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Automated Seeding Using Radio Controlled Aircraft

KEYWORDS: Aerial Seeding, Unmanned Aerial Vehicle, Global Positioning System, Wind Detection

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ABSTRACT *Few attempts have been made, especially in the Indian subcontinent, to modernize agricultural practices such as seeding and fertilizer delivery. In an attempt to increase efficiency, we have successfully tackled the seeding process by employing a manual RC controlled UAV. Our prototype has an on-board automated seeding mechanism capable of precise seed dispersal at a pre-calibrated flow rate, automatically accounting for factors such as altitude, ground position and wind speed. We intend to further develop our prototype into a 'generic automated aerial platform' capable of precisely dispersing seeds, fertilizer, pesticides or any mixture of the same.*

I. INTRODUCTION

Aerial seeding is a procedure in which most of the developments till date have largely been restricted to manned aircraft. It was specifically used to repopulate forest land as early as the 1930s (Horton, 2008). The technique became an operational reality in the 1960s when it was successfully implemented in the Wetter Southern forests and Australian Newsprint Mills Concession area (Hodgson & McGhee, 1992). However, since then, this application has not witnessed any serious concentrated efforts towards achieving total automation of the seeding procedure. Very few if not any employ Unmanned Aerial Vehicles for this purpose.

A big advantage of aerial seeding of cover crops is that more acres can be seeded in less time than with ground equipment (US Department of Agriculture, 2010). In a country like India, where majority of the workforce is engaged in agriculture, but techniques employed are still primitive, experimenting with such modern techniques becomes all the more important. We believe that successful implementation of this technique can play an important role in ushering an era of modern practices, thereby increasing overall productivity.

This attempt involves design and development of a prototype that utilizes an electronic system capable of taking into consideration the speed of the proposed UAV, altitude and wind direction, all being major factors affecting seeding. In accordance with ambient conditions, it then disperses seeds at pre-calibrated rates. The prototype developed also ensures that seeding is not affected by the presence of strong cross-winds that can disperse seeds to areas not intended to be seeded. Combined with an effective method to analyze and interpret the results, the prototype ensures effective seeding takes place.

This prototype is capable of serving as a platform for delivery of other services as well. This consideration was at the back of our minds during the design phase. The seed bay housing the seeds is not a permanent fixture, but an easily removable entity which can be replaced say for example by a tank housing pesticides to be sprayed. Other such applications can be thought of.

Figure 1: Aerial Seeding Prototype

II. IMPLEMENTATION

The prototype design involved two main phases, the aircraft design and the seeding instrumentation. Prior to which the design considerations were taken into account.

Design Considerations: These are the factors considered prior to the design of the prototype.

Seeding Rate for Optimal Dispersal: Seeding rate in case of aerial seeding needs to be directly varied depending on the ground speed and the height above ground level at which the aircraft is flying. These parameters have to be kept in mind during the control of flow rate of the seeds being dispersed.

Wind Conditions: Winds can hamper the seeding process by dispersing the seeds to areas that are not intended to be seeded. Any aerial seeding exercise has to account for this.

Effective Analysis of Seeding Process: At present a robust method of analysis of aerial seeding is not in practice. A technique had to be developed to enable us to find how effective the seeding has been during a particular run.

Aircraft Design: The design of the aircraft involved the following aspects:

Wing Selection: A suitable Aspect ratio was chosen for the aircraft by choosing right chord length. Good or high aspect ratio reduces the vortex- induced drag produced by the wing, decreases sinking speed and increases the maximum co-efficient of lift.

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Aerofoil Selection: To cater to heavy payload requirements airfoils similar to heavy lifting aircrafts were considered. But it was realized that these aircraft are designed for payload range and efficiency - all qualities not required in our design. Modern heavy lifting aircraft also change airfoil shape for take-off with the help of high lift devices such as flaps. To reduce weight, our aircraft was not fitted with any high lift devices meaning that the aerofoil chosen must have inherent high lift characteristics. Considering Design for Manufacturing and Assembly principles flat bottom airfoils were chosen.

During the construction phase the airfoils were cut out first on a balsa sheet and then were placed at equal intervals from each other over a span of 60 inches. A spar was placed through these airfoils at right angles. This gave the wing rigidity in the initial stage before the leading trailing edges of the wing were built. Two 12 mm thick airfoil shaped light weight plywood were stuck at the ends of the wing to provide strength during impacts caused during landing when the wing touches the ground first. After this the whole system was covered with balsa sheet for extra rigidity and then finally wrapped it with silver foil which makes the wings wetted surfaces. Choice of the thickness of the Balsa sheet was critical so as to maintain a desirable amount of stiffness and rigidity at curves and surfaces experiencing pressure during lift generation.

Aerofoil used was n-22-il N-22 with max thickness at 12.4 to 30 percent of chord and max chamber of 4 to 40 percent of chord was chosen (Airfoil N-22, airfoiltools.com).

It was determined the flow is laminar using the equation below where Re is Reynolds Number whose value was found to be 156564.2. V, ρ and μ are standard values of velocity (38 km/hr), density and viscosity of air near sea level. D is the characteristic length.

