# Programming 3 (P3): Traffic Control

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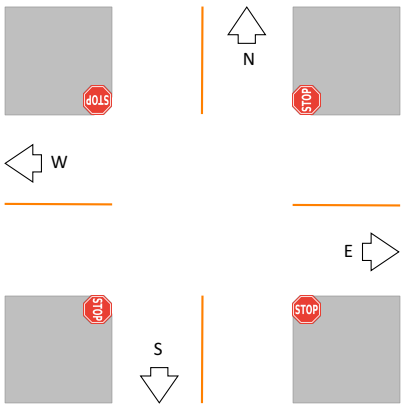
Due Time: 10PM, 4/9/2021

In this programming assignment, you will use `pthread` with `semaphore` to implement a `traffic control` system with stop signs at an intersection.

## 1 Stop Signs

We consider a typical intersection with stop signs as shown in the following picture: It has four directions




(E, W, S, and N). The road on each direction has only one lane with one stop sign.

In the following, we describe the traffic control policy for cars. In this system, each car is represented by one thread, which executes the subroutine `Car` when it arrives at the intersection:

```
Car(directions dir) {
    ArriveIntersection(dir);
    CrossIntersection(dir);
    ExitIntersection(dir);
}
```

Data type `directions` is defined as

```
typedef struct _directions {
    char dir_original;
    char dir_target;
} directions;
```

where `dir_original` and `dir_target` show the original and targeted directions, respectively.

`ArriveIntersection` When a car arrives at the intersection, if it sees any first car at other stop signs arriving earlier, it should wait until none of them is stuck at the intersection, but it doesn't need to wait until all of them finish crossing. Otherwise, it can either drive through, or turn left, or turn right (U-turn is not allowed) depending on the following condition:

- If it attempts to `drive through`, make sure that no car from the opposite direction is turing left, or any car is turning right to the same lane;
- If it attempts to `turn left`, make sure that no car is driving through the intersection in the opposite direction, or any car is turning right to the same lane;
- If it attempts to `turn right`, make sure that no car is driving to the same lane.

We assume there is no collision for two turning-left cars from the opposite directions. You could use `usleep` for the arrival time.[1]

`CrossIntersection` We assume that it takes fixed time periods ($\Delta_L$, $\Delta_S$, and $\Delta_R$ for turning left, going straight, and turning right, respectively) to cross the intersection and print out a debug message. You could use the `Spin` function [2] to simulate the crossing.

`ExitIntersection` It is called to indicate that the caller has finished crossing the intersection and should take steps to let additional cars cross the intersection.

# 2 Testing

Fix all the time periods described above as follows: ($\Delta_L = 3$s, $\Delta_S = 2$s, $\Delta_R = 1$s). The simulation will run until all cars finish crossing. In the main thread, you need to create threads, one for each car. The arrival pattern in the simulator is described as follows:

```
cid arrival_time dir_original dir_target
0   1.1          N            N
1   2.0          N            N
2   3.3          N            W
3   3.5          S            S
4   4.2          S            E
5   4.4          N            N
6   5.7          E            N
7   5.9          W            N
```

Associated with every car is a unique id (`cid`) as the car number, the arrival time (`arrival_time`) for the given car, and the original `dir_original` and targeted `dir_target` directions. For example, the first line shows Car 0 arriving at Time 1.1 which originally goes northward and continue to go northward. Make sure that your simulation outputs information that clearly shows that your solution works. The message should indicate car number and both original and targeted directions. In particular, messages should be printed at the following times:

- Whenever a car arrives at an intersection;

[1] `http://linux.die.net/man/3/usleep`

[2] Download this: `http://pages.cs.wisc.edu/~remzi/OSTEP/Code/code.intro.tgz`. You can find the `Spin` function in `common.h`.

- Whenever a car is crossing the intersection;
- Whenever a car exits from the intersection.

