Flying multi agent control for detect an object

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Journal of Physics: Conference Series

PAPER • OPEN ACCESS

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To cite this article: RH Tjahjana 2020 *J. Phys.: Conf. Ser.* **1567** 022083

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Abstract. This paper exposes two flying vehicles control. The objective of this paper is proposing control design use optimal control approach for flying multi-agent to detect an object. In optimal control approach, beside the dynamical system model, the cost functional is needed. In this paper, the dynamical system model is dynamical system of flying vehicle and the cost functional is the functional which make the vehicles move together to detect the lost object. The scope of this exposition is how to control two flying vehicles move around an object. The two flying vehicles must satisfy the simulation scenarios as follows. Both of the flying vehicles forced do not move far each other and also do not collide each other. Besides mathematical analysis of the model, like controllability and observability of the model, the result of this paper, present the theorem and the proof the cost functional which guarantees that the booth of the vehicles can fly satisfy the scenario. The result also exposes the simulation of controlling two vehicles. The conclusion of this paper states that the optimal control method can be used to solve the problem of control two flying vehicles to detect the lost object.

1. Introduction

The loss of the aircraft during its flight is a sad event. After the aircraft determined lost, the next action is to search as soon as possible to help the passengers and the cabin crew. Sometimes, searching the loss vehicles use more than one searcher aircraft. The goal use more one aircraft is searching process more accurate. Another inspiration of this paper comes from the situation that two or more flying vehicles detect an object or something. The flying vehicles move together to improve the probability to detect an object. At the same time, controlling two aircraft to fly together to detect an object is an interesting problem. The effect of controlling two flying vehicles or more at the same time is very dangerous. For example, if they are collision each other will have disadvantages and also dangerous for searched aircraft. So, the simulations of controlling two flying vehicles before demonstrate it is needed. The event of lost an aircraft become motivation this paper. This paper actually does not especially expose finding lost aircraft, but this paper exposes two flying vehicles in detect an object generally.

Research in flying vehicles is interesting for many researchers. The publications about flying vehicles for example can be found in [1] which describes a vision-based quadrotor micro aerial vehicle that can autonomously execute a given trajectory and provide a live, dense three-dimensional (3D) map of an area. Paper [2] evaluated the effectiveness of the system for stabilizing and controlling a quadrotor micro air vehicle, demonstrate its use for constructing detailed 3D maps of an indoor environment, and discuss its limitations. Reference [3] exposed collision detection and avoidance using ADS-B Sensor and Custom ADS-B like solution. Paper [4] described three-dimensional path planning for uninhabited combat aerial vehicle based on predator-prey pigeon-inspired optimization in a dynamic environment.

Next, paper [5] explored the usage of different game controllers as input devices to control an UAV. In an explorative study, participants fulfill a predefined flying task and report their expectations before and experiences after performing the flight with different gaming controllers. The resulting insights are a basis for further interaction research activities. Then [6] developed a planar trajectory model. This model in [6] is used to predict the dive behavior of the Aqua MAV, and investigate the efficacy of passive dives initiated by wing folding as a means of water entry. The paper [6] also includes first field tests of the Aqua MAV prototype where the folding wings are used to initiate a plunge dive. In [7] presented an optical-aided navigation method for automatic flights where satellite navigation might be disturbed. The proposed solution follows common approaches where satellite position updates are replaced with measurements from environment sensors such as a camera, radar as required. The next paper exposed pedestrian detection for UAVs using cascade classifiers with mean shift presented in [8]. Recently research in multi flying vehicles can be listed as follows. In [9] considered Finite-time leaderless consensus of uncertain multi-agent systems against time-varying actuator faults. Next, distributed output consensus of heterogeneous multi-agent systems via an output regulation approach can be found in [10]. Autonomous control for multi-agent non-uniform spraying can be considered in [11] and integrated design of fault estimation and fault-tolerant control for linear multi-agent systems using relative outputs can be read in [12]. Before this paper, in [13] the authors solved the problem for controlling a flying vehicle or controlling single flying vehicle.

After consider the newest research in multi flying vehicles, the authors try to solve the controlling two flying vehicles for detect an object with an optimal control theory approach. As a control problem, controlling two flying vehicles with additional requirements like no collision between two vehicles and two flying vehicles cannot move far each other is an interesting problem. Explicitly, how to control two aircraft which flying together around a region to detect an object with additional requirements above is a nice problem. In this paper, the control design uses optimal control approach. In the optimal control problem, the dynamical model of flying vehicles is needed. The requirements for the flying vehicles movement can be summarized in the cost functional model. The novelty in this paper, behavior of two vehicles modeled in the cost functional andthe coupling between two vehicles just in collective duty.

