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Application of 3D Printing: Seed-Dispersal Drone

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Abstract: 3D printing is one of the most widely used tools for prototyping. The printing parameters determine the precision, quality, and weight of the final product. This work presents the application of 3D printing to produce a drone designed for seed dispersion in large or hard-to-access areas. These characteristics are often found in areas that need reforestation, such as forested areas. The designed drone has a payload capacity of 500 g of seeds and is equipped with a hopper intended to disperse seeds from plant varieties commonly found in regional forests. Preliminary results show that it is possible to disperse seeds over areas of 200 m² and from altitudes of up to 400 meters.

Keywords: Reforestation, Precision Agriculture, forest seeds.

I. INTRODUCTION

3D printing, also known as additive manufacturing, has made significant steps in recent years. Its uses range from rapid prototyping and small-scale production to the design of complex geometries. Due to its versatility, 3D printing has become a highly valuable tool in education. Despite the apparent simplicity of operating 3D printers and obtaining 3D-printed parts, it is necessary to understand how printing parameters affect the resulting piece and, therefore, the final product in which the printed part is used.

The parameters to consider in 3D-printing applications can be classified into several categories: design, geometry, process, and material. Each category comprises subcategories, which are shown in Figure 1.

On the other hand, new technologies have been widely applied in agriculture: improvements in seed conservation and storage, soil nutrient monitoring, measurement of environmental conditions, and even the use of robots in crops are just some examples of technologies already used in agriculture [1, 2]. The application of these technologies to improve crops according to each crop's specific requirements gives rise to the term precision agriculture [3]. Precision agriculture refers to monitoring nutrient conditions, soil status, climate, and the specific needs of each crop [4].

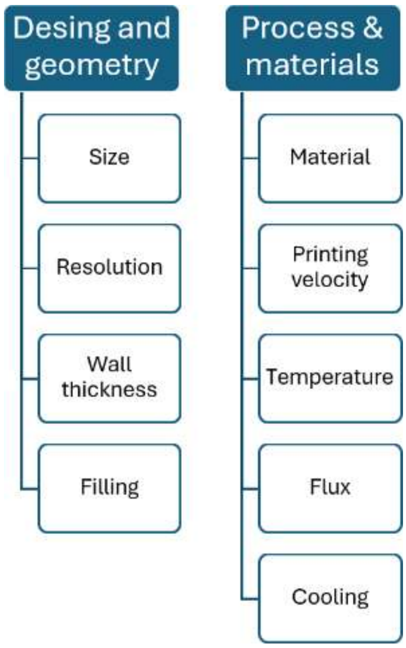

Fig. 1: Design parameters in 3D-printing applications.

In precision agriculture, unmanned aerial vehicles (drones) have been used to monitor humidity and soil conditions [5–7]. Additionally, drones have been used for reforestation in hard-to-access locations. This work presents the development of an unmanned aerial vehicle designed for seed dispersal [8, 9]. In particular, the drone design in this work accounts for the sizes of seeds from native plant

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varieties, enabling the dispersal of native tree seeds [10, 11].

Drones dedicated to seed dispersal vary; regarding payload capacity, it is common to find drones with capacities of 5-10 kg. However, these designs use 6 and 8 motors, which increases cost but, in turn, provides greater stability and redundancy. Recent models have capacities of up to 40 kg to improve efficiency by reducing the number of trips needed to cover a given area, at the expense of higher drone costs.

A key aspect to consider in designing a seed-dispersal drone is the seed release mechanism. Examples include drones equipped with pressurized containers, biodegradable capsules, dispersal of germinated seeds, or even combinations of seeds with fertilizers [12, 13]. This work presents the design of a drone with a hopper. The drone can disperse seeds from regional flora and is compatible with the size of seeds from native trees.

II. DEVELOPMENT

The drone's development was divided into stages. First, the drone's mechanical design, which includes the structure that constitutes the drone and on which all electronic components are placed. Second, the electronics—including motors, a telemetry system, GPS, a battery, and a controller—purchased as part of a development kit [14]. An essential part of the drone is the hopper, which stores seeds and includes an electromechanical mechanism to release a set quantity. Finally, a graphical interface displays real-time flight parameters, including battery charge level, the number of satellites connected to the telemetry system, potential critical flight errors, and the drone's camera image. The drone's connection scheme is shown in Figure 2.

