无人机实验报告

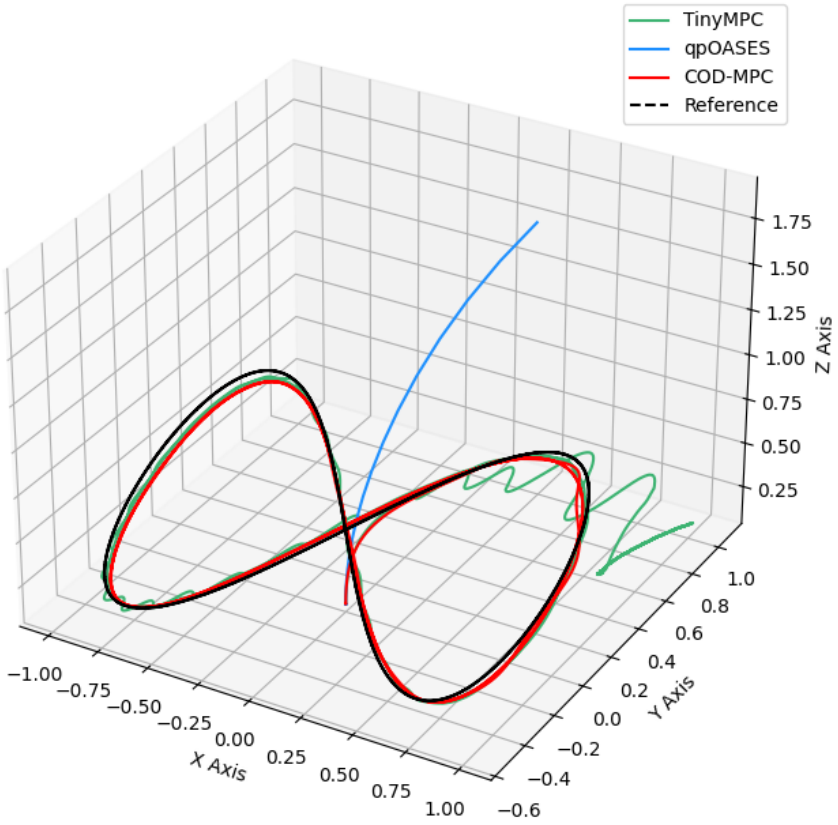
20250808

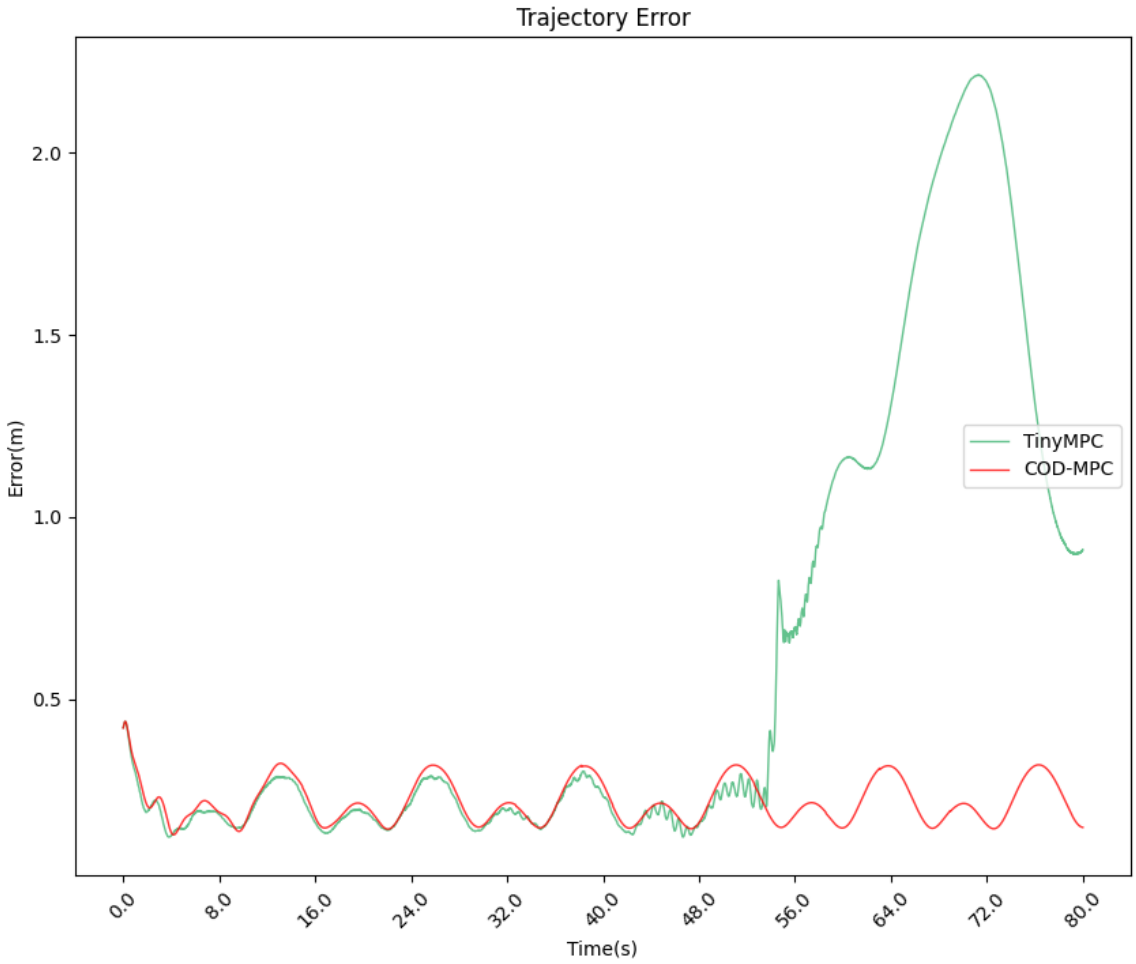
问题发现

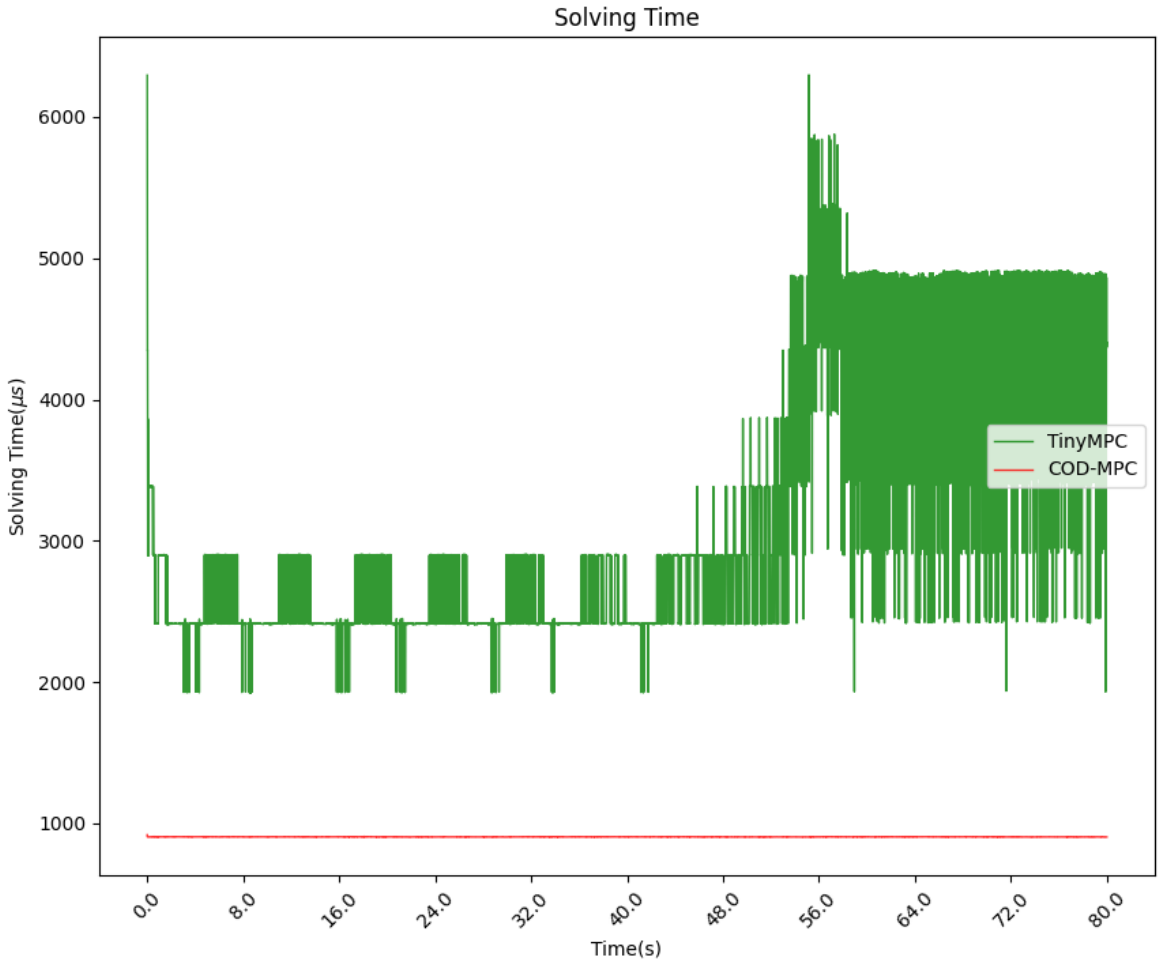
实验中发现，tinympc大约会在40s之后发生抖动，然后乱飞

见以下图片

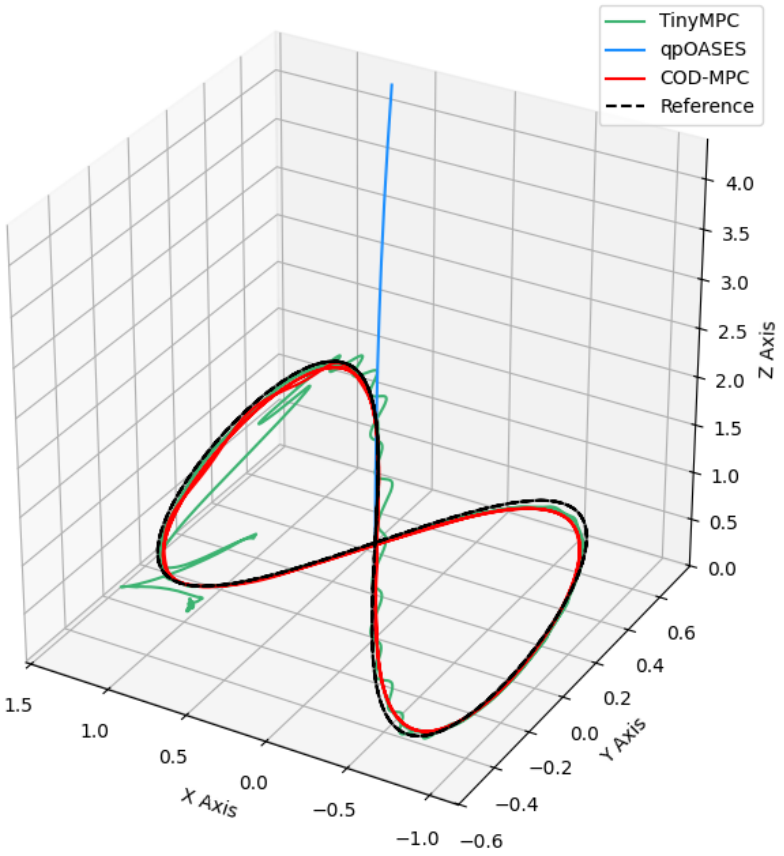
只沿倾斜30°

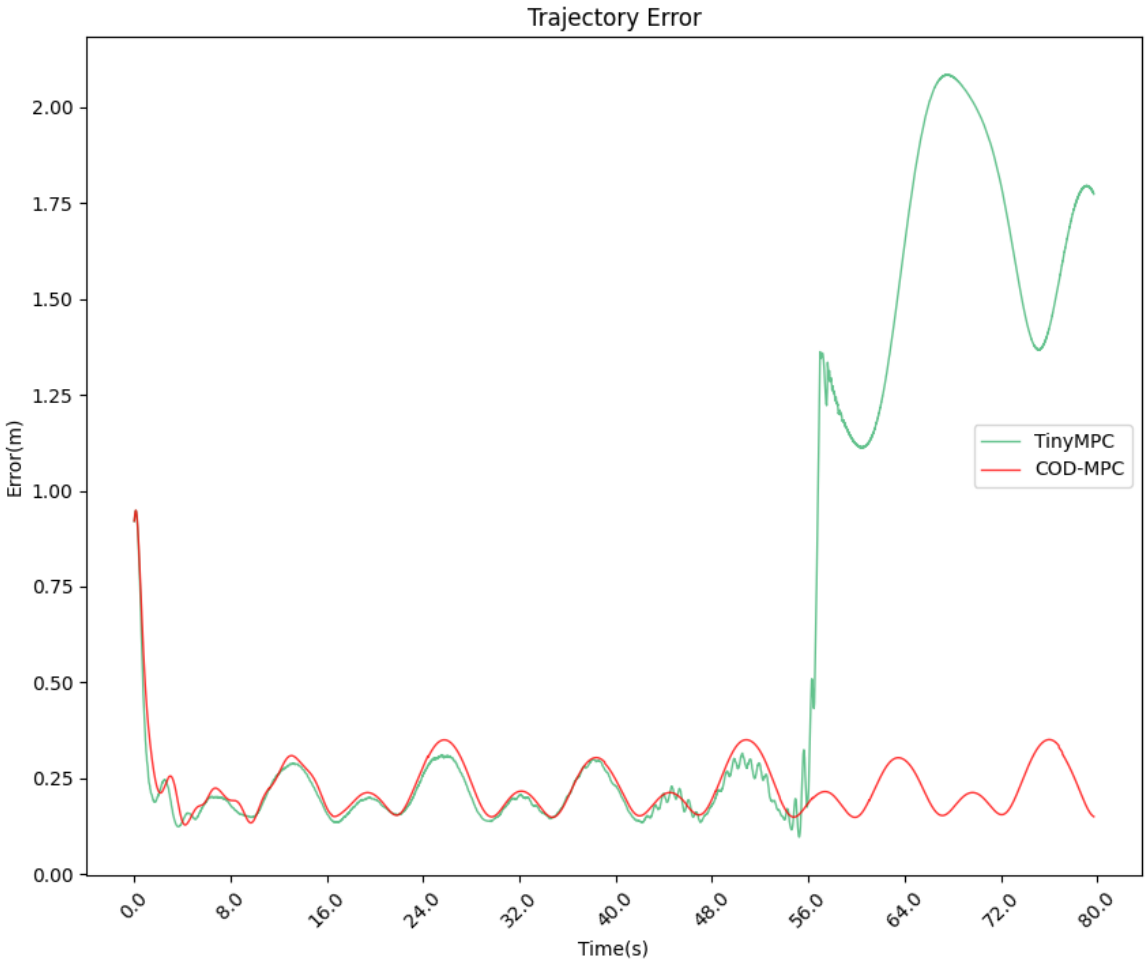


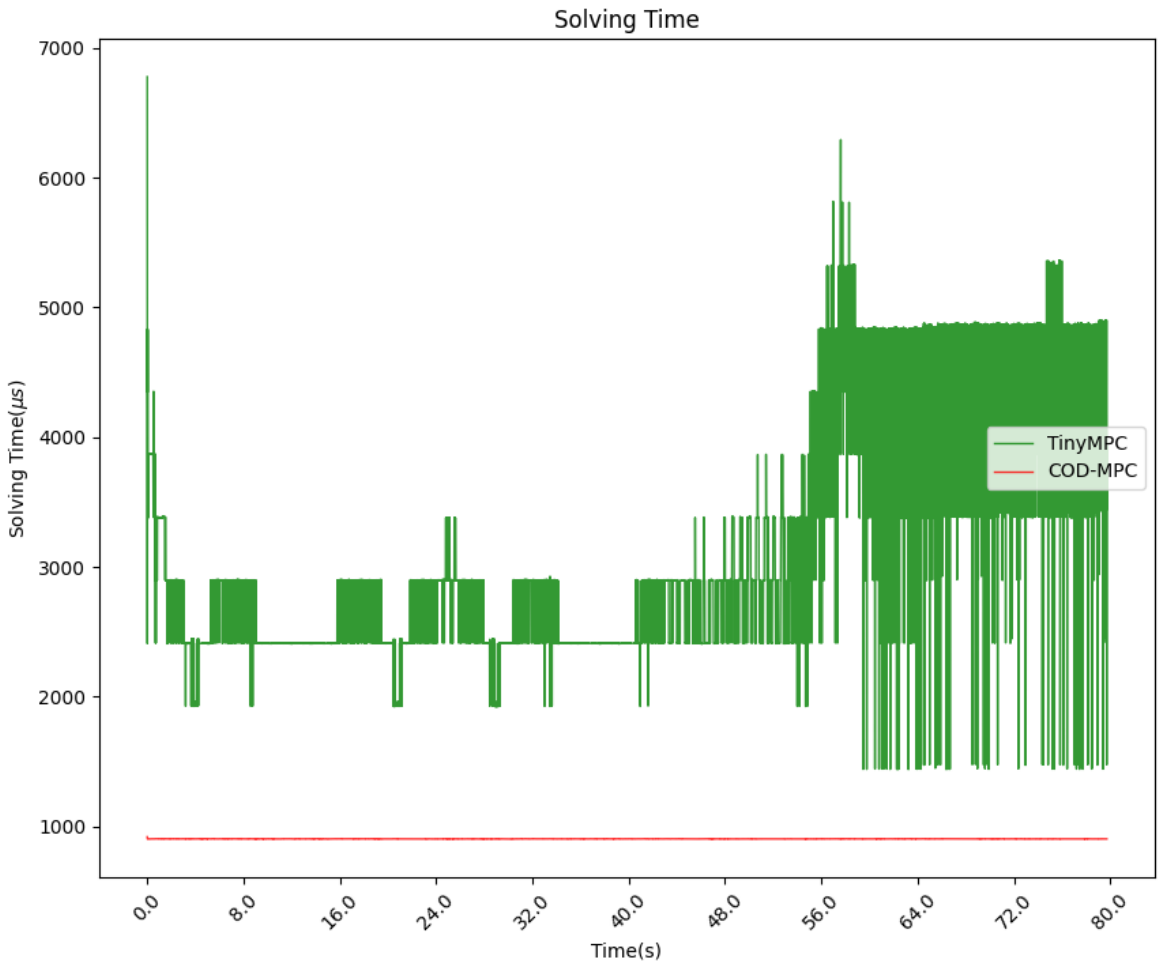

Trajectory Error
Error(m)
2.0
1.5
1.0
0.5
0.0
8.0
16.0
24.0
32.0
40.0
48.0
56.0
64.0
72.0
80.0
Time(s)
TinyMPC
COD-MPC


Solving Time
Solving Time(μs)
6000
5000
4000
3000
2000
1000
0.0
8.0
16.0
24.0
32.0
40.0
48.0
56.0
64.0
72.0
80.0
Time(s)
TinyMPC
COD-MPC

沿x,y 都倾斜30°


TinyMPC
qpOASES
COD-MPC
Reference
X Axis
Y Axis
Z Axis
1.5
1.0
0.5
0.0
−0.5
−1.0
0.6
0.4
0.2
0.0
−0.2
−0.4
−0.6
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0


Trajectory Error
Error(m)
Time(s)
TinyMPC
COD-MPC
0.00
0.25
0.50
0.75
1.00
1.25
1.50
1.75
2.00
0.0
8.0
16.0
24.0
32.0
40.0
48.0
56.0
64.0
72.0
80.0



出现此问题的原因

直接原因：