$Re=\rho*V*D/\mu$

Using Coefficient of lift (C) vs. angle of attack (α) graph for this airfoil the lift generated for this application was deduced from the equation below where S is the planform area, w wingspan, c chord length.

Lift Coefficient was taken as 1.1.
$S=w*c$

$L=0.5*V2*\rho*C*S$ (Anderson Jr. 2005)

Lift (L) generated was found to be 24.795N; theoretically corresponding 2.52 kg in weight but the lift generated gets reduced practically due to wing tip vortices losses. So we considered around maximum of 15 to 20 percent loss in lift The following data shows that the lift is excessively low due to lack of wetted surface of the wings platforms to generate lift. Hence theoretically the aircraft should not lift. But during the practical experimentation the aircraft did lift due to possible concept of prop-wash. According to the concept, the wind or the airflow from the propeller generates wind speeds much higher than the aircraft speed, generating an extra lift on the wing. Even by increasing the speed from 38 km/hr to 40 km/hr the lift generated also increases drastically by 2.75 N which is capable to carrying weight of up to 2.8 kg.

Fuselage and Tail Section: The fuselage is made again with balsa sheets but of thicker size. The balsa wood was used along the whole length of the fuselage considering the granular orientation of balsa sheets. For extra strength at critical places where stresses were more, ply wood was used .The firewall, other former walls and engine mount of the aircraft were again made of plywood.

The tail assembly consists of the vertical fin and the horizontal fin. Attached to the fins are the control surfaces, rudder and elevator respectively. The tail has been made of the thickest available balsa sheet that is 6 mm thick balsa sheet to avoid what is known as warp during flight, during turbulent wind conditions.

Landing Gear: Landing gear is a system made of 3mm diameter mild Steel rods and hollow tires. The advantage that we get is the shock absorbing ability .As the conditions that we had predetermined were that the land for takeoffs and landing will be rough and not very flat hence we did a thoughtful selection of this system for the application. The landing gear is attached to the fuselage by a small piece of ply wood, which is a part of the fuselage, helping in extreme cases of rough landings. During a very rough landing this small piece of plywood comes out to avoid the fuselage taking the rest of the impact, hence safeguarding the structure of the fuselage and the other parts.

Seeding Instrumentation: The following hardware scheme was adopted to achieve the set goal.

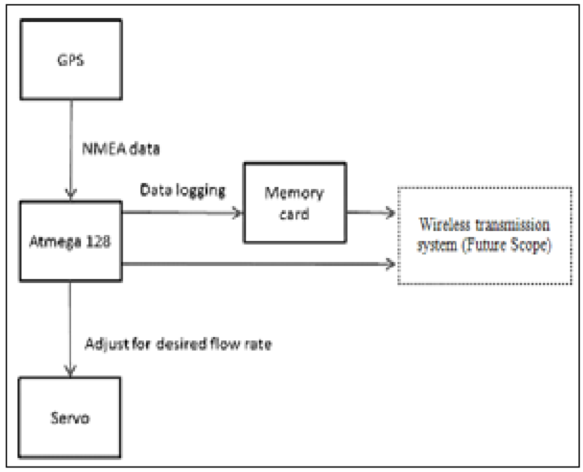

Figure 2: System Block Diagram

GPS (Global Positioning System): GPS is almost always employed to aid in tasks such as location fixing and navigation. However, to obtain a fix and maintain accuracy, a clear line of sight is generally required to space satellites. In the context of our application, this requirement was naturally fulfilled as seeding is carried out in farms, where the line of sight is not obstructed due to any tall structures etc. The GPS performs the function of chief data source, by providing data on vital parameters like airspeed, altitude and other NMEA data, which is further analyzed by the microcontroller.

Microcontroller: It is the microcontroller used on the UAV which looks after all the critical functions. Its primary task is to accept and analyze the NMEA data originating from the GPS module. It analyses quantities such as altitude, air speed, position etc, and when certain predetermined values are reached it commences the seeding operation. Another important task is to adjust the servo to such a value so that the seeding takes place at the predetermined flow rate. It can also be thought of as the brain of the entire system and is the entity which monitors critical pre-programmed interlocks, most importantly the wind interlock which is described later. Thus the microcontroller basically monitors all ambient conditions till they are in pre-programmed value ranges, and then accordingly manipulates the servo.

Servo Motor: We have made use of the servo motor as the Final Control Element (FCE).It is chiefly concerned with adjustment of flow rate. The flow rate is adjusted by the microcontroller by adjusting the position (angle) of the servo. The microcontroller adjusts the movement of the servo to match the flow rate that the user selects before take-off.

Memory Device: The memory card is chiefly concerned with storing the GPS data so that the user can later (post-flight) view all the parameters achieved during the flight. It is vital because the user can later analyze this data, and can tune the future flight parameters accordingly to optimize future flights. This data can be accessed in standard format by using any standard memory card reader and laptop. The stored data includes latitude and longitude co-ordinates, speed, and altitude. We have also incorporated a binary variable which indicates whether seeding is taking place or not. Thus, at a particular position co-ordinate, if the servo is open, then the value of the variable will be 1, else it will be 0. This can be used to generate visual simulations of the area seeded, and the co-ordinates of the un-seeded points can be marked. These can be targeted in successive flights.