Since various web interface development packages are available online, a web-based graphical interface was employed.

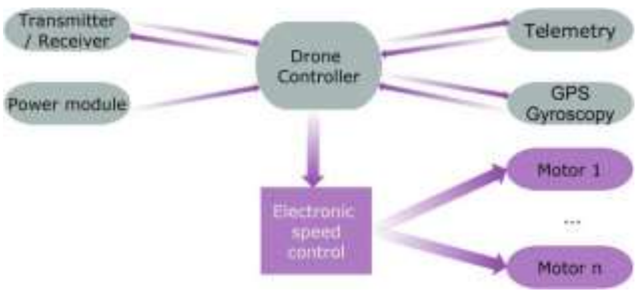

Fig. 2 Block diagram of the drone's main components

A. Drone design

The drone design began with several commercial models and existing prototypes as references [15–17, 20–22]. It was decided to design a modular multirotor drone to reduce parts size and complexity. The modular design assumed parts that could be fabricated via 3D printing, enabling easy component replacement. The main design consists of four arms, a base, and a hopper for seed storage and release. One important part is the drone's arms, which must meet performance, durability, and efficiency criteria.

For the drone's design, the following points were considered: a) Aerodynamic system, which defines the power required for correct operation. b) Mechanical design: proposed to withstand the loads to which the drone will be subjected. c) Drone control device/system: enabling communication (telemetry and radio control) and geolocation; the considered parameters values are presented in Table 1.

Parameter	Values	Observations
Maximum drone weight	2 kg	This weight does not include the payload
Maximum payload	500 g	Useful load (weight of the seeds)
Flight endurance	10 min	Considering an altitude of 20 m and a speed of 1 m/s

TABLE 1. Drone design parameters.

B. Battery selection

For battery selection, the following aspects were considered: continuous discharge rate (C), battery capacity (Q), and battery voltage (V). The continuous discharge rate allows estimating the current the battery can deliver continuously without being damaged; this intensity can be estimated using Equation 1.

$$C=Q/1000 \quad (1)$$

It is necessary to consider motor consumption when estimating flight time (T), because motors consume the most current. For the remaining components, their consumption is minimal compared to the motors and was therefore ignored. Flight time can be calculated using Equation 2.

$$T=(C\times V)/P_t \quad (2)$$

where: Pt is the total motor consumption, V is the battery voltage, and C is the battery capacity. For this work, a 4-cell battery with a nominal voltage of 14.8 V and 9.5 Ah, and a discharge rate of 90 C, was considered.

C. Mechanical design

For the mechanical design, a cross-style (X) chassis was considered to simplify the mechanical design. For the calculation of total force, the force of each motor and the proposed number of rotors were used, as in Equation 3.

$$E_t=(n_m)\times f_e \quad (3)$$

where n_m is the number of motors and f_e is the force of each motor. In this case, Racer star 2212 motors were selected; this type provides a force of 790 g, so with at least four motors, the total force would be 3.16 kg at maximum power.

The drone arm design, shown in Figure 3, includes multiple triangular cutouts whose primary objective is to reduce the arm's weight without compromising structural strength [16, 17]. Moreover, the arm's geometry ensures a uniform distribution of mechanical stresses during flight, which is critical because the arms must withstand forces generated by motors and propellers, as well as vibrations and dynamic movements. The circular base where motors are mounted features strategically placed perforations that securely and stably hold the motors, optimizing the connection between the arm and the motors.

Other aspects to consider in the drone's structural design are aerodynamics and payload capacity. The latter is crucial because this drone is intended to lift seed loads.