接收位姿话题（`/reed_quad_x/odometry_sensor1/odometry`）的队列 在刚开始发生抖动前一点的时间会**满**，导致tinympc没有使用最新的状态量x进行计算，导致求出来的控制量u会偏大（尤其是τ_x会比前面正常飞时大），导致了姿态角ϕ的变化比较大，从而出现了抖动

根本原因：

经过排查，队列会满的根本原因是:ROS端的主要控制代码的这两行没有注释掉，导致电机转速话题的频率只有约90Hz(低于100Hz)，而位姿话题的频率是稳定的100Hz。这就导致入队比出队更快，从而使得队列满了。

```
rospy.loginfo(f"PC Execution time: {execution_time:.2f} μs")  # 原本没有注释
rospy.loginfo(f"ARM Execution time: {running_time:.2f} μs")   # 原本没有注释
```

注：为什么我一开始没有注释这两行？

因为电机转速话题的发布（下面这行代码），是在PC端的计时范围内的。

```
# 发布控制命令：电机转速
self.publish_cmd(motor_speeds)
```

而PC端的时间没有超过10ms，导致我以为 **电机转速话题的发布**以及**gazebo对电机转速话题的响应** 也是在这10ms内完成的，但事实发现并非如此。

解决方法

注释掉了这两行，电机转速话题的频率能稳定在100Hz左右，最低也只是99点几Hz

```
# rospy.loginfo(f"PC Execution time: {execution_time:.2f} μs")  # 原本没有注释
# rospy.loginfo(f"ARM Execution time: {running_time:.2f} μs")   # 原本没有注释
```

附：修改后ROS端的主要控制代码见下方：

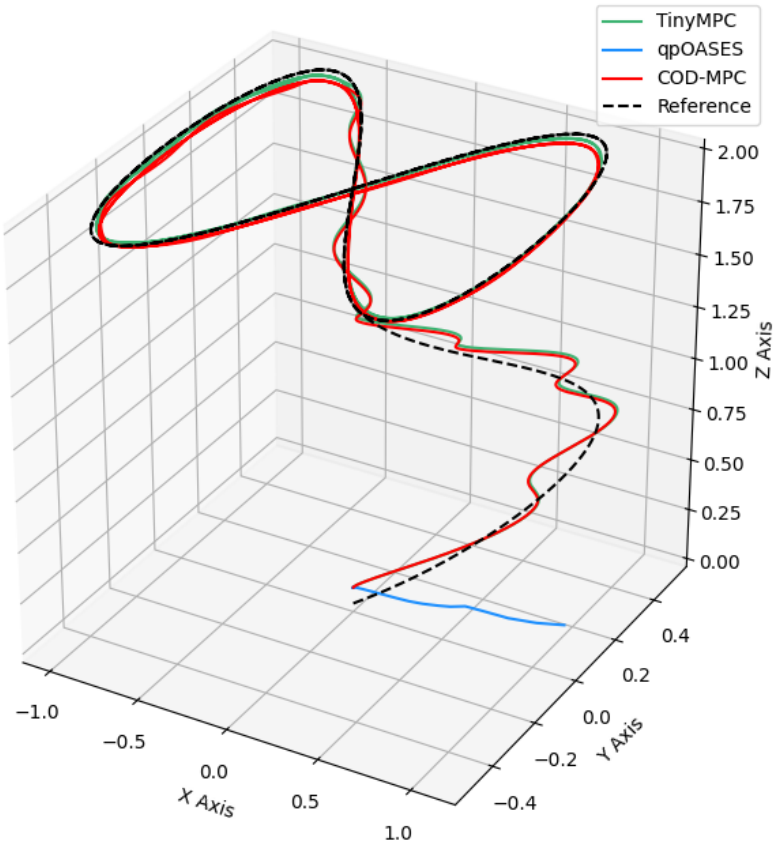
```
# MPC main
def control_loop(self):
    '''
    控制主循环, 分为2个阶段:
        1.准备阶段: 不飞 (为了便于在仿真中观察无人机刚起飞时的现象)
        2.飞行阶段: 按照预定轨迹飞行。
            有2种方法:
            2.1 利用tinympc求解问题
            2.2 利用FPGA求解问题
    '''
    try:
        rospy.loginfo("=======MPC control loop started.==========")
        count = 0
        sp_obj = sp.SerialPortNode()

self.odometry_subscriber=rospy.Subscriber('/reed_quad_x/odometry_sensor1/odometry'
,Odometry,self.odometry_callback ,queue_size=1)
        while True:
            msg = self.odom_queue.get()
            start_time = time.perf_counter()
            count += 1
            # 解析消息，更新状态
            (roll, pitch, yaw) = euler_from_quaternion([
                msg.pose.pose.orientation.x,
                msg.pose.pose.orientation.y,
                msg.pose.pose.orientation.z,
                msg.pose.pose.orientation.w
            ], axes='sxyz')
            self.state = np.array([
                msg.pose.pose.position.x, msg.pose.pose.position.y,
msg.pose.pose.position.z,
                msg.twist.twist.linear.x, msg.twist.twist.linear.y,
msg.twist.twist.linear.z,
```

