Problem Statement

The purpose of this project is to develop a series of systems model for traffic passing through a 4-way intersection, controlled by traffic light. We will assume that arrangement of traffic lights and road lanes is fixed and that the lights switch from red to green to amber in a regular repetitive pattern. Moreover, we assume that driver behavior is constrained by the road rules (we keep this part really simple) and the desire to avoid vehicle collisions.

Terminology

Terminologies are the first thing we should define before start the project. Because of the complexity of the intersection control system, terms can bring us better understanding of the properties.

- Cycle: one complete sequence of signal indications
- Phase: part of a cycle allocated to any combination of traffic movements receiving the right of way simultaneously during one or more intervals.
- Conflict points: the potential points in a cycle that is possible to make collision.
- Level of Service: is defined in terms of average stopped delay per vehicle for signalized intersection.
- Queue: the total number of vehicle waiting at the intersection

A sample Intersection

When considering about an intersection, we should consider the following subsystems:

- **Control system:** the control design subsystem, the facility subsystem, and the signal control subsystems.
- **User system:** includes pedestrians, drivers, and traffic engineers.
- **Physical intersection:** the geometric information, pavement information and the traffic information.

To design the systems model for traffic passing through a 4-way intersection, the core in this project is how to design the control system so that the drivers and pedestrians can perceive precise and reliable information, with maximized system capacity and safety.

Since this project is addressed on the logical design, it's necessary to clarify the response system between road user and control system and the design concerns of control system. There are 7 kinds of basic control system for an intersection.

i) No control
ii) Guide signing only
iii) Guide and warning signing
iv) Yield control
v) Stop Control
vi) Signalization
vii) Police officer

Considering the real world situation, we only discuss four cases in our system.

- No control
- Stop control: Stop sign is needed in one/both direction; the vehicle will pass according their arriving sequence, first in first out.
- Yield control: Yield sign is needed in minor direction, no control in major direction. Cars proceed with caution.
- Signal control: Signals are needed. For each direction, signal cycle and signal phase design is based on the traffic information.

2. Goals & Scenarios

Goals 1. The system must be safe.

- Scenario 1.1: The setting of phases should eliminate the conflict points to a reasonable extend.
  - The straight traffics in orthogonal direction can't pass the intersection together.
  - The left turn traffic can't pass the intersection at the same time with the straight traffic in opposing direction.
- Scenario 1.2 : The time setting of each phase should be reasonable.

    - The setting of green phase length must be long enough for a single vehicle cross the intersection from **static status.**
    - The setting of red phase length must be long enough for a single vehicle in opposite vehicle cross the intersection from **static status**.
    - The setting of yellow phase length must be long enough for an **approaching vehicle** to notice.
    - The setting of pedestrian light length must be long enough for a **senior** person to cross the intersection.
- Scenario 1.3 : The driver must perceive the traffic before action
    - The driver should check the traffic on the same direction.
    - The driver should check the traffic on the opposite direction.
    - The driver should check the traffic on the orthogonal direction.
    - The driver should check the traffic light.
    - The driver should check the pedestrians.
- Scenario 1.4:The pedestrian must perceive the traffic before action.
    - The pedestrian should check the traffic light.
    - The pedestrian should check the traffic on orthogonal direction.
    - The pedestrian should check the right turn traffic on same direction.
    - The pedestrian should check the left turn traffic on opposite direction.

Goals 2. The system must be efficient.

- Scenario 2.1 :The timing for each phase should be long enough for cleaning the queue.
- Scenario 2.2 :The length of a cycle should inside a proper range.
- Scenario 2.3 :The computed capability should be optima.

Goals 3. The system must be economic.

- Scenario 3.1: The setting of phase should be compatible with the traffic volume.
- Scenario 3.2: The setting of traffic light should be compatible with traffic volume.
- Scenario 3.3: The sign system should be compatible with the traffic volume.

Goals 4. The system must be compatible with traffic law.

- Scenario 4.1: The control design should according to the current traffic law.
- Scenario 4.2: The users should be aware of the traffic law.
    - The driver should be aware of the traffic law.
    - The pedestrian should be aware of the traffic law.
- Scenario 4.3: The sign design should according to the current traffic law.

Goals 5. The system must be feasible.

- Scenario 5.1:The control design should be compatible with the sign system.
- Scenario 5.2:The control design should be compatible with the road geometries.
- Scenario 5.3:The LOS of the designed intersection can't below grade f.

