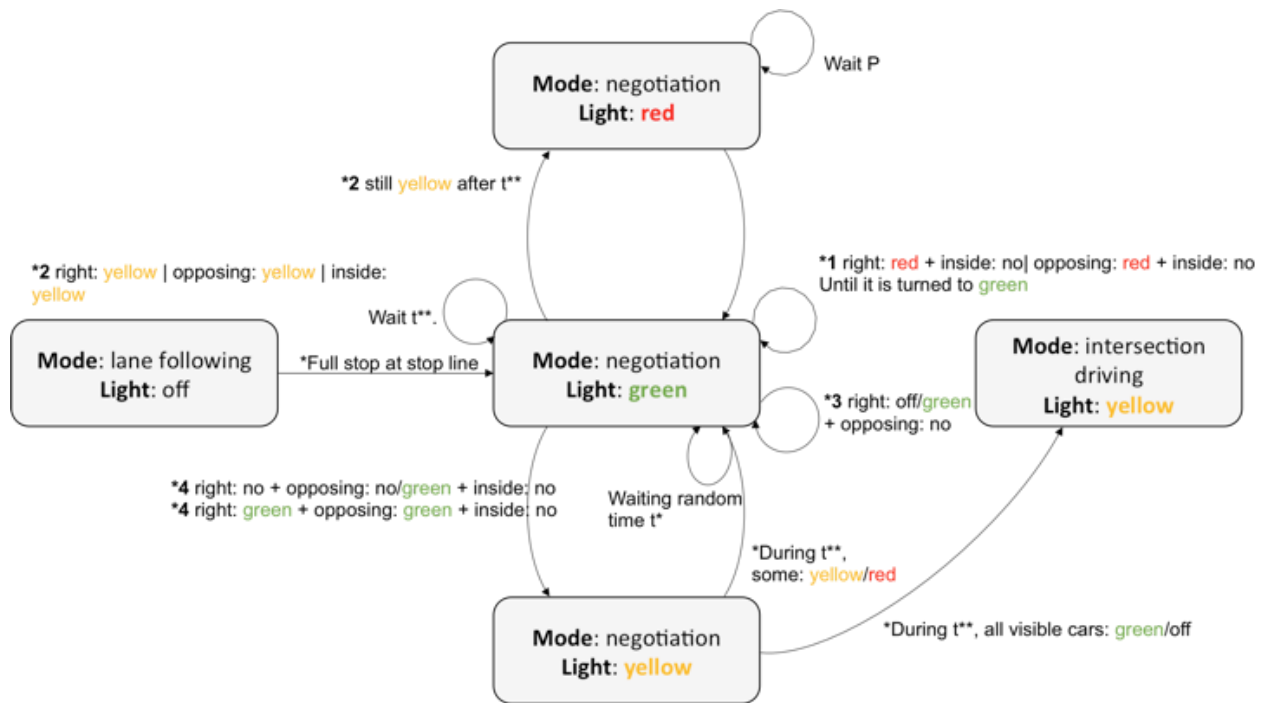
4. Lane Change Maneuvers in Multiple Lane Driving

People in Duckietown don't like to look back before they change the lane. Therefore a correct lane change maneuver consists of the following steps:

1) The vehicle that wants to change the lane (ego-vehicle), signals its intention until it has traveled at least d m with the light on (distance d should be calibrated with respect to sensing capabilities), before it takes any steering action. After this it performs the indicated lane change maneuver, making sure that it does not hit other cars from behind.

2) When vehicles in the corresponding adjacent lane of the ego-vehicle perceive the ego-vehicle's lane change intention, they have to make sure that they will not crash into the ego-vehicle from behind.

3) One can only change to adjacent lanes.

