Unmanned Aerial Vehicles Inspired by Birds: Engineering Allied to Nature

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Abstract.

This papper describes a modeling and prototipate flapping wing ornithopter model. Before the studies about FMAV mechanisms and systems, four models were built to understand and replicated the theorical foundations based on Technology Readiness Levels. During the modeling process, fatigue results and material choices were expected and happened based on reference literature and wing model switching was effective for modeling success. The prototyping phase is being initiated based on the results found in the modeling.

Keywords. Flapping Wings, Ornithtopter, UAV, MAV, FMAV and TRL.

1. Introduction

Unmanned Aerial Vehicles (UAV's) is a growing branch of research [1]. They can be employed in several fields, such as medical, monitoring, maping, military and delivery tasks [2]. This versatility comes from the UAV's smaller dimensions and weight, lowers costs and suitable for any situations.

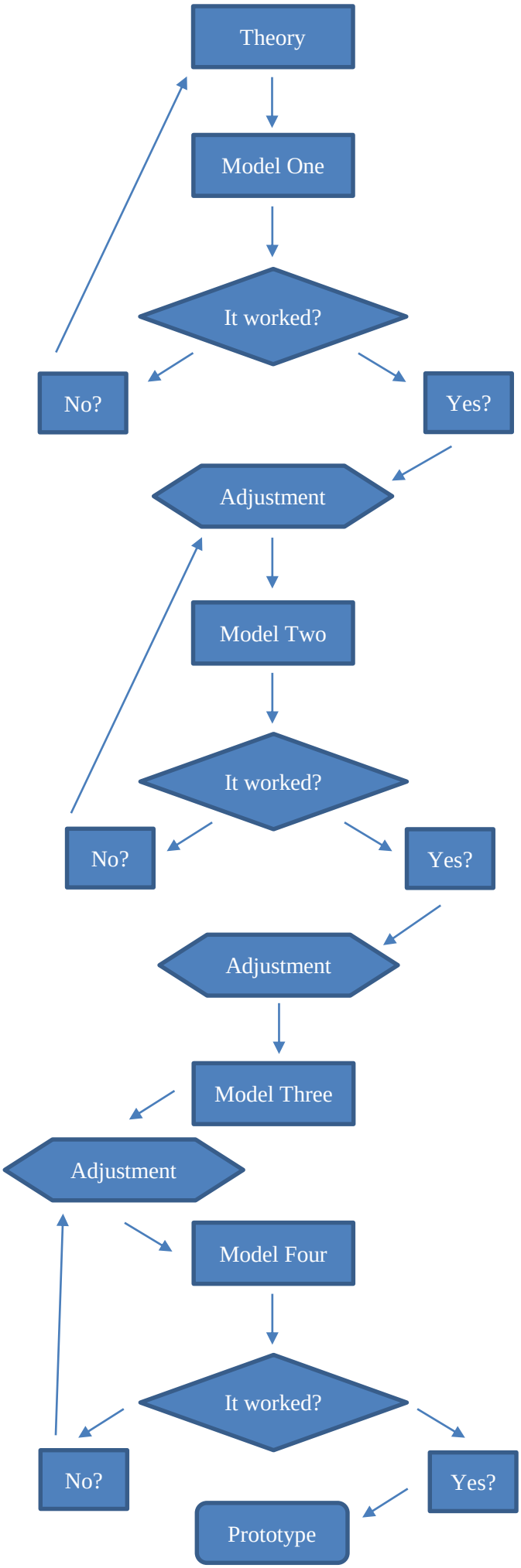
The capacity to transport cargos is another important ability performed by UAV's. Several itens including medical transportation food, sensors and infrastructure goods are just a few of a the possibilities listed. In medical field, UAV's can optimize time and delivery time [3]. The UAV's in then in used to overcome some logistic and geographic challenges, such as remote areas, trafic jams, high cost operations as well as decrase the products disposal. Flapping wings vehicles (FWV) have thein received considerable attention, since they present great agility, ability for concealment and high flight efficiency. They have also been integrate in multiple disciplines, controller designs, computer science mechanisms and many other applications.