3. Use cases

3.1. Identify Actors

- **Drivers**
- **Pedestrians**
- **Signal System**

- **Physical Intersection/ roadway**
- **Laws**

3.2. Define Users

User 1: Pedestrians

Requirements:

1. Safety: when the pedestrian is crossing the street, no car
2. Perceivable: the information of when to walk and when to stop is perceivable to the pedestrian.
3. Comfortable: the allowable time for walk is long enough to cross

User 2: Driver

Requirements:

1 Safety: the number of conflicting points is as small as possible.

2 Perceivable: the signals are perceivable and clear to the driver.

3 Comfortable: the allowable time for walk is long enough to cross the street.

User 3: Signal System

Requirements:

1. Safety: the system has the least possibility of traffic accidents.
2. Efficiency: The capacity of the intersection is maximized.
3. Economy: The total investment of this system is minimized.
4. Advanced requirement*:
   a. Environmental consideration: air pollution, vibrations pollution, light pollution.
   b. Regional consideration: the influence to the up flow traffic and down low traffic.

3.3. Initial Use Case Modeling

The use cases represent system goals or system functions.

Since we consider the safety, efficiency and economy of the system, the behavior of driver drives through an intersection can be divided into 3 parts:

1. Driver's action: go straight ahead or turning left or right
2. Driver's preservation: watch the traffic lights, the traffic in other lanes and the pedestrians, etc.
3. System function: cycle length and phase setting.

3.4. System boundary

The driver, other traffic, pedestrian and other obstacles, and traffic lights are all external systems.

Use case (1): Cycle length setting.

Description: The cycle length setting should improve the capability of the intersection.

Primary Actor: Roadway, Law.

Preconditions: The roadway geometries and traffic data are known, drivers always follow the traffic law.

Flow of events:

(1) Collect daily traffic volume.

(2) Limited the cycle length in 50 seconds to 90 seconds according to the daily traffic volume.

Post–conditions: traffic data is known, and the cycle length is limited.

Use case (2): Phase setting

Description: The phase setting should improve the capability of the intersection.

Primary Actor: Roadway, Law.

Preconditions: The roadway geometries and traffic data are known, drivers always follow the traffic law, and the cycle length is known.

Flow of events:

(1) Decide the number of signal phases.

(2) Decide the time setting for each phase.

Post–conditions: Traffic cycle length and detailed phase setting are given.

Use case (3): Watch the traffic lights.

Description: The driver should be able to perceive the traffic light information.

Primary Actor: Driver, signal system.

Preconditions: The traffic signal system is available and stable; drivers always follow the traffic law.

Flow of events:

(1) The traffic lights are perceivable.

(2) The driver has correct understanding of the traffic light.

Post–conditions: the driver is clear about the current signal status and has enough expectation of the possible change.

Use case (4): Watch traffic traveling in the same direction.

Description: The phase setting should improve the capability of the intersection.

Primary Actor: Driver Roadway, Law.

Preconditions: The roadway geometries and traffic data are known; drivers always follow the traffic law.

Flow of events:

(1) Watch the traffic in the same lane.

(2) Watch the traffic in the other lanes.

Post–conditions: Perceive the traffic in the same direction and find a proper

Use case (5): Watch for oncoming traffic.

Description: The driver should perceive the oncoming traffic before do any proceed action.

Primary Actor: Driver, Roadway, Law.

Flow of events:

(1) Watch the oncoming (includes the traffic in orthogonal direction) straight traffic.

(2) Watch the oncoming (includes the traffic in orthogonal direction) left-turn traffic.

(3) Watch the oncoming (includes the traffic in orthogonal direction) right-turn traffic.

Preconditions: The driver has perceived the signal information

Use case (6): Watch out for pedestrians and other unexpected obstacles.

Description: The driver should try to avoid the collision of pedestrian and vehicle.

Primary Actor: Driver, Pedestrian, Law.

Preconditions: The driver has already perceived the traffic signals and other traffic. **Post–**

conditions: The signal information and traffic information are ready.

Use case (7): Drive straight ahead.

Description: Driver should be able to drive the vehicle straight ahead.

Primary Actor: Driver, other traffic, law.

Precondition: The signal information and pedestrians' information is perceived.

Flow of events:

(1) Judge if the integrated information allows driving.

(2) Execute under the limitation of Law. **Post–**

conditions: The driver drives the car pass the intersection Use

case (8): Turn right.

Description: The phase setting should improve the capability of the intersection.

Primary Actor: Driver, Roadway, Law.

Preconditions: The traffic signal system is available and stable; drivers always follow the traffic law, the driver has perceived the signal information and traffic information in all direction.

Flow of events:

(1) If the traffic light is green and the gap is large enough when there is yield control.

(2) Turn right with proper execution.

Post–conditions: The driver drives the car pass the intersection.

Use case (9): Turn left.

Description: The phase setting should improve the capability of the intersection.

Primary Actor: Driver, Roadway, Law.

Preconditions: The traffic signal system is available and stable; drivers always follow the traffic law, the driver has perceived the signal information and traffic information in all direction.

Flow of events:

(1) If the traffic light is green and the gap is large enough when there is yield control.

(2) Turn left with caution.

Post–conditions: The driver drives the car pass the intersection.