Modification of results obtained by Modified internal Model Control for designing digital height control measuring system above rough sea level

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1. Introduction
The design of height control system achieved by using a new method for designing and tuning digital control system. The performance of the controller is tested along different phases of flight in order to stabilize the height over rough sea conditions and reject the effect of wind attacking and coup with sharp maneuvers.

2. Cascade MIMC controller for real height and pitch.
2.1 calm sea measurements
In this analysis, as mentioned previously, the transfer function $G_h(s) = \frac{k_{p2}}{s(T3s + 1)}$ is used, followed by real altimeter measurements. The same pitch controller, as used in Ref [2] is analyzed, and the parameters for the height controller are obtained from Table 1 for gain scheduled MIMC controller.

In Fig. 1 the real height is presented for the ideal case i.e. for the flight over calm sea. In, Figure 1(a) the MIMC controller is designed by definition, which means that the additional pole $p_3 = -\frac{1}{T3}$ is cancelled by the height controller.

Parameter $\alpha_h$ is set to be $\alpha_h = 0.95$ then in Figure 1(b) the height controller is changed so that the cancellation of the pole $p_3 = -\frac{1}{T3}$ is performed not in the controller but in the feedback path, after the antialiasing pre-filter. This cancellation is performed by using:

$$G_f(z) = \frac{z - a}{(1-a)z}$$

(1)

Where, $a = \exp(-\Delta t / 2) = 0.985$, and sampling time $\Delta t = 0.03$.

Finally, the results obtained by applying the real height controller are presented, where $\frac{P_{mo}^{-1}(z)}{z}$ is given by Ref [1] and the output of the antialiasing pre-filter is followed by:

$$G_f(z) = \frac{z - 0.988}{(1-0.988)z}$$

(2)

The designed height controller (for the 2nd phase) in Figure 1 is applied to phase 1. To eliminate the overshoot the function $G_f(z)$ is modified to be:

Figure 1 Real height measurements, over calm sea. (a)-(b) 2nd phase
2.2 Ideal measurements
Design parameters for pitch and height controllers for each phase of flight are given in Ref [1, 2]. The results can be seen in Figure 2 for the second phase of flight for the cascade MIMC controller.

3. Closed loop system response of the cascade MIMC controller. Real measurements, obtained from altimeter
Finally, the proposed cascade MIMC controller is used in a realistic scenario, including not ideal height measurements and calm sea, as done until now, but taking into account the realistic measurements of the height obtained from the altimeter, when the missile is flying over rough sea surface.

The controller \( C_\alpha \) starts after launching to stabilize \( \alpha \) to the reference value \( (\alpha_{ref} = 0.122\, rad) \). At the measured height of \( hm(t) \leq 40m \), the height controller is activated \( (h_{rref1} = 15m, \alpha_{ref} = 0) \) and at the end \( h_{rref} \) is changed to \( h_{rref2} = 5m \). At the middle of the simulation time, a large disturbance \( (d=0.4) \) is activated. A fixed parameter cascade MIMC controller guarantees robust performance/stability along the time of flight, i.e. for all the linearized models despite the large parameter variations. Results are shown in Figure 3.

The cascade MIMC controller was designed as a constant parameter type for all phases of flight with high closed loop performance. However constant value of \( k_c \) and \( k_o \) for fixed parameter controller type can not guarantees the maximum performance of the closed loop system in every phase of flight, and this is why a cascade gain scheduling controller is designed with slightly different parameters to perfectly compensate any oscillations, and further to reduce the effect of the load disturbance to the minimum. The parameters are given in Table 1.

4. Conclusions
It was demonstrated that, by applying a second order antialiasing pre-filter a high performance autopilot, could be obtained. MIMCcontroller could reject the load disturbance and cope with against high measurements noise generated by altimeter measurements. The results obtained confirm that the proposed cascade MIMC controller guarantees high closed loop system performance both in the set point response and in the load disturbance rejection.
control signal and pitch angle

Also by using simple gain scheduling procedures to schedule one parameter during the time of cruising phase, excellent closed loop performance was obtained.

References

Figure 3 Closed loop system response of the cascade MIMC controller in the second phase of flight. Real measurements, obtained from altimeter.

Table 1 Cascade controller design parameters

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<tr>
<th>MIMC controller type</th>
<th>$K_c$</th>
<th>$K_o$</th>
<th>$K_h$</th>
<th>$K_\alpha$</th>
<th>Applied</th>
</tr>
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<tbody>
<tr>
<td>Constant parameter MIMC</td>
<td>12</td>
<td>2</td>
<td>315</td>
<td>0.13</td>
<td>For all phases of flight</td>
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<td>Gain scheduling MIMC</td>
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<td>2</td>
<td>315</td>
<td>0.13</td>
<td>For phase 1,2</td>
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<tr>
<td></td>
<td>12</td>
<td>2</td>
<td>315</td>
<td>0.13</td>
<td>For phase 3,4</td>
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