Proposed Methodology for inspection of road networks using Unmanned Aerial Vehicles (UAV)

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Abstract: The disorderly growth of the vehicle fleet in the world has caused immeasurable road phenomena. In particular, in Brazil, from 2009 to 2019 there was an 80% growth in the existing vehicle fleet in the country. This increase has caused an intense flow of vehicles on the existing road networks in the country, which, in contrast, only offers about 12% of its existing paved network. Thus, this work aims to propose an innovative methodology in Brazil for inspections of road networks aiming at the identification of apparent pathologies through Unmanned Aerial Vehicles (UAVs), since, the reflex of the increase in the vehicle fleet has caused deterioration pavements due to increased flow and overloads of heavy vehicles. To this end, inspections were carried