Wireless transmission system: Incorporating zigbee into the prototype would help transmit the flight parameters real time to the operator so that he/she can take any corrective steps to improve flight performance during the flight itself rather than observing the data later. This would mean a significant improvement in the amount of information available to the operator at any particular moment during the flight. Inclusion of this unit depends on cost as well as range constraints. We plan to incorporate some form of wireless transmission system on board the UAV in our successive iterations, which will enable us to obtain real-time data.

Wind Detection: One of the primary concerns during aerial seeding is wind. If there is a strong wind, the seeding has to be stopped otherwise the seeds would be carried away and dispersed to areas not to be seeded. To address this issue we realized that it was essential to have some sort of a wind sensor on board. For seeds to hit their intended target, no cross-winds should exist. Wind in the direction of flight (including prop-wash) can be neglected as it won't affect the direction in which seeds disperse. Also we need to just detect whether the cross-wind magnitude is greater than a pre-determined threshold. We thus came up with the solution detailed below.

It utilizes a wind vane, commonly used to find the direction of wind. Since it is mounted on the aircraft it will always point in the direction the aircraft is travelling. If there is a strong wind from any direction other than the direction of flight, the vane will get displaced. The change in direction of the vane will be detected by a proximity sensor mounted inside the fuselage. This information would be given to the microcontroller to stop the seeding process

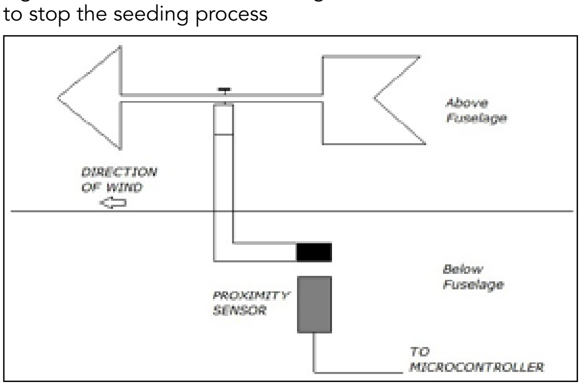

Figure 3: Wind Detection Sensor

III. TEST FLIGHT, RESULTS & DISCUSSIONS

Test flight description: A test flight with all electronics on board was carried out on 18/04/2014 at Saswad, Pune to check all systems. A CG check and range check was also carried out prior to the flight.

The figure below shows the flight path of the prototype. The blue dots represent the areas that were seeded by the aircraft. The Red dots represent the areas where the seeding did not take place owing to the predefined conditions not being met. This technique of representing the GPS Data log helps us get an idea of the effectiveness of seeding thereby giving the operator an idea of the area which is to be seeded in the consecutive run, if needed.

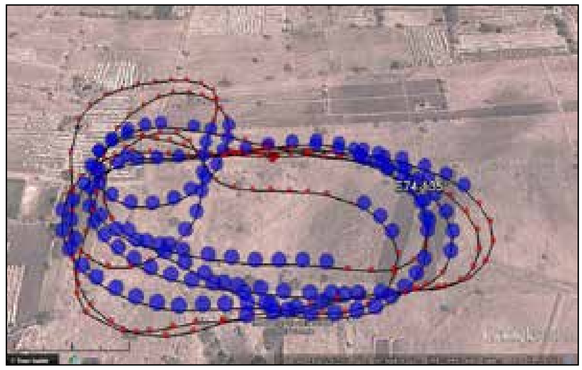

Figure 4: Seeding Map

Limitations of the system: There are certain inherent limitations of the systems at present

GPS Accuracy: The error is present because accuracy can vary between modules, time of day, clarity of reception, etc. Once the module starts moving, the track is relatively accurate. However if it's in the vicinity of tall structures, the accuracy can suffer.

Seed Carrying Capacity: The present system will be able to carry only 250g of seeds. But for seeding large areas larger seeding carrying capacity is needed. But the prototype can be scaled up to larger size without much effort. The basic electronic system would remain the same. The system could also be adopted for manned aircraft.

Need of a skilled operator: The aircraft needs a skilled operator for flying. The autonomous seeding mechanism does help not to overburden the operator but the flight path traced by the aircraft is dependent on the skill of the operator.

Future Scope: The addition of the following components could address the limitations present in the system.

DGPS System: Differential Global Positioning System (DGPS) is an enhancement to Global Positioning System that provides improved location accuracy, from the 3 meter nominal GPS accuracy to about 10 cm in case of the best implementations thereby improving the seeding effectiveness.

Autonomous Flight: A control system could be designed to make the flight path autonomous. Such a control system would eliminate the need of a manual operator.

IV. CONCLUSIONS

We believe we have designed a robust platform that can be pushed into its intended service with minor modifications.

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We would like to thank the creators of http://www.gpsvisualizer.com/ an online utility that creates maps and profiles from GPS data.

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