The ornithopters field, try to mimic natural flight movements. A group in this field is a micro aerial vehicles (MAV), which have twenty centimeters of lenght and can fly at ten meters per second [7]. Festo SmartBird is an example of that [6]. Using a flapping wing by a servo motor – which turn the positive wing attack angule in negative angule whitin a short during and partially linear kinematics inspired in zoolical observing on flying locusts and seaguls can fly. Festo was a pioneer in flapping wing motion studies and is a reference in currently studies.

Lung-Jieh and Esakki also built a flapping wing model [7]. Although, they used a small bird model with a lenght and weight reduce. This model evolves from Golden-Snitch bird – which had 5.6 grams and 20 cm of lenght. Their goal was industry tecnlogy and educate students in ornthopters field.

2. Methodology

The applied modeling was based on literature and experimentation – trial and error were widely used in the first and second models. Third model was unsuccessful, however it was essential to build the fourth model – based on the errors. Below is a flowchart of the modeling and the methodology applied.



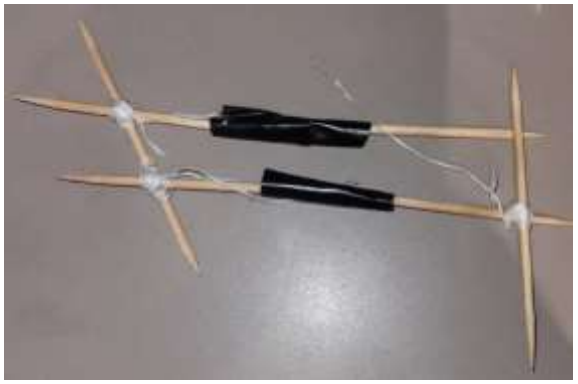
2.1 Modeling Importance

In any prototyping process, modeling steps are most important, because the project evolution can be verified. The steps can be analyzed accordingly the Technology Readiness Levels (TRL's) [8]. From research gaps until reaching the final results, each steps is broken down into technological advances. The FMAV did in this project reached TRL 1, 2 and 3. Because the modeling phase starting in basics principles and finished in analytical experimentation.

2.2 First Model

The main difficulty was understand the flapping mechanism [9] based on Festo SmartBird [6]. A simple wing simulation system was built using six wood toothpicks. Two bars were made joing the sticks with tape – in each bar, two sticks were used. The other two sticks were positioned in vertically and anguled with 45° in relation to the bars and joined using dental floss, as shown in the figure Figure 2.1.

Figure 2.1 First Model Wing



However, tape and floss union had problems with torsion movements in tests, such as in [9]. Althtoug, the flapping movement happened satisfatory . As it was only possible to apply concepts, model one reached TRL 1.

2.3 Second Model

The second model objectives was to solve the union problems and build a pair of wings. For that, toothsticks were changed to wood ice cream sticks – resulting in mechanical strenght. All of unions were maded by tape and pins – this resulted in better rotations with less wear than dental floss. The wings were fixed in cardboard support, as shown in figure in Figure 2.2.

Figure 2.2 Second Model Wing

The flapping movement was better than first model and reached the goals – having a pair of wings that rotates and fixed on a support. However, pin holes loosened during testing. Other problem was in construction, because low presision resulted in errors in wings angules of attack – were expected [10] but were much large. The model was also on TRL 1.

2.4 Third Model

Last model built was unsuccessful. A wood ice cream support was built using two rectangules joined by pins to simulated a bird body. Although, the support had no resistance and fall when wings were added. A tail was also developed, but was too heavy and cracked. Two figures it was show the body and tail.

