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Uso de vehículos aéreos no tripulados en la determinación de índices de condición superficial de pavimentos
Use of unmanned aerial vehicles in the determination of pavement surface condition indices

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Resumen-- **La infraestructura vial juega un papel fundamental en el desarrollo de las naciones, tanto en términos de calidad de vida como de crecimiento económico. En Colombia, la gestión de pavimentos es un aspecto crucial para mantener las carreteras en buen estado y garantizar su correcto funcionamiento. Actualmente, los métodos tradicionales de evaluación de pavimentos son costosos y ambiguos, por lo que se busca implementar nuevas tecnologías como los vehículos aéreos no tripulados (VANTs) para optimizar este proceso. La investigación que se presenta tiene como objetivo determinar la viabilidad de utilizar VANTs para calcular el índice de regularidad internacional (IRI), un indicador clave para evaluar la condición superficial de los pavimentos. A través del procesamiento de imágenes capturadas por los VANTs, se extraerá información detallada de la superficie de rodadura, la cual será analizada en software especializado de gestión vial. Esta información permitirá identificar zonas con daños potenciales y predecir su evolución en el tiempo, facilitando la toma de decisiones oportunas para el mantenimiento y rehabilitación de las carreteras.**

La implementación exitosa de esta tecnología tendría un impacto significativo en la gestión de pavimentos en Colombia, permitiendo una evaluación más eficiente, precisa y económica de la red vial nacional.

Palabras clave— UAS; infraestructura; administración de pavimentos; Sistemas de Información Geográfica.

Abstract— **Road infrastructure plays a fundamental role in the development of nations, both in terms of quality of life and economic growth. In Colombia, pavement management is a crucial aspect of keeping roads in good condition and ensuring their proper functioning. Currently, traditional pavement evaluation methods are expensive and ambiguous, so new technologies such as unmanned aerial vehicles (UAVs) are being implemented to optimize this process. The research presented aims to determine the feasibility of using UAVs to calculate the International Regularity Index (IRI), a key indicator to assess the surface condition of pavements. Through the processing of images captured by the UAVs, detailed information will be extracted from the running surface, which will be analyzed in specialized road management software. This information will make it possible to identify areas with potential damage and predict its evolution over time, facilitating timely decision-making for road maintenance and rehabilitation.**

The successful implementation of this technology would have a significant impact on pavement management in Colombia, allowing for a more efficient, accurate and economical assessment of the national road network

Index Terms— UAS; infrastructure; pavement management; Geographic Information Systems.

I. Introduction

ROADS are the most important road asset managed by the State. This type of infrastructure is fundamental in the socioeconomic development of the nation, as its function is to move goods, people and the supply of services (Herra Gómez, 2018) To carry out these activities, it is important that the roads are functional, safe and comfortable. To achieve this, routine maintenance activities must be carried out according to what was initially scheduled (Biçici & Zeybek, 2021) in turn, having

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infrastructure with optimal conditions reduces the environmental and vehicular externalities of the operation of the road corridor (Kashiyama et al., 2020)

In Colombia, the National Institute of Roads (INVIAS) has standards and manuals related to the construction, auscultation, maintenance and administration of road assets (Ministerio de Transporte, 2006; Ministerior de Transporte, 2016) In relation to auscultation, these evaluations involve technical, functional and structural elements of the pavement (Pacha & Zárate Torres, 2020) In particular, functional evaluation involves the calculation of the surface conditions of the pavement and their respective indices. As a result of this assessment, it is possible to correlate elements of the structural state according to the type of damage and its severity (De Solminihac T. et al., 2019) Another application of the results obtained is the creation of behavioral models, which, according to Solminihac *et al.* (Solminihac et al., 2019) are mathematical expressions that predict the evolution of the pavement condition over time, based on initial or commissioning conditions and throughout the useful life. The purpose of these models is to predict the effects of proposed maintenance activities and their relationship to the quality assurance of functionality indicators.

In the international context, the use of unmanned aerial vehicles (UAVs) and the application of artificial intelligence techniques have made it possible to automate auscultation processes (Chun et al., 2021; Gopalakrishnan, 2018; Gui et al., 2018; Hoang, 2018; Pan et al., 2018; Wang & Ye, 2022; Yousaf et al., 2018; Zhang et al., 2020). On the other hand, the implementation of LiDAR technology and high-resolution cameras has made it possible to determine conditions more accurately (Ragnoli et al., 2018; Tan & Li, 2019) The application of UAVs has proven to be an application with acceptable technical conditions and reduce the cost of capturing information. Recently, research has focused on the number and distribution of field control points for the survey of civil infrastructure (Jofré Briceño et al., 2021; Prosser-Contreras et al., 2020).