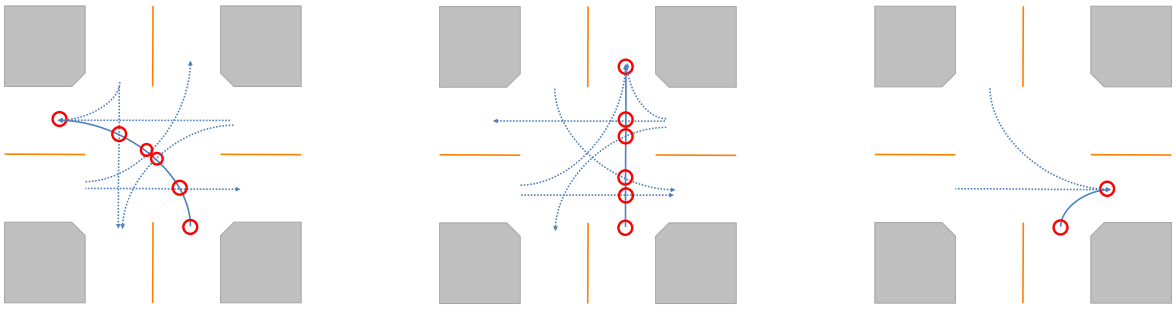
This is the right output for the arrival pattern given above:

```
Time 1.1: Car 0 (->N ->N) arriving
Time 1.1: Car 0 (->N ->N) crossing
Time 2.0: Car 1 (->N ->N) arriving
Time 2.0: Car 1 (->N ->N) crossing
Time 3.1: Car 0 (->N ->N) exiting
Time 3.3: Car 2 (->N ->W) arriving
Time 3.3: Car 2 (->N ->W) crossing
Time 3.5: Car 3 (->S ->S) arriving
Time 4.0: Car 1 (->N ->N) exiting
Time 4.2: Car 4 (->S ->E) arriving
Time 4.4: Car 5 (->N ->N) arriving
Time 5.7: Car 6 (->E ->N) arriving
Time 5.9: Car 7 (->W ->N) arriving
Time 6.3: Car 2 (->N ->W) exiting
Time 6.3: Car 3 (->S ->S) crossing
Time 6.3: Car 4 (->S ->E) crossing
Time 8.3: Car 3 (->S ->S) exiting
Time 9.3: Car 4 (->S ->E) exiting
Time 9.3: Car 5 (->N ->N) crossing
Time 11.3: Car 5 (->N ->N) exiting
Time 11.3: Car 6 (->E ->N) crossing
Time 14.3: Car 6 (->E ->N) exiting
Time 14.3: Car 7 (->W ->N) crossing
Time 15.3: Car 7 (->W ->N) exiting
```

# 3 Coding and Hints

You are recommended to use threading programming in C/C++. The programming should be tested in the Ubuntu environment in your P1 and P2, not in the `xv6`. Your executable file should be named as `tc`.

Use the sample code from `https://gist.github.com/tausen/4261887` as the basic framework. Make sure to identify the key resources each car needs to acquire, which you need to model with semaphore. The following figures show the different scenarios: turning left, crossing straight, and turning right. For each red circle, you need to create a semaphore.



For the head-of-line lock, when a car starts crossing, it should release the head-of-line lock so that the other cars behind can start crossing ASAP. For the other semaphores, the car should release them after finishing crossing. If a flow of cars with the same original direction go towards the same targeted direction back-to-back, they should be allowed to go back-to-back if all conditions are met. In this case, you could follow the example of readers' operations in the readers-writers problem to synchronize them.

# 4 Submission

You are going to report the following things:

(a) Describe in details how you implemented it in the report.

(b) Write a detailed report with the screenshots of the testing results. Each screenshot should include your username and the current time, which show that you did it by yourself. If your output is different from the expected one, provide a reason for the cause.

(c) Specify the contribution made by each member if you work as a group.

The report should be written in a ".docx", ".doc", or ".pdf" format. All source codes should be well formatted with good comments. Submit the report and the source code to Programming P3 on Canvas. Any compression file format such as `.zip` is not permitted.