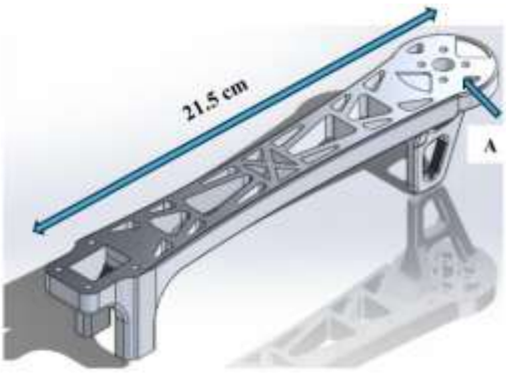

Fig.3 CAD design of the drone arm. Portion A of the figure is the base on which the motor will be mounted.

One of the parts where stress is concentrated in a drone is the motor mounts, which in this case are the drone arms. Therefore, the drone arm design was subjected to a stress analysis—specifically, a static analysis under a 10 kg load. Figure 4 shows the results of the SolidWorks analysis.

The stress value is obtained by multiplying the drone's total load by a safety factor. In this case, the drone's total weight is 2.85 kg, considering the seed hopper (100 g) and the seeds (500 g). Safety factors commonly range from 1.5 to 4, with lower values used for ductile materials like metals and higher values for brittle materials. In our case, a safety factor of 3.5 was chosen to account for potential issues with parts manufactured via 3D printing.

The von Mises strain results show that the design has strain values within the elastic region. Figure 4B shows the results of the static displacement analysis, performed under a 10 kg load.

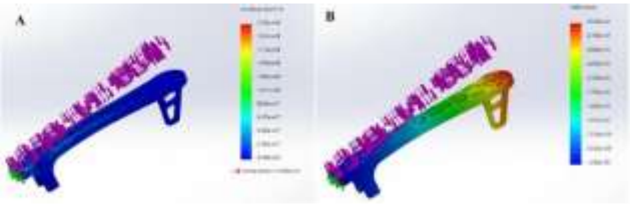

Fig.4 Stress and strain analyses performed on the drone arm under a 10 kg load. A) Von-Mises stress, B) Plastic deformation.

In the drone design, 6- and 4-propeller models were considered. Preliminary tests showed that, in our case, a four-arm drone offered greater stability while also simplifying control. The chassis shape uses a central platform extending to the arm mounting points, which allows balanced load distribution and helps maintain drone stability during flight, crucial to avoiding tilt or instability.

Figure 5A shows the drone's main structure. In red is the drone's central platform, designed to provide a solid, lightweight structure that supports components such as the flight controller and motor arms. In gray are the arms that support the motors.

Various flight tests were carried out to address necessary aspects, such as the take-off and landing phases. Modifications were made to reduce the drone's weight without affecting flight stability, ensuring it can lift a 600 g hopper. Figure 5B shows an assembly of the drone structure, hopper, and landing structures.

Fig. 5 CAD design of the seed-dispersal drone. A) Main platform B) Assembly of the platform and the dispersal hopper.

D. Seed-dispersal hopper

The dispersal mechanism was designed considering the dimensions of plant varieties native to the high-mountain region of the state of Veracruz [11]. For the hopper design, the largest seeds in the region were considered, which have dimensions of 25 mm by 12 mm [10]. Figure 6 shows the CAD design of the hopper (6A) and details of the support for the seed release mechanism (6B). The release mechanism is a guillotine type, using an MG995 servo motor and a 3D-printed gate.

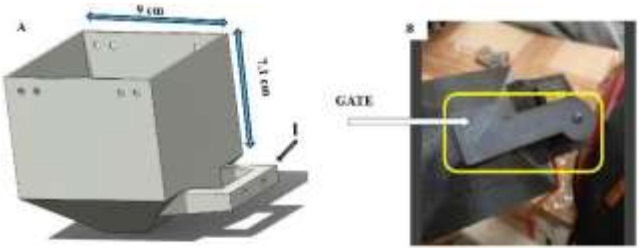

Fig. 6 A) CAD design of the hopper for loading and dispersing seeds, B) Bottom view of the hopper for seed releases, 1) Support for the seed release mechanism.