II. Methods

The development of the research includes 5 stages. The first includes flight planning activities and the determination of optimal conditions for information capture, these parameters were extracted from the recommendations of similar studies (Atencio et al., 2022; Romero-Chambi et al., 2020) The second stage includes the realization of the flight, for this, it was carried out through the Phantom 3 model, the specifications of the camera are exposed in Table 1.

In the third stage, the images are processed using the tools of the Agisoft Metashape photogrammetric software, the workflow is shown in Fig. 1.

The fourth stage involves extracting data from the digital elevation model. To automate this stage, a sequence of tools was developed in ArcMap software (ArcGIS), the schema presented in Fig. 2. In the last stage, the IRI is calculated according to the sampling range (Badilla Vargas, 2011; Sayers, 1995) and processed through the ProVAL software.

TABLE I
Sensor characteristics

Feature	Value
Sensor	1/2.3" CMOS
Effective Pixels	12 MP
ISO Range	100 – 1600 (photo) and 100 – 3200 (video)
Lens	FOV 94° 20mm (35mm format equivalent) f/2.8
Image Size	4000 x 3000

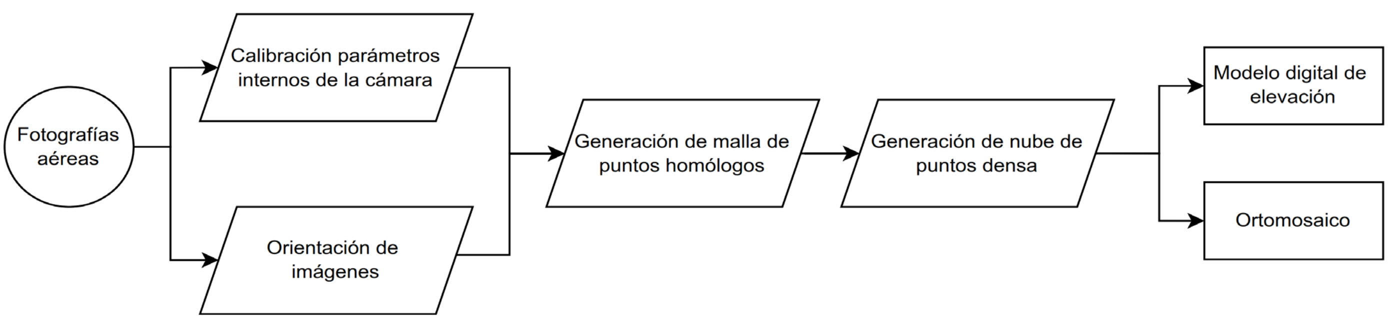

Fig. 1. Processing of photogrammetric information. (Source: Authors).

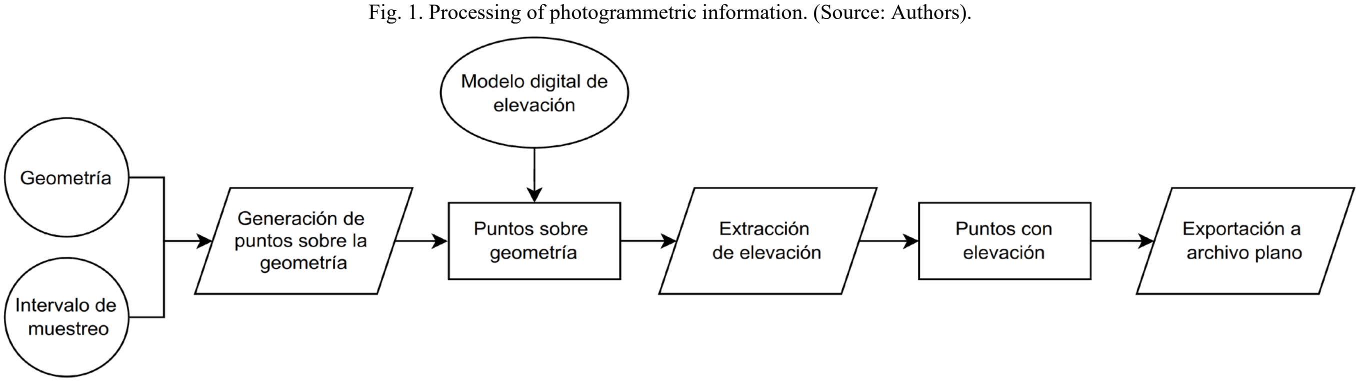

Fig. 1. Tool structure for data extraction. (Source: Authors).

