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Short Communication: Switching Control Approach for Stable Transition State Process on Hybrid Vertical Take-off and Landing UAV

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THE paper discussed in this short communication is titled "Switching Control Approach for Stable Transition State Process on Hybrid Vertical Take-off and Landing UAV", authored by Ghozali Suhariyanto Hadi, et al, published in Journal of Unmanned System Technology, Vol. 4 (2), pp. 51-56.

The paper reports an ongoing development of a quadrotor-and-fixed-wing hybrid UAV, specifically on the design of flight controller that will be responsible in maintaining flight stability during transition phase between flight modes.

The authors identify six distinctive flight modes in a complete flight cycle (Section III). The specific control action or sequence of control actions are also described for each flight mode. Based on the sequence of these flight modes, a set of control systems are to be designed (Section IV). Two flight controllers are used, one of which is responsible in maintaining vertical flight and hover modes and the other is responsible in maintaining cruise flight mode. A mathematical model is provided that represents the controlled plant system (Equations (1)–(19)). This is the nonlinear model of the hybrid UAV. It is unclear how the model is used since the authors do not describe any further about it, which is unfortunate. However, there are three approaches that the authors could have done with it.

The first approach is to obtain a nonlinear controller by using the nonlinear model as it is. The resulting nonlinear controller is expected to perform well within the designed working envelope. While a nonlinear model can generally covers most of the possible working condition of the system it represents, it is rarely used to design the controller at early stages of the design process, especially when information about most parameters of the system is not available, or its availability is subject to uncertainty. Therefore, linear model -based design can be used as alternative approach, until all required data is collected and ready to use.

The linear model can be obtained analytically by carefully deriving it from the nonlinear model that is being kept in equilibrium at one working condition. The equilibrium condition is an element of a set of working conditions that represents the designed trajectory of the system, *i.e.*, the six distinctive flight modes described in Section III are the equilibria of interest of the UAV's motion system. From each equilibrium system's response to a finite amount of perturbation, *e.g.*, from the input, is derived. The result of this process is another nonlinear model in the form of polynomial function describing the relation between perturbations to system's response with respect to the equilibrium. For sufficiently small perturbation, the higher order terms of the polynomial are so small that the polynomial is reduced to a linear function. And as a MIMO system, the linearized model is expressed by Equation (20**)**.

The third approach is by first assuming the model structure, typically as expressed by Equation (20**)**, then obtaining all parameters (elements) of matrices A and B using parameter identification technique through a series of data collecting flight. This approach requires the real UAV to fly at trim conditions (equilibria) and then be perturbed. The perturbation and the corresponding system response are recorded and processed using parameter identification technique, obtaining each element of matrices A and B for every trim condition.

As suggested by the presented data in the paper (Figure 5), the design process of the UAV flight controller is at the stage of determining the equilibria along the designed trajectory of the controlled system. The equilibria along the designed trajectory are apparently stable as shown in Figure 10 and Figure 11. However, the authors do not provide any basis in obtaining the stabilizing gain of the controller, which is very unfortunate: the resulting control solution offers no engineering value. The authors could use one of the existing well-established methods in analyzing the stability of the control system, *e.g.*, by using root locus (since the control system is linear).

Overall, there are many things that can be criticized about the paper. Two most prominent things are the content of the paper and the writing style. The content of the paper is incomplete: without proper analysis, it is difficult to draw a solid conclusion. The writing style of the paper is messy where presentation of idea and data is not well-structured that one may find it a little hard to follow.

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However, the paper offers a very interesting subject in control system literature, and has great potential to contribute valuable information that will enhance scientific knowledge in control engineering. By itself, the subject of the paper is very interesting. With all the engineering challenges that reside within, it is only natural that the development process takes more time and more effort than initially expected. As more data gets collected, the authors will be enabled to conduct their analysis more properly, and the paper will have much more to offer as a control engineering literature. Critical comments in this short communication are intended to be constructive to achieve better quality in future research publishing efforts.

Keywords—VTOL, fixed-wing hybrid UAV, switching control, transition state, flight control system.

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