For seed dispersal, the drone has two modes: time-programmed and manual. In the tests, dispersal was performed manually; that is, the operator directly activated the dispersal mechanism via the drone's remote control. The number of seeds dispersed depends on the variety, as seed size varies among varieties. For seed dispersal, it is necessary to consider the altitude at which dispersal will occur because, at higher altitudes, seeds become more widely dispersed. The remote control used has a range of approximately 5 km. In the tests carried out, the drone was raised to between 10 m and 40 m, and the battery provided a flight autonomy of 8 to 12 minutes.

It is important to emphasize that seed release relies solely on gravity. To increase the likelihood of seed germination, tests were conducted with oyamel seeds with husks; average seed dimensions were 25 mm long by 12 mm wide.

E. Flight programming

Figure 7 shows a screenshot of the flight control software. The red section shows an aerial view of the test area provided by the telemetry system. The blue section shows the drone's tilt angle provided by the gyroscope, and it also shows the drone's state—armed or disarmed. This window also displays errors that may occur during flight. The yellow section shows flight parameters such as altitude and speed.

Fig. 7 Flight control screen.

III. FUNCTIONAL FLOW

A. Drone

Figure 8A shows the constructed drone; in blue are the parts that make up the drone's main structure, while in black is the hopper designed for transporting and dispersing seeds. The final design has a structure that was modified to reduce weight without affecting flight stability, while ensuring the drone can lift a 600 g hopper. This weight includes the hopper itself (100 g) and the seeds for dispersal (500 g).

B. Hopper

Figure 8B shows an image of the constructed hopper; within the same image, lentil seeds appear for demonstration purposes, as well as a test of the quantity of seeds released. The designed hopper has a capacity of 500 g, and the seeding mechanism's actuation time can be programmed to release the required number of seeds.

Fig. 8 A) Photograph of the constructed drone, 1) landing gear, 2) hopper, 3) main platform and controller, 4) rotor arm, 5) battery, 6) antenna, 7) seed-release mechanism. B) Picture of the designed hopper.

C. Final tests

For seeding, the AltHold flight mode was implemented and tested to maintain a constant altitude during operation. This mode is effective in dispersal tests because it allows more controlled flight, which is important for tests in hard-to-access locations. The seed delivery system has been tested in both manual and timed modes, with more than 15 successful tests demonstrating the design's effectiveness and system performance under controlled real-world conditions. Figures 9A and 9B show photographs from the drone tests. Figure 9C shows the drone during the seed-dispersal process, as well as a close-up of the dispersal.

Fig. 9 A) Initial flight phase of the drone, B) flight at 20 meters altitude, C) moment of seed release; the inset shows seeds falling from the drone in detail.

The tests conducted show that our design can fly for 8 to 12 minutes due to the battery capacity. This time was sufficient to disperse seeds over an area of 200 m², with seed drops at approximately 5-meter intervals. Flight and seed-dispersal tests were conducted in the town of Cuitláhuac (Veracruz, Mexico).

IV. CONCLUSIONS

During the tests, it was necessary to continuously adjust the PID controller parameters to maintain flight stability across different conditions. It is important to note that with AltHold flight mode, position control no longer uses the geolocation system, so the pilot must have more experience to control the aircraft. Moreover, for flight-mission programming, the pilot must physically locate the points that will delimit the drone’s route.

The modular design and 3D printing facilitate scaling up or down. Scaling may be necessary to carry a larger quantity of seeds or to use higher-capacity batteries, enabling longer flight time. Because seeding germination is outside the manuscript’s scope, no further controls were performed on the dispersed seeds.

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REFERENCES

[1] M. A. M. Al-Obaidi, M. A. H. Radhi, R. S. Ibrahim, and T. Sutikno, Technique smart control soil moisture system to watering plant based on IoT with arduino uno (2020, no. 5). 2020, doi: 10.11591/eei.v9i5.1896

[2] R. R. Shamshiri et al., “Research and development in agricultural robotics: A perspective of digital farming,” International Journal of Agricultural and Biological Engineering, vol. 11, no. 4, pp. 1–14, 2018, doi: 10.25165/j.ijabe.20181104.4278.

[3] O. Santillan and M. Renteria, “Agricultura de precisión,” F. Consultivo, Ed., ed: Foro Consultivo A.C:, 2018.

