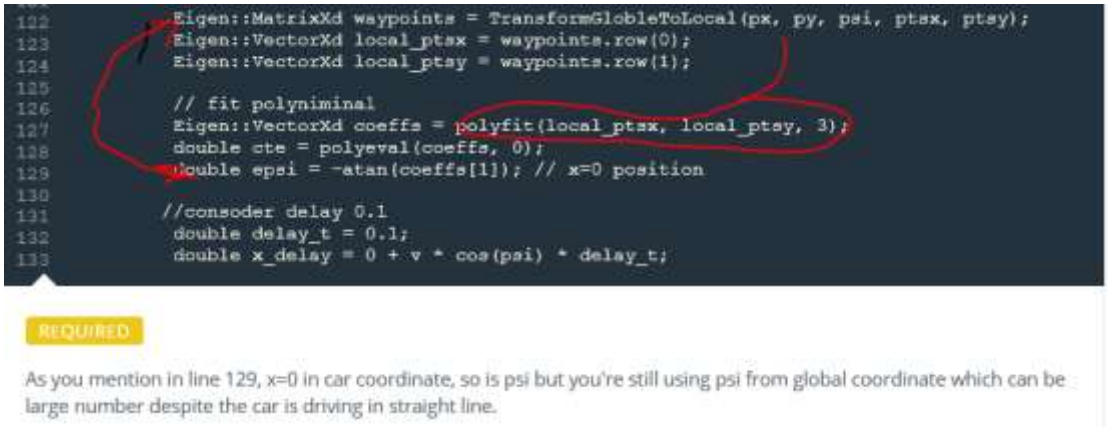
**Question：**




**I don't get your point here, I think I have already transfer to vehicle coordinate.**

**CarModel:**

The car model is a bicycle model which consists of 6 variables: [x,y,psi,v,cte,epsi]. They are x and y vehicle position, vehicle orientation, vehicle speed, cross track error and orientation error. To measure the constrains, the model has been transformed to the following equations.

```
fg[1 + x_start + t] = x1 - (x0 + v0 * CppAD::cos(psi0) * dt);
fg[1 + y_start + t] = y1 - (y0 + v0 * CppAD::sin(psi0)*dt);
fg[1 + psi_start + t] = psi1 - (psi0 - v0 * delta0 / Lf * dt); //modify turn direction as mentioned
fg[1 + v_start + t] = v1 - (v0 + a0 * dt);
fg[1 + cte_start + t] = cte1 - ((f0 - y0) + v0 * CppAD::sin(epsi0)*dt);
fg[1 + epsi_start + t] = epsi1 - ((psi0 - psides0) - v0 * delta0 / Lf * dt); //modify turn direction as mentioned
```

Lf measures the distance between the front of the vehicle and its mass center. f0 is the evaluation of the polynomial f at point x0 and psides0 is the tangential angle of the polynomial f evaluated at x0.

**Timestep Length and Elapsed Duration (N & dt)**

The number N determines the number of variables optmized by the controller. So, higher N will result in extra computational cost. Here is the code for time consuming.

```
start = clock();
count++;
vector<double> result = mpc.Solve(state, coeffs);
stop = clock();
durationTime += ((double)(stop - start)) / CLOCKS_PER_SEC;
if (count == 10){
    std::cout << "Time consume" << durationTime << std::endl;
}
```

| N | dt | Time consume(10 times) | Path follow stable |
|---|---|---|---|
| 5 | 0.1 | 0.146 | Unable to follow |
| 10 | 0.1 | 0.284 | yes |