2. Method

Optimal control is the main method used in this paper. With this method, a mathematical model is needed. The dynamical model describes the mathematical model of the flying vehicle. The cost functional model describes the collective task of two flying vehicles, in this paper is flying together and satisfy the special requirements like no collision between two air vehicles and no move far each other. The goal of two flying vehicles to perform this duty is to make the detection process to the lost object more efficient. The dynamical model of the-*i* flying vehicles which used in this paper is

$$\begin{aligned} \dot{r}_{n_i} &= V_i \cos\psi_i \cos\gamma^{c}{}_{i} \\ \dot{r}_{e_i} &= \mathrm{V_i} \sin\psi_i \cos\gamma^{c}{}_{i} \\ \dot{r}_{d_i} &= V_i \sin\gamma_i \\ \dot{\psi}_i &= \frac{g}{V_i} \tan\phi^{c}{}_{i} \end{aligned} \tag{1}$$

The dynamical model above follows the model from [14]. The detail explanation about this model also can be read in [14]. Model (1) works in North-East-Down coordinate axis. This paper uses north axis as vertical axis and east axis as horizontal axis,this paper neglecting the down-axis. So, the flying vehicles move in two dimensions. The mathematical analysis of the controllability and observability each flying vehicle is similar to paper [13]. The common duty of two flying vehicles is modeled by the cost functional. The cost functional which used in this paper is

$$J = \frac{1}{2}\int_0^T \delta \sum_{i=1}^{2} V_i + \beta\big(dis(1,2)\big)^2 + \frac{\rho}{\big(dis(1,2)\big)^2} dt \tag{2}$$

Journal of Physics: Conference Series **1567** (2020) 022083 doi:10.1088/1742-6596/1567/2/022083

Consider cost functional equation (2), the symbols δ, β and ρ are constant. The first summand of the cost functional is model the sigma input or control. The second summand of cost functional (2) make the flying vehicles do not move far away. The third one makes no collision between two flying vehicles. The symbol $dis(1,2)$ describes the distance between flying vehicle 1 and flying vehicle 2. The selection or the forming process of the cost functional model is not free process. The cost functional has big effect in optimal control problem. The cost functional, beside has relation with common duty of two flying vehicles, also has an important role in optimal control problem. The important role of cost functional is formally stated in the next theorem.

Theorem 2.1
The optimal control problem in this paper is exist.
Proof:
Each summand in (2) is convex, so(2) is convex. Then the existence of the optimal control is guaranteed. The definition of convex function can be found for example in [15].

3. Convergence analysis

The optimal control approach relates between the dynamical model and the cost functional into Hamiltonian Function. From Hamiltonian Function, use the partial derivative with respect to state variables and the partial derivative with respect to additional variables namely co-state variable, the Hamiltonian system is earned. The state variables in this paper are r_n, r_e and ψ. Number of state variables for each flying vehicle are 3 then the number of the co-state variables for each flying vehicles are also 3. In vector notation, since in this paper done for 2 flying vehicles then the state variables for this paper are $[r_{n_1} \quad r_{e_1} \quad \psi_1 \quad r_{n_2} \quad r_{e_2} \quad \psi_2]^T$. The main difficulty in optimal control method is no fixed values for co-state variables. If the values of the co-state variables are given randomly, the values for the state variables may be are not suitable with initial and boundary condition for state variables.Many methods to approximate for the value of the co-states variables can be found in [15]. This paper does not describe the method to approximate the value of the co-state variables. The simplest statement for convergence analysis is given as follows, if the values for co-state variable converge to the exact value for co-state variable then the computed value for state variables convergence to the values for state variables or initial and boundary condition. The analytical result about convergence analysis formally given in the theorem and its proof as follows,

Theorem 3.1
If the computed value of the co-sate variable is converges to the exact value of the co-states variables then the computed state variables values is converges to state variable vector.