[4] L. C. Caicedo Rosero, G. Lara Hernandez, K. Morales Almanza, and J. J. A. Flores Cuautle, “Sensores Electrónicos en la Agricultura de Precisión,” Ideas en Ciencias de la Ingeniería, vol. 2, no. 1, pp. 4–16%V 2, 2024–02–04 2024, doi: 10.36677/ideaseningenieria.v2i1.22176.

[5] T. Qu et al., “Drone-based multispectral remote sensing inversion for typical crop soil moisture under dry farming conditions,” Agriculture, vol. 14, no. 3, p. 484, 2024, doi: 10.3390/agriculture14030484

[6] K. Wu et al., “A new drone-borne GPR for soil moisture mapping,” Remote Sensing of Environment, vol. 235, p. 111456, 2019, 10.1016/j.rse.2019.111456

[7] A. Halla, N. Narra, and T. Lipping, “Role of Drones in Characterizing Soil Water Content in Open Field Cultivation,” in New Developments and Environmental Applications of Drones: Proceedings of FinDrones 2020: Springer, 2021, pp. 121–137, doi: 10.1007/978-3-030-77860-6_7

[8] M. Hentschke, E. Pignaton de Freitas, C. H. Hennig, and I. C. Girardi da Veiga, “Evaluation of altitude sensors for a crop spraying drone,” Drones, vol. 2, no. 3, p. 25, 2018, 10.3390/drones2030025

[9] A. García-Munguía et al., “A review of drone technology and operation processes in agricultural crop spraying,” Drones, vol. 8, no. 11, p. 674, 2024, doi: 10.3390/drones8110674

[10] Secretaría de Medio Ambiente. Catálogo de semillas forestales del banco de Germoplasma Vegetal Coahuila, Secretaría de Medio Ambiente, Coahuila, México, 2021. [Online]. Available: https://sma.gob.mx/wp-content/uploads/2021/06/CATALOGO_SEMILLASSb.pdf

[11] J. E. Rivera Hernández, R. Muñoz Márquez, A. Vargas Rueda, G. Alcantara Salinas, N. Real Luna, and R. Sánchez Páez, “Flora, vegetación y paisaje de la región de las altas montañas de Veracruz, México, elementos importantes para el turismo de naturaleza,” Agro productividad, vol. 12, no. 12, 2019.

[12] G. Singh, A. Singh, and G. Kaur, “Role of Artificial Intelligence and the Internet of Things in Agriculture,” in Artificial Intelligence to Solve Pervasive Internet of Things Issues, G. Kaur, P. Tomar, and M. Tanque Eds.: Academic Press, 2021, ch. 16, pp. 317–330, doi: 10.1016/B978-0-12-818576-6.00016-2

ISSN: 3139-2385

[13] M. I. Ejimofor, C. O. Aniagor, S. N. Oba, M. C. Menkiti, and V. I. Ugonabo, “Artificial intelligence in the reduction and management of land pollution,” in Current Trends and Advances in Computer-Aided Intelligent Environmental Data Engineering, G. Marques and J. O. Ighalo Eds.: Academic Press, 2022, pp. 319–333, doi: 10.1016/B978-0-323-85597-6.00009-4

[14] Vatel Vanguardia en Telecomunicaciones. “La casa del dron.” Vatel Vanguardia en Telecomunicaciones. https://www.lacasadeldron.mx/categoria-producto/refacciones/ (accessed 06/07/2025, 2025).

[15] C. Martínez Abril, “Diseño y desarrollo de un prototipo físico de dron cuadricóptero,” Universitat Politècnica de València, 2019.

[16] P. G. Mar-Hernández, J. C. Grijalva-Acuña, A. Cerón-Franco, and V. M. Martínez-Álvarez, “Diseño y manufactura de un dron cuadrirrotor,” Volumen 1, Año 3, p. 10.

[17] A. Santiago Huete, “Diseño y fabricación de un prototipo de dron,” Universitat Politècnica de València, 2023.

[18] J. Nistal Lastra, “Diseño de un drone programable de bajo coste,” 2017.