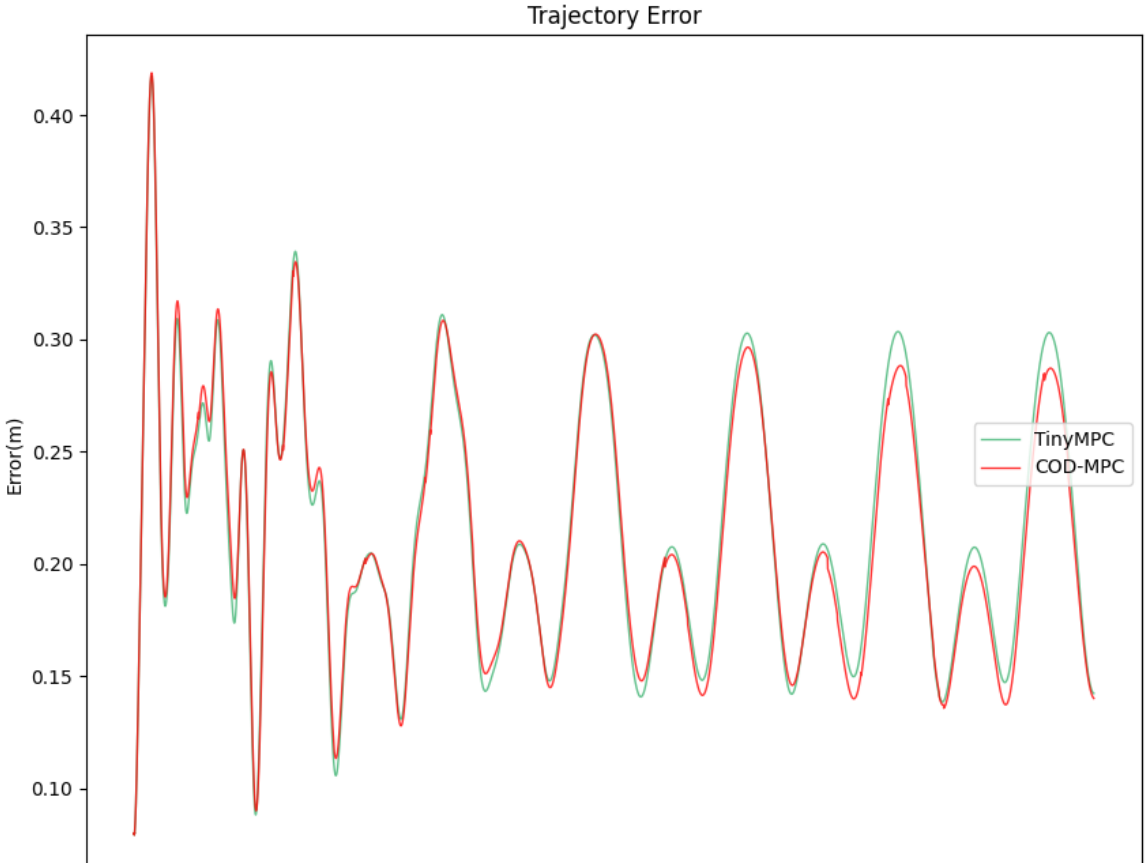
```
                roll, pitch, yaw,
                msg.twist.twist.angular.x, msg.twist.twist.angular.y,
msg.twist.twist.angular.z
            ])
            #rospy.loginfo(f"count : {count}, State: {self.state}")
            # 位置更新
            self.xk[:,0]=self.state
            # 开始计时
            # 求解问题
            sp_obj.send_floats(self.traj_idx, self.state)
            self.traj_idx += 1
            self.controlVector, status = sp_obj.receive_floats()
            if status != 0:
                rospy.logerr(f"Error receiving control vector: {status}")
                continue
            # 结束计时
            #rospy.loginfo(f"count : {count}, control: {self.controlVector}")

            # 利用FPGA求解问题，得到4个控制量
            thrust, torque_x, torque_y, torque_z, running_time =
self.controlVector

            # 利用 PC上的求解器 求解问题
            # thrust, torque_x, torque_y, torque_z=self.LQR_solve(self.idx)
            # thrust, torque_x, torque_y, torque_z=self.Tinympc_solve(self.idx)

            #rospy.loginfo(f'Thrust: {thrust:.2f}, Torques: ({torque_x:.2f},
{torque_y:.2f}, {torque_z:.2f})')
            # 把推力转换为转速
            motor_speeds = self.thrust_to_motor_speeds(thrust, torque_x, torque_y,
torque_z)
            motor_speeds=np.array(motor_speeds)

            # 发布控制命令：电机转速
            self.publish_cmd(motor_speeds)

            #rospy.loginfo(f"x0:{self.xk[:,0]}")
            if count < TRAJ_SAMPLE_NUM - self.N - 1:
                self.xk_history.append(self.state)
                self.uk_history.append(self.controlVector)
            elif count == TRAJ_SAMPLE_NUM - self.N - 1:
                rospy.loginfo("data collection finished, saving to csv...")
                df_xk_history = pd.DataFrame(self.xk_history, columns=['px', 'py',
'pz', 'vx', 'vy', 'vz', 'roll', 'pitch', 'yaw', 'wx', 'wy', 'wz'])
                df_uk_history = pd.DataFrame(self.uk_history, columns=['thrust',
'tau_x', 'tau_y', 'tau_z', 'arm_time'])
                df_xk_history.to_csv(FILE_ROOT+'xk_history.csv', index=False)
                df_uk_history.to_csv(FILE_ROOT+'uk_history.csv', index=False)

            end_time = time.perf_counter()
            execution_time = (end_time - start_time) * 1000000  # 转换为微秒
            # rospy.loginfo(f"PC Execution time: {execution_time:.2f} μs")  # 原本
没有注释
            # rospy.loginfo(f"ARM Execution time: {running_time:.2f} μs")   # 原本
```

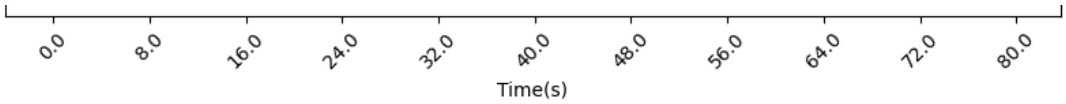
```
    没有注释
        except queue.Empty:
            pass
```