Figure 2.3 Third Model Support

Figure 2.4 Third Model Tail

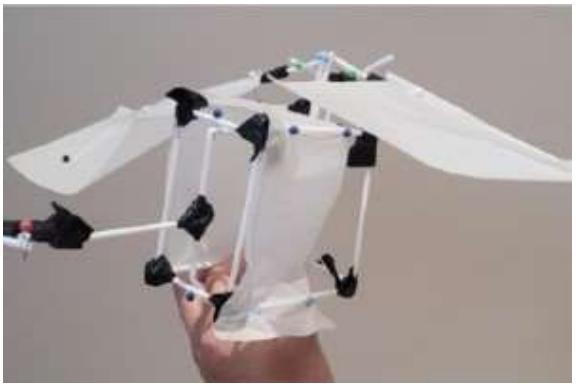
Supporting the bird structures continued to be a challenge. The support was discarded and tail was not reused. There was no change in the TRL's.

2.5 Fourth Model

It was still necessary to developed a structure for the bird body. For that, wood sticks were changed to plastic lollypop sticks (pls. The bird body was built in rectangule form using pls, pins and tape. The wings were also changed. The Festo model were complex and Lung-Jieh and Esakki model [7] was adhered. An "L" was made with pls and pins – mass reduction and better aerodynamics. A simple tail made using pls, tape and pins was increased in the bird body, but only with lateral movements. It was possible to add a primitive fairing too, using parchment paper – low mass and mechanical resistance. The built structures were represented in figures below.

Figure 2.3 Base Structure of Fourth Model

Figure 2.4 Final Model – Rear Vision



This is the last model in the modeling phase. Prototyping will need to find other materials for pls and the fairing. It also will be necessary to develop and add the functional mechanisms (such as a gears and a servo motor) – achieve the TRL 3.

2.6 Prototype Phase

The shape of the bird and the materials are the main goals of prototyping. Rectangular body shape will be kept with size reductions. Lollypop sticks, tape and pins will be exchanged. PETg or ASA will be used to the body construction – these two materials can withstand more than 373 K temperature, good to fly in any conditions. To improve mechanical resistaince and relieve internal tensions, thin carbon tubes will be added in the structure. Monocolt paper it will be used in fairing, because is mechanical strenght and withstands considerable temperature variations too. With these changes it is expected to reach TRL 4 and

5 (component validation in laboratory followed by validation in relevant environment).

3. Results

The FMAV developed was successful in understading the principles and mechanisms. Modeling phase analyzed wing torsions and problems to size possible prototype materials. Computer simulations have not been done yet, so no equations have been added.

The first model, based on Festo Smart Bird [6] aimed at understand the wing movement using simple materials – wood toothpicks, tape and dental floss. The model was fragile and broken and the project .materials used in first model due to the problems and enlarge dimensions and the concepts formulated was applied reaching TRL 2. Using wood ice cream sticks, tape and pins a pair of wings was built and fixed in a support. However, the pins loosened with the testes and the torsion in wings caused angule problems and malfunctions. Third model was unsuccessful, because the body developed could not support the components. The wing model it was too heavy and was changed based on Lung-Jieh and Esakki model [7]. Thereby, the wing had mass reduction and aerodynamic gain – lower drag. Furthermore, wood ice cream sticks were changed for plastic lollypop sticks. A rectangular body with fairing and simple tail was added in model reaching TRL 3. However, in prototype the materials will need to be changed to withstand greater mechanical stress. PETg or ASA will be used in the body construction with thin carbon tubes and monocolt will be used as fairing.

4. Discussion

Mimic the movements of nature is a difficult work. In relation to the movements of birds becomes even more difficult, because the flapping. To approach this movement, a set of gears, servo motor and other materials are used to form the flapping wings mechanisms. This system works by torsion the wings to rotate. The all models developed in this study tried to replied that – first based on the Festo model and then on the Lung-Jieh and Esakki model. Starintg from an initial model just understand the movement principles (TRL 1) to a final model with body, fairing and wings (TRL 2 and 3). It was possible to reach a satisfactory results – even with the use of simple and low desing accuracy. The prototyping will need to solve the observed materials and construction problems. The proposed solution can result in the evolution of the project to TRL 4 and 5.

5. References

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