Reactive Control of Autonomous Drones

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1.Problem

Most of the existing control platform of the autonomous drones could be architected as the Ground Control Station(GCS) and the autopilot software. In the GCS, actions need to take at each waypoint. While the GCS let people configure high-level mission parameters, the autopilot software implements the low-level motion to control the drone. Most existing autopilot implementations run in a time-triggered fashion. Time-triggered is so deterministic that it could simplify the implementations. However, some effort still need to be devoted to improve the control accuracy and flight time.

2.Solution

The authors of this paper came up with a new method called Reactive Control to solve the problem above. This method has 3 advantages. First one is that it could lessen the need to over-provision control rates because it run the control logic only upon recognizing the need to. Second advantage is it could improve hardware utilization by sparing those unnecessary processing. Last one is that it could attain more timely control decisions since the fact that if sensor inputs change often, control runs repeatedly.

The efficiency of autopilot can be increased by executing control decisions only upon recognizing the need to, based on observed changes in the navigation sensors, that allows rate of execution dynamically adapt to the circumstances.

3.Methodology

1) First of all, author redefines drones reacting conditions. For the Time-triggered method, the control decision may change because of a little difference from the sensor input data. In the improved Reactive Control method, the controller logic function is redesigned. The control decision will not changed when the drones in the similar condition, which means the sensor input is a little different from before.

2) Then they change the trigger algorithm. In the original method, the triggers may appear concentrated in a close time because of the sensors are sampled simultaneously in a frequency. This may cause the additional executions made by similar condition. Also, the triggers got a probability to not be recognized in the worst case. To avoid the unlucky condition of multiple triggers are not been recognized, author change the sampling frequency and add Hyperperiod triggers and Failsafe triggers.

3) Author use Reactive Programming(RP) technique to employed the Reactive Control. RP is a method for realizing the maintains in a continuous interaction condition. Then, Embedded RP to specialized libraries, and set Hyperperiod to improve the control efficiency. A data dependent graph serve for the control logic. Also remain the original sensor input and output method to implementing the reactive control fashion.

4.Evaluation

To make the evaluation, this paper compare the performance of implementations using reactive control against to the original time-triggered versions.First part is to compare the navigation and flight time.

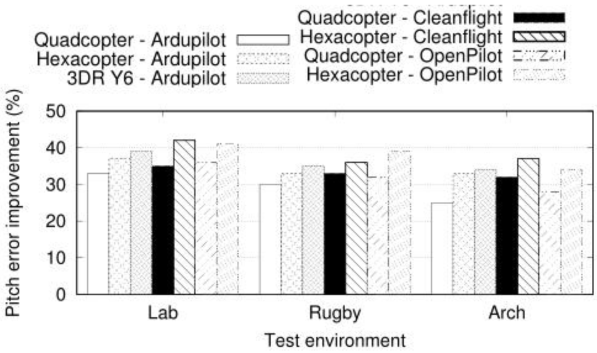

Figure1: Average improvement in pitch error

Figure 1 shows the average improvement in pitch off error enabled by reactive control. It is obvious that the improvement ranges from a 41% reduction with Cleanflight in LAB to a 27% reduction with Ardupilot in the challenging ARCH. Because of the improvement, it is the opportunity to spare iteration of the control loop which enable more accurate control decisions. This testifies the opportunity for downsizing the hardware, as reactive control can utilize it better and at the right times.

Plus, the improvement in attitude error translate into more accurate motion control. This reduces the energy overhead in attitude corrections. As a result, battery utilization was improved and flight times was increased.

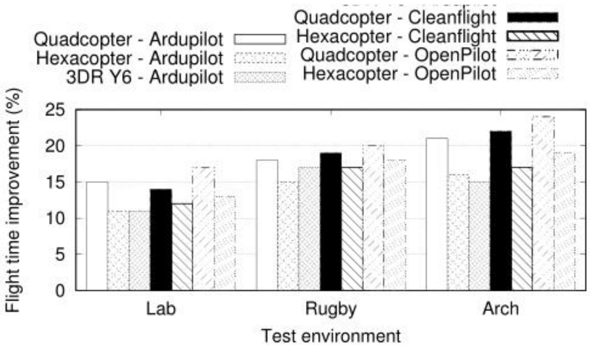

Figure2: Improvement in flight time

Figure 2 shows the results. Reactive control reaches up to a 24% improvement compared to time-triggered control, with a worst-time improvement of 11%. This result means flying more than 27 min instead of 22 min with OpenPilot in ARCH. This improvement reactive control enables in this respect are thus extremely valuable. Therefore, the improvement in navigation and flight time is significant.

In the second part, authors compared the end-user application. First of all, they did the 3D reconstruction of static objects by using aerial pictures. The results shows that point cloud is 23% or 29% more dense when using the reactive control in LAB or RUGBY. This means reactive control thus translates into tangible benefits also in a challenging end-user application. Then, author demonstrates how reactive control is enable to implement active sensing functionality.

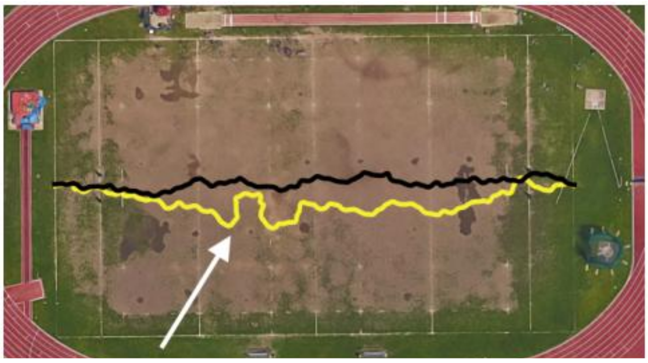

Figure3: Example of ARVA-driven navigation when using reactive control (black) and time-triggered processing (yellow)

According to the **Figure 3**, the path followed by reactive control appears fairly smooth. On the other hand, time-triggered control shows a convoluted trajectory at about one-third of the distance, where the drone's yaw is basically +90° compared to the target. This show that, on average, reactive control lead to a 21%(11%) reduction in the duration (length) of the flight.

Besides the average, time-triggered control shows higher variance in the results, occasionally producing highly inefficient paths.

5.Conclusion

Reactive control is an improvement method of the traditional time-triggered control for the drones to adapt all the dynamic environment in the daily use. It modifies the way of the sensors work and improve the control logic from the controller, solving the probabilistic failure problem and embedded the implementation to the hardware to earn a better performance and time cost control method.