重新测量后的结果

飞行于2m

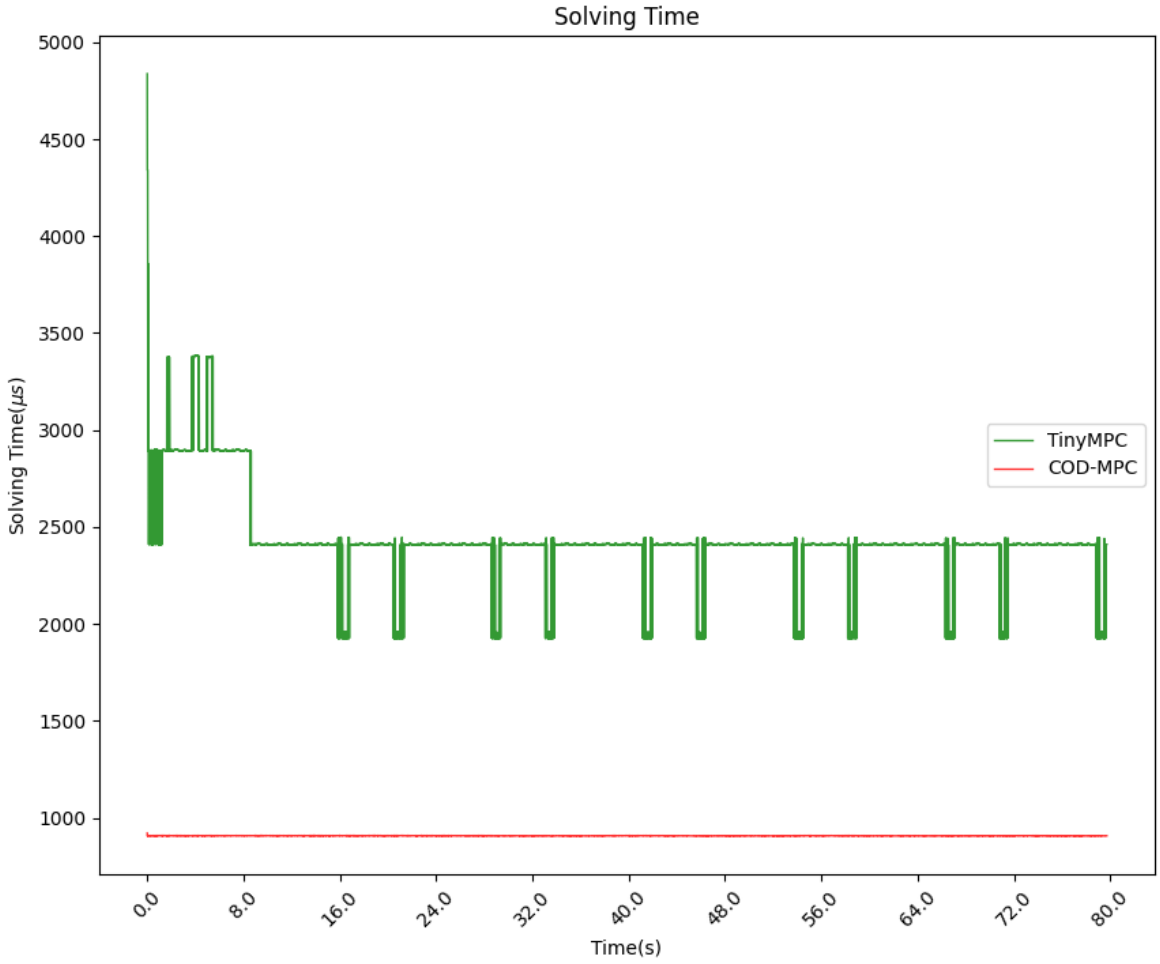

TinyMPC
qpOASES
COD-MPC
Reference
X Axis
Y Axis
Z Axis


Trajectory Error
Error(m)
TinyMPC
COD-MPC



轨迹误差（单位：米）

solver	mean	max
TinyMPC	0.215368	0.417517
COD-MPC	0.213171	0.418830

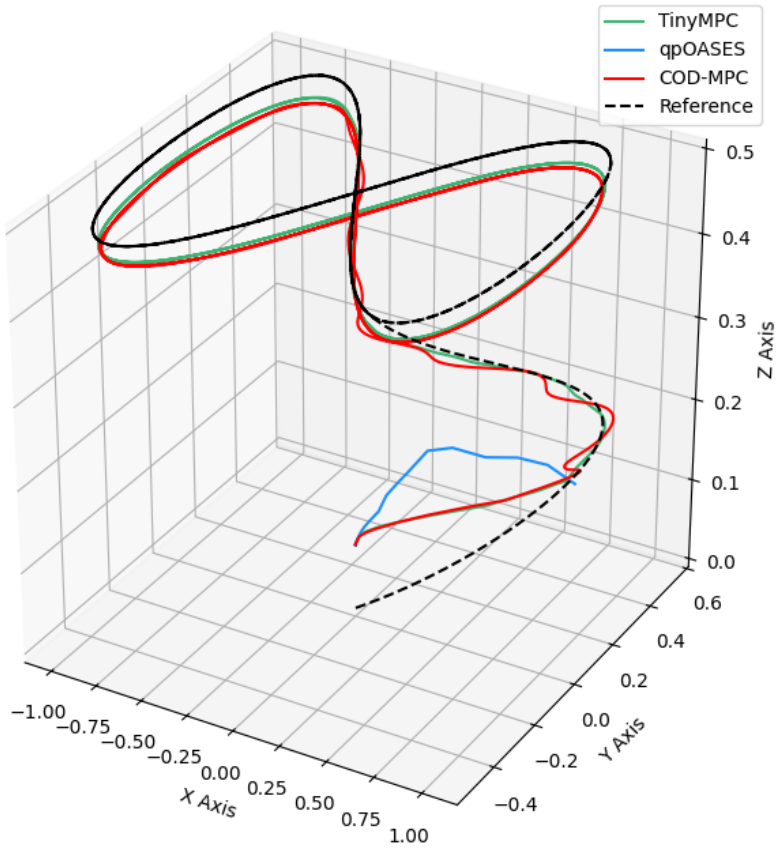


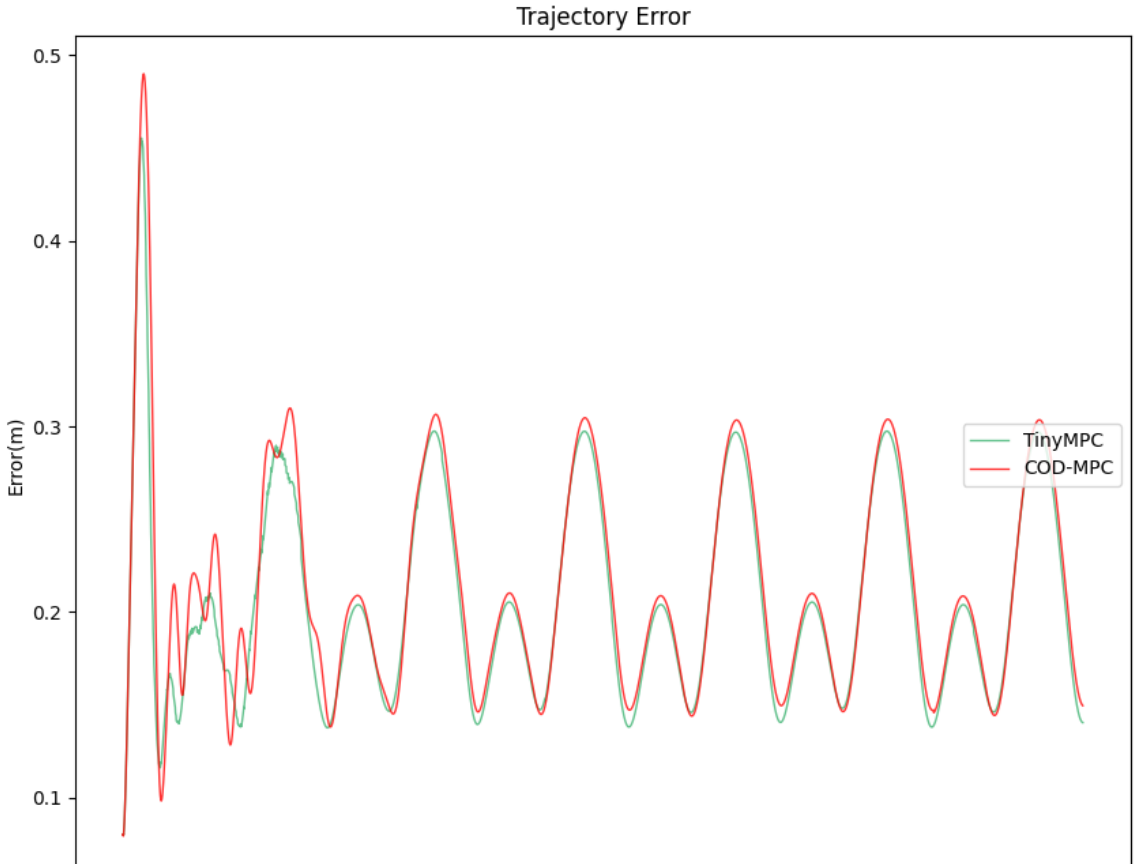
求解时间（单位：微秒）

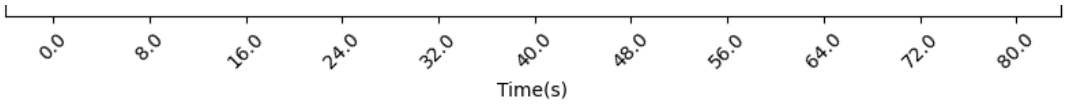
solver	mean	max
TinyMPC	2429.235530	4837.460938
COD-MPC	907.007263	920.259216