III. Results

There is no consensus on optimal flight parameters. This process must be done through iterative processes. The experimental designs developed for this purpose are carried out through the application of techniques such as Taguchi factors to converse statistical sufficiency (Gisbert et al., 2020)

As a result of stage 3, the dense point cloud shown in Fig. 3 (a) was extracted. It is possible to identify that it is a one-lane road with two lanes of traffic. Figure 3 (b) shows the alignment from which the data were extracted. Fig. 4 shows the longitudinal profile obtained during the flight at 40 m.

From the extraction of data from the ProVAL software, the IRI is presented based on the sampling range. Figure 5 shows the results of the flight.

A. Discussion of the results

From the results obtained, it is possible to affirm that it is necessary to analyze the flight height and overlaps in a timely manner. Some authors (Cruz Toribio & Gutierrez Lazares, 2019) recommend capturing information related to variables such as GSD between ranges of 0.30 to 0.35 cm/pixel. On the other hand, the time of capture of the information is relevant, Atencio *et al.* (Atencio et al., 2022) recommend hours with less shade.

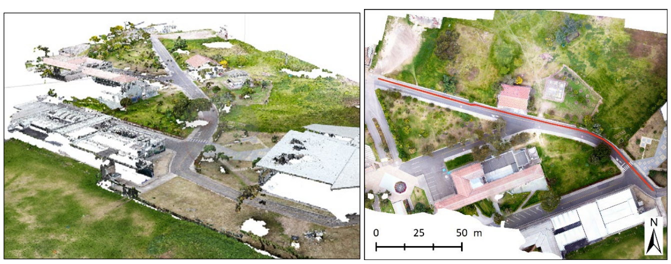

Fig. 3. Dense point cloud of the generated model. (Source: Authors).

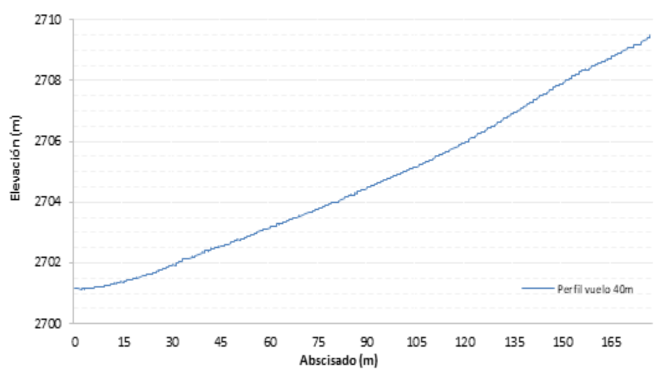

Fig. 4: Longitude profile of the analysed section. (Source: Authors).

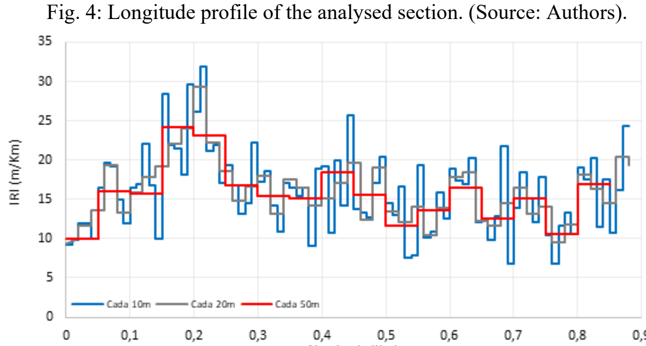

Fig. 5: Variation of the IRI as a function of the sampling range. (Source: Authors).

On the other hand, the implementation of control points in the field is essential. Despite obtaining a low error for the flight of 40 m, it is advisable to adjust the model by arranging control points in the field (Ferrer-González et al., 2020)

IV. Conclusions

From the results obtained, it is concluded that the results do not depend on the flight height but on the surface sampling distance (GSD), therefore, it is recommended that, in the information capture process, values between 0.3 to 0.4 cm/pixel are ensured.

The continuous information capture resulting from this methodology allows the analysis of the profiles and behavior of the IRI in the circulation width. This represents an advantage in relation to the collection of information.

Through the systematic review process, the relevant variables in the processing of images captured with UAVs were identified. The use of these platforms represents time savings and increased security in the data capture process. The quality of the information is acceptable in project-level analyses. As a reference in future research, the objective of these should be to look for the combination and distribution of ground control points and their influence on the quality of the results. On the other hand, another source of research is the implementation of artificial intelligence techniques for the extraction and processing of information from dense point clouds.

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