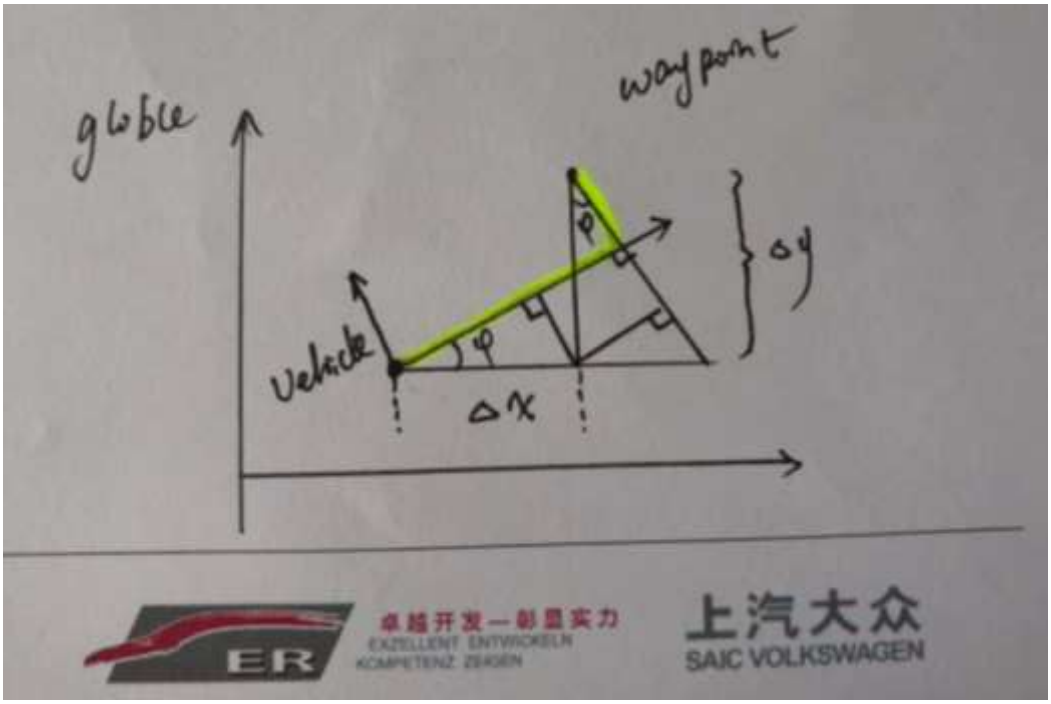
| | | | |
|---|---|---|---|
| 15 | 0.1 | 0.416 | Unable to follow |
| 20 | 0.1 | 1.57 | Unable to follow |
| 10 | 0.05 | 0.264 | Yes but less stable |
| 10 | 0.15 | 0.4137 | Yes but less stable |
| 10 | 0.2 | 0.628 | Yes but less stable |
| 5 | 0.2 | 0.13 | Unable to follow |

It was found that if N * dt is too low, the vehicle will oscillate around the lane center. If N * dt is too high, the prediction period is too long and the vehicle may leave the sharp turn.
If N is too high, the computational time increase, and so long time may lead to unable to follow. if N is too low, the MPC curve becomes too volatile for the car to be able to drive.
The influence of dt is not observed that clear.

The conclusion above may also be affected by other parameters I choose, like the parameters of cost functions and the speed to follow. And I guess the main reason for my first question is because the speed chosen, when I turn the value from 45 to 20, it becomes much better. Since the predicted position is more accurate in short distance.

**Polynomial Fitting and MPC Preprocessing**

Before fitting the path returned from the simulator, we have to transfer the waypoints from global position to vehicle coordinate.



```
Eigen::MatrixXd TransformGlobleToLocal(double x, double y, double psi, const vector<double> &ptsx, const vect
    assert(ptsx.size() == ptsy.size());
    int len = ptsx.size();
    Eigen::MatrixXd waypoints(2, len);
    for (int i = 0; i < len; i++) {
        waypoints(0, i) = cos(psi) * (ptsx[i] - x) + sin(psi) * (ptsy[i] - y);
        waypoints(1, i) = -sin(psi) * (ptsx[i] - x) + cos(psi) * (ptsy[i] - y);
    }
    return waypoints;

}
```

**Model Predictive Control with Latency**

Latency was considered in the main function. The next state was predicted before calling the MPC solve by using vehicle model.

```
//consoder delay 0.1
 double delay_t = 0.1;
 double x_delay = 0 + v * cos(psi) * delay_t;
 double y_delay = 0 + v * sin(psi) * delay_t;
 double psi_delay = 0 - v * delta / 2.67 * delay_t; //modify turn directic
 double v_delay = v + a * delay_t;
 double cte_delay =(cte - 0) + v * sin(epsi)*delay_t;
 double epsi_delay=epsi - v * delta / 2.67 * delay_t;

 Eigen::VectorXd state(6);
 state << x_delay, y_delay, psi_delay, v_delay, cte_delay, epsi_delay;
```