(文件夹：tinympc_uart_100Hz_time_vary_2m_2，CODMPC_uart_100Hz_time_vary_2m)

飞行于 0.5m

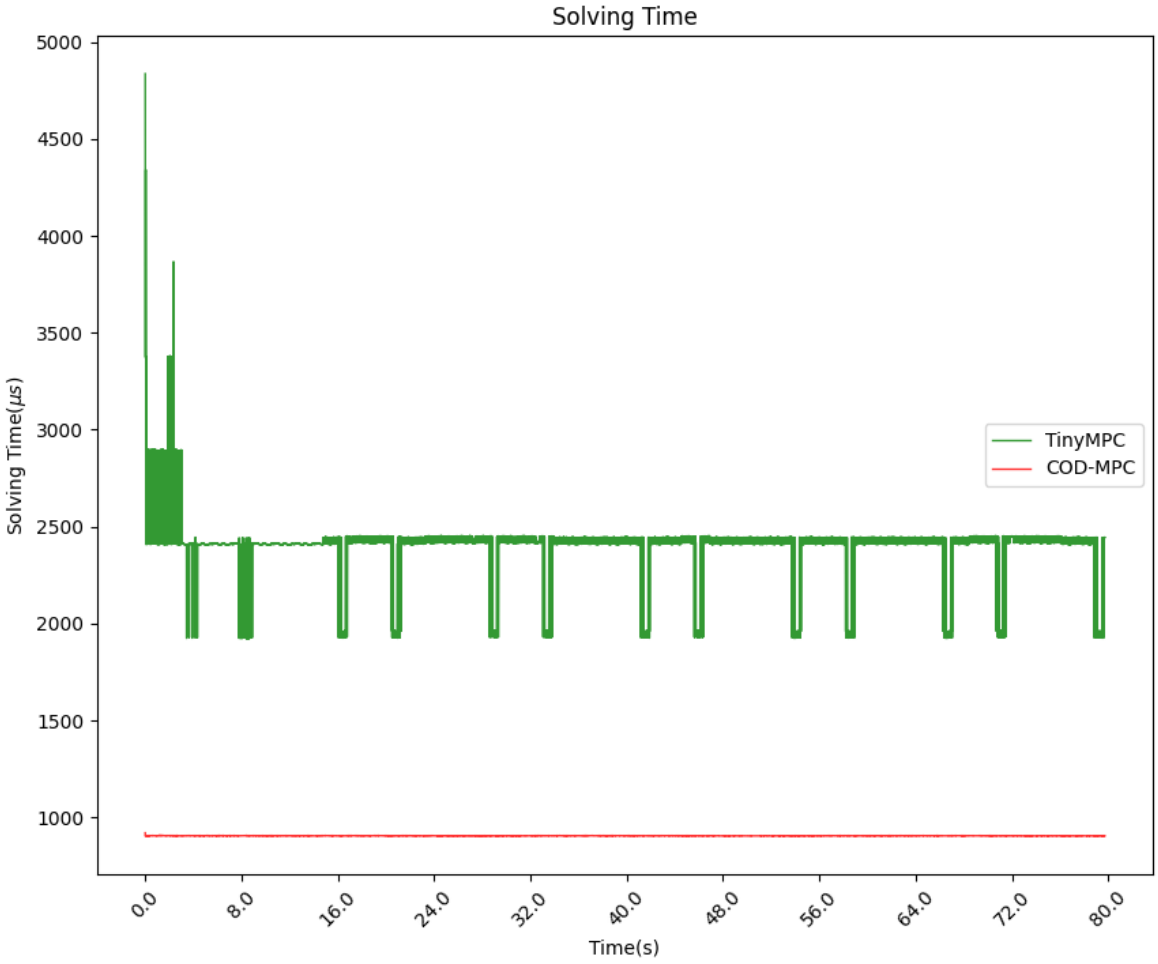

TinyMPC
qpOASES
COD-MPC
Reference
X Axis
Y Axis
Z Axis


Trajectory Error
Error(m)
TinyMPC
COD-MPC



轨迹误差（单位：米）

solver	mean	max
TinyMPC	0.205621	0.455427
COD-MPC	0.213188	0.490060

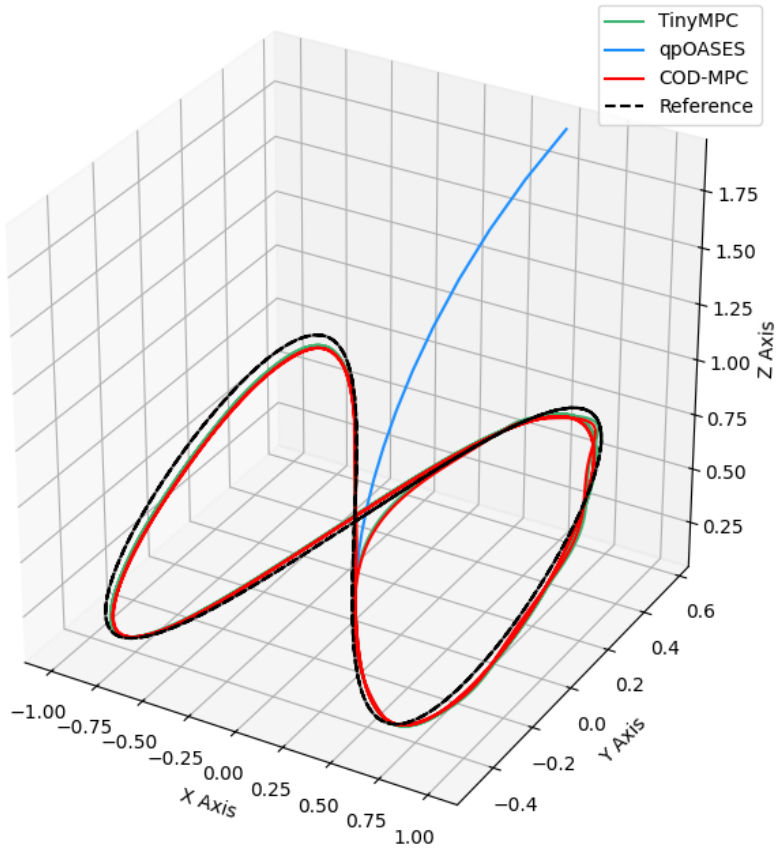


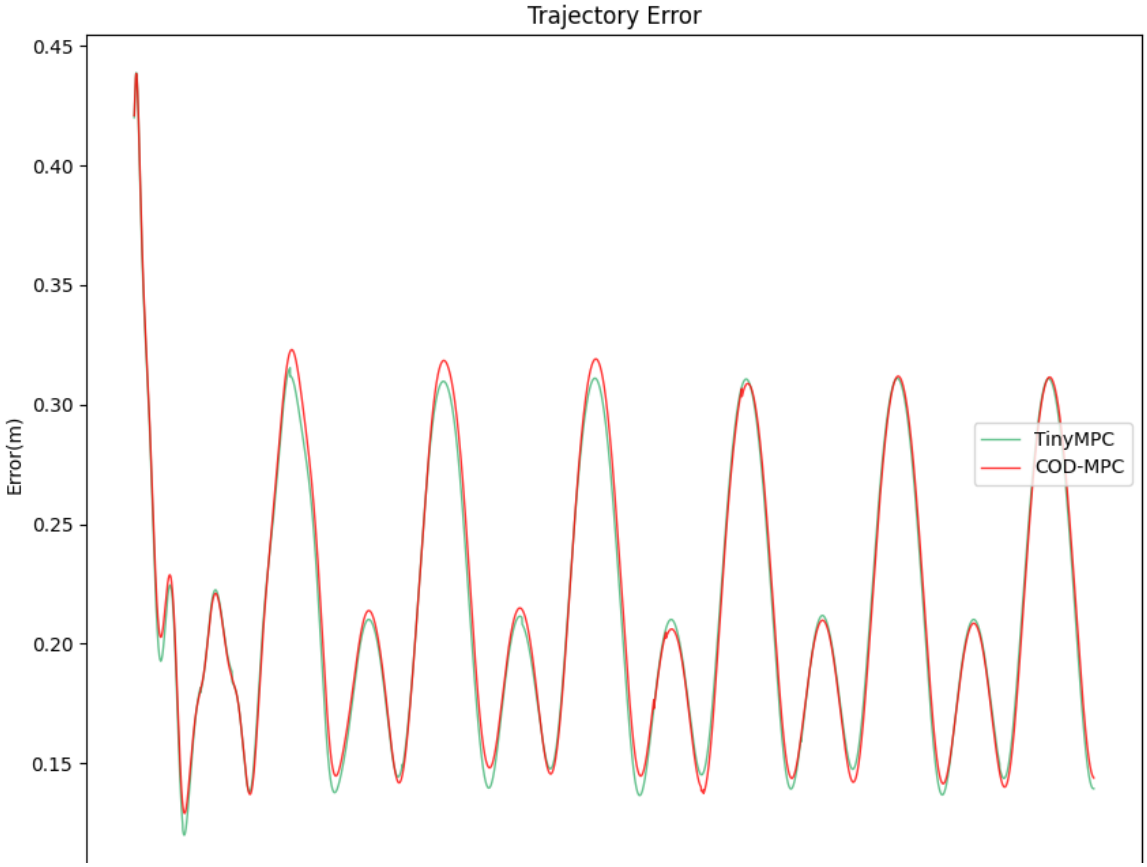
求解时间（单位：微秒）

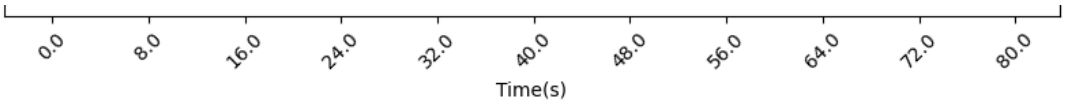
solver	mean	max
TinyMPC	2401.052741	4835.918945
COD-MPC	904.748750	919.779175

(文件夹：tinympc_uart_100Hz_time_vary_50cm，CODMPC_uart_100Hz_time_vary_50cm_3)