Proof:
To make the proof of the theorem simpler, the following notations are needed. The notations for the exact value of co-state variable vector and computed co-state variable vector are given **CV*** and **CV** respectively. Also, the notations for the value of state variable vector and computed state variables are given **SV*** and **SV** respectively. Now, with these notations the theorem can be restated as follows, If the **CV** is converges to **CV*** then the **SV** converges to **SV***. Consider that, if **CV** is converges to **CV*,** means for any positive number ϵ, satisfy $||\mathbf{CV}^* - \mathbf{CV}|| < \epsilon$. Now, consider if $||\mathbf{CV}^* - \mathbf{CV}|| < \epsilon$, then the value of co-state variables which substituted to the ordinary deferential equation system and the values of the state variable on the boundaries are earned. Since $||\mathbf{CV}^* - \mathbf{CV}|| < \epsilon$ then values of co-state variables is the exact value of co-state variables then the values of the computed state variables is as close as possible with the values state variables as required. As a result, since the computed state variables is as close as possible with the values state variables as required then we can conclude that $||\mathbf{SV}^* - \mathbf{SV}|| < \alpha$, for any possitive number α.■

Journal of Physics: Conference Series **1567** (2020) 022083 doi:10.1088/1742-6596/1567/2/022083

After expose the convergence, the problem is ready to solve. The simulation result of this paper is given in the next section.

4. Simulation result

Before, the simulation result given, the simulation scenario is needed to expose. The simulation scenario is given as follows: two flying vehicles must move in around the searched object. The searched object is known in prediction location from the fact of the object location or the report from the witness. So, the duty of the two flying vehicles is move around the location to detect the exact location. If the location for the searched object is estimated and the searcher flying vehicles is sent to move around the location and the simulation can be done.

Suppose the witness of the sad event like lost of the aircraft give the information that lost aircraft in the position 12 miles to the east and 4 miles to the north from their position. The searcher team will fly two flying vehicles to detect the object in reported position. The first flying vehicle or flying vehicle1 move from position (6.75, 7) to (9.5, 0) and the second one move from (12, 11) to (17.5,0) in 10 minutes. Consider that the information from the witness can be viewed as estimated location (12, 4). As optimal control problem, the problem that must be solved is minimized functional (2) with initial time is 0 and final time T=10, subject to dynamical equation system (1) with i=1,2 with initial condition for each flying vehicles are (6.75 , 7) and (12,11) also the boundary condition for each flying vehicles are (9.5,0) and (17.5,0). The unit of time is minute and the unit of the distance is mil. The optimal trajectory each flying vehicles and estimated position can be found in Figure 1. The interpretation of optimal trajectory is trajectory for each vehicle with minimum distance or maximum probability for detect the lost object with coordinate (12,4).

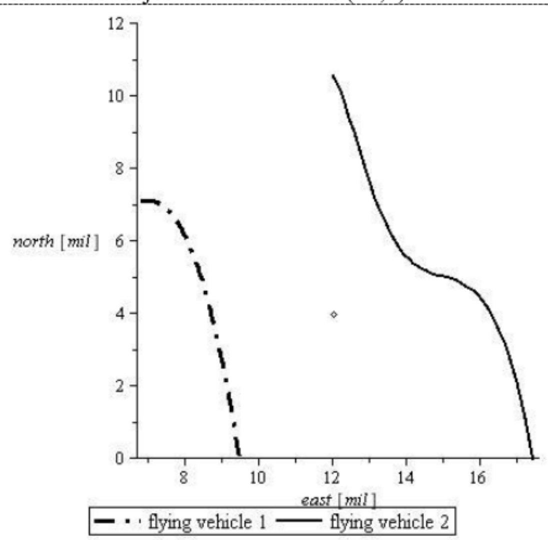

Figure 1. Simulation result.

The interpretation of optimal trajectory is trajectory for each vehicle with minimum distance or maximum probability for detect the lost object in coordinate (12,4). Through this optimal trajectory the lost object will be found as soon as possible. On the optimal trajectory closest to the object, the searcher team will most likely find the lost object.

5. Conclusion

From the introduction, the main background of the problem can be seen. The main problem is controlling two flying vehicles to detect a missing object. The method used to solve this problem is optimal control. Furthermore, the existence of optimal control problem and convergence analysis is exposed in this paper. The simulation result is given in the section before the conclusion section. As conclusion, the optimal control method works successfully to solve the problem of controlling two flying vehicles. The solution of the problem through optimal control method need mathematical model. The mathematical model consists of two model i.e. dynamical model of flying vehicles and the cost functional model. The dynamical model describes the flying vehicles which simulated and the cost functional describes the duty of two flying vehicles. Use optimal control method, the optimal trajectory each flying vehicles can be found.

Acknowledgments

This research supported by FSM Diponegoro University under research grant with contract number 4903/UN7.5.8/PP/2019.

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