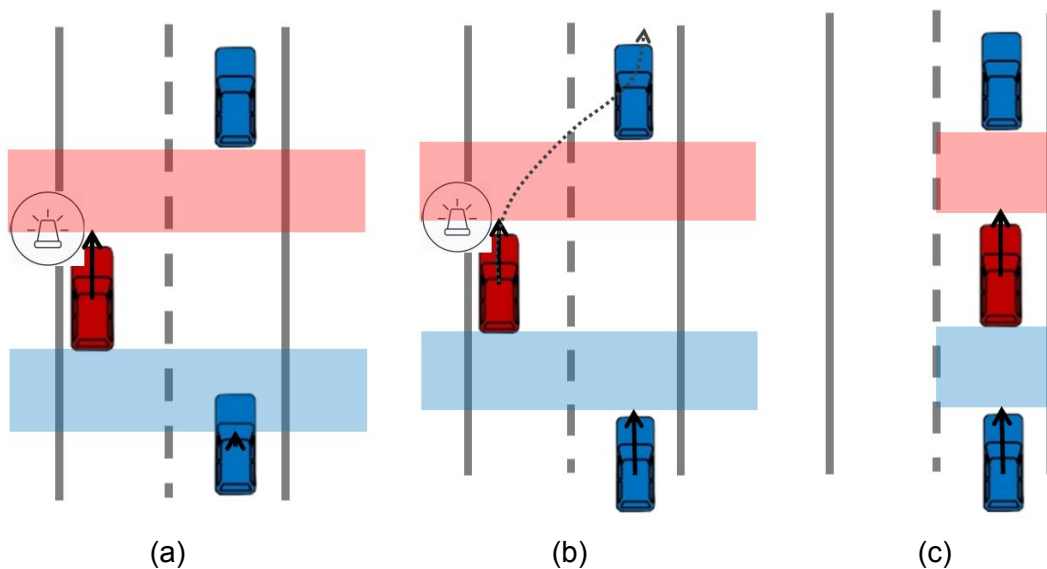See Figure 1 for an illustration.

| (a) | (b) | (c) |

Figure 1: The red bar represents the region where the (red) ego-vehicle cannot guarantee to avoid rear-end collisions. Similarly the blue bar represents the region where the following vehicle on the right lane cannot guarantee to avoid rear-end collisions. In (a) the ego-vehicle shows his intention for a lane change. This adds obstacles to the path of both the ego-vehicle and the following vehicle. The distance d is then used for these vehicle to move out of the dangerous regions, i.e. the red and blue bar. Once the ego-vehicle has driven d meters, all distances should be respected and the lane change maneuver can be performed, see (b). Finally, in (c), when the maneuver is completed the signal is switched off and all vehicles have only to be concerned about the vehicles inside their lane.

Appendix. The appearance of DuckieTown

- How wide are the roads?
- How wide are the lanes?

List the colors: (Liam, Luca)
- brightness
- Traffic light:
    - RED traffic light
    - GREEN traffic light
- Front of the car:
    - WHITE
- Top of the car:
    - off
    - BLUE: for crossing
- Back of the car:
    - "tail lights" = RED2:
    - "brake lights" = RED3
    - "turning signal" = ORANGE: turning

Appearance of roads (Luca, Liam)
The width
The appearance of the lines to the side (color, width, ...)

Duckietown traffic lights (Luca, Liam)
Each intersection has 4 LEDS
Each LED is visibile from one lane
Each LED has two states: GREEN and RED
Invariant: at most one lane is green
What is the heightfor traffic lights

Appearance of a car (Luca, Liam)
Each car:
- needs an LED on top for communication
- this LED is BLUE:
    - what is the height wrt to the road
- need two LEDs on the back: PURPLE or ORANGE
- there is a PLATE on the front and the BLACK

Traffic Signs (city council member: Changhyun)

These are the traffic lights that are actionable:

- the ones that specify **traversability**; equivalent to one edge of the graph:
    - one way
    - no turn left/right
    - do not enter
    - speed limit (5 and 10)
    - cross road (intersection), side road (L or R)
    - T intersection

These are the ones that are decorative (useful for SLAM):

-         stop, yield

-       stop ahead,   yield ahead

-       signal ahead

-       no park

-       pedestrian (duck)