只沿y轴倾斜30°

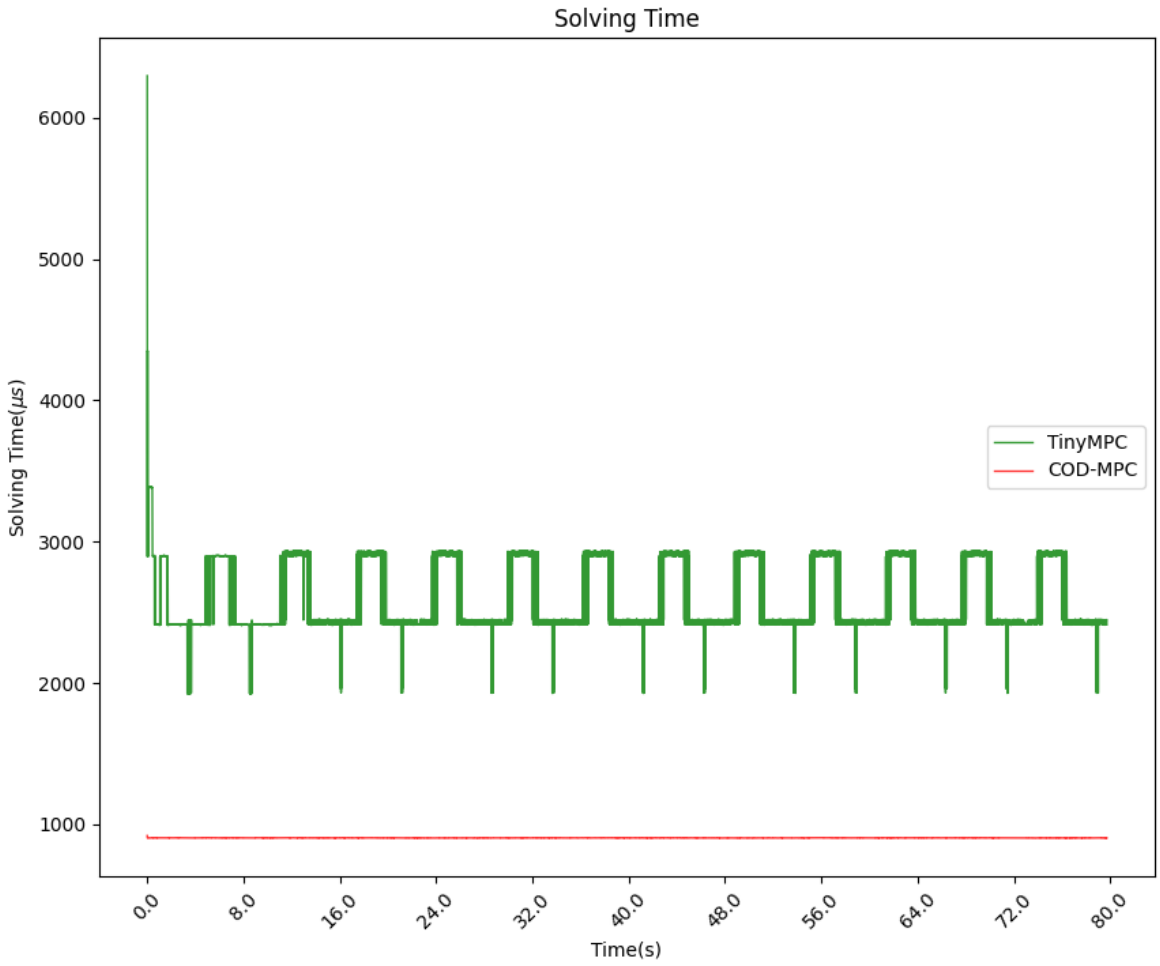

TinyMPC
qpOASES
COD-MPC
Reference
X Axis
Y Axis
Z Axis


Trajectory Error
Error(m)
TinyMPC
COD-MPC



轨迹误差（单位：米）

solver	mean	max
TinyMPC	0.212488	0.438783
COD-MPC	0.214873	0.438455

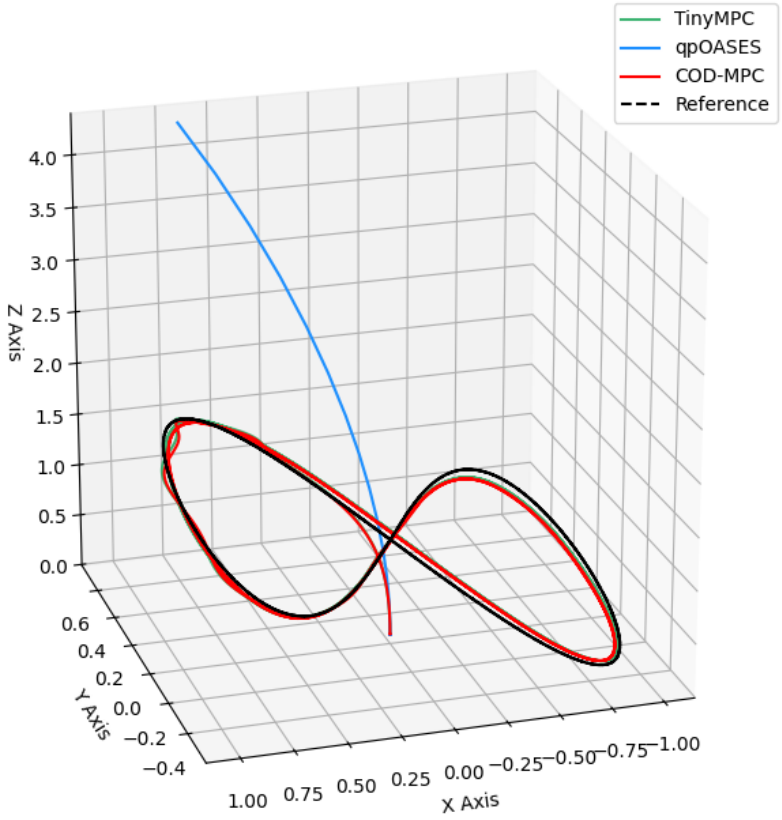


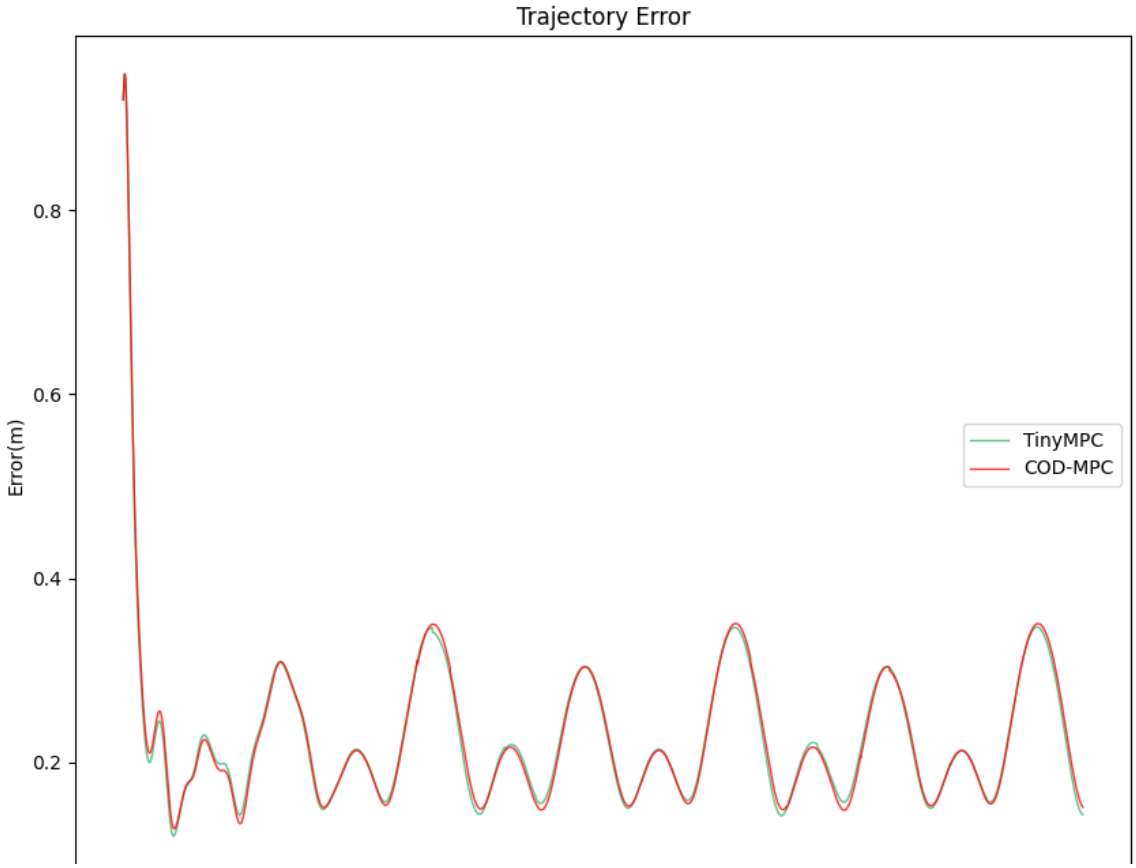
求解时间（单位：微秒）

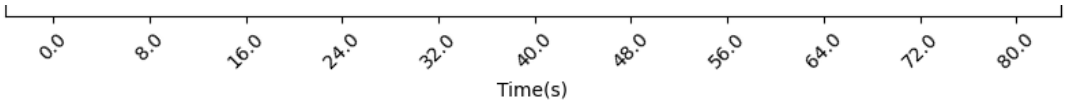
solver	mean	max
TinyMPC	2584.501181	6295.121582
COD-MPC	904.703286	919.989197

(文件夹：tinympc_uart_100Hz_time_vary_y30dg_5， CODMPC_uart_100Hz_time_vary_y30dg_2)

沿x,y 都倾斜30°

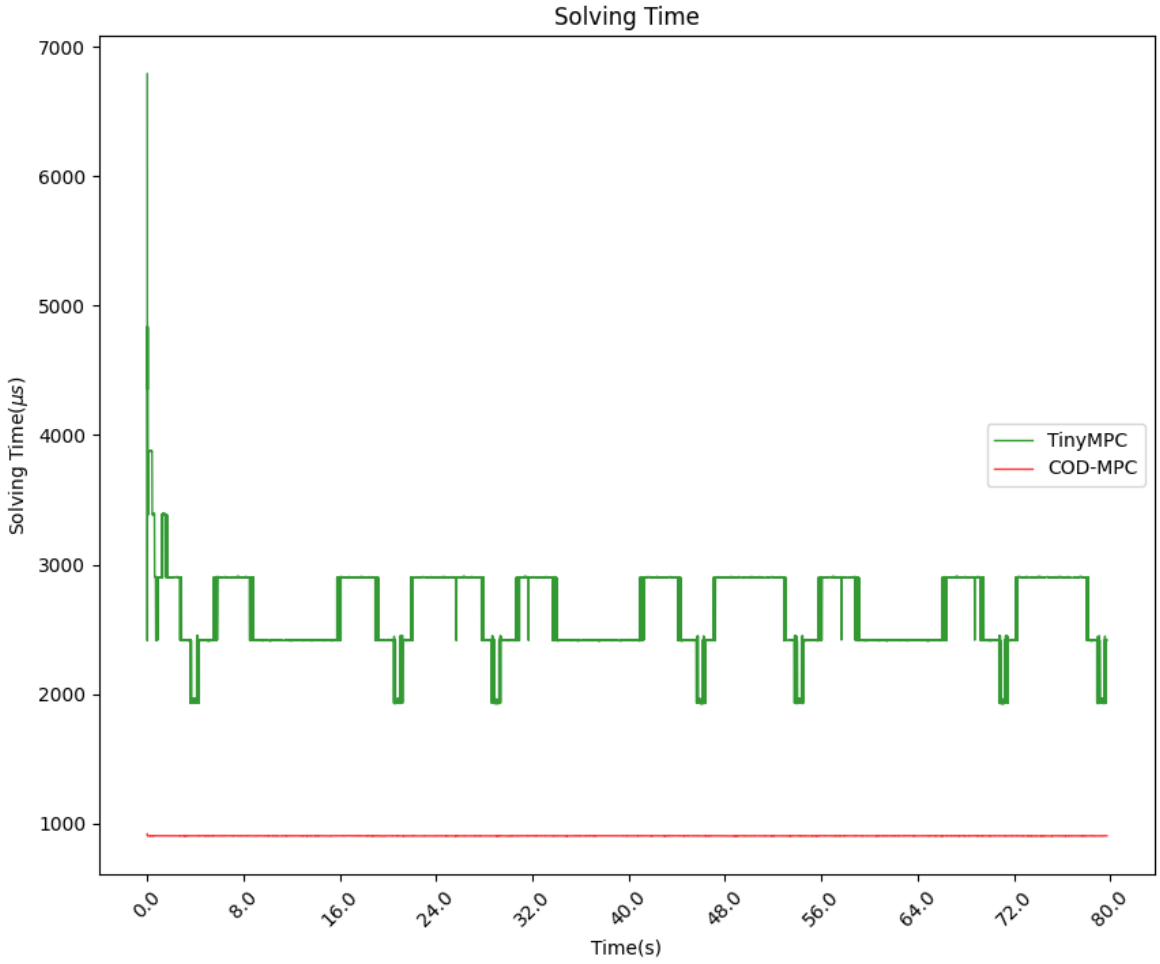

TinyMPC
qpOASES
COD-MPC
Reference
Z Axis
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
Y Axis
0.6
0.4
0.2
0.0
−0.2
−0.4
X Axis
1.00
0.75
0.50
0.25
0.00
−0.25
−0.50
−0.75
−1.00


Trajectory Error
Error(m)
0.8
0.6
0.4
0.2
TinyMPC
COD-MPC



轨迹误差（单位：米）

solver	mean	max
TinyMPC	0.227947	0.948328
COD-MPC	0.228441	0.948065



求解时间（单位：微秒）

solver	mean	max
TinyMPC	2637.460911	6790.526855
COD-MPC	904.759855	919.059204

(文件夹: tinympc_uart_100Hz_time_vary_y30dg_x30dg_5, CODMPC_uart_100Hz_time_vary_y30dg_x30dg_2)

总结

在轨迹误差上，TinyMPC与COD-MPC其实差不多； 但是在求解时间方面，COD-MPC 的求解时间远远小于TinyMPC。而且，轨迹越复杂，TinyMPC所需要的求解时间更长，而 COD-MPC 的求解时间却能够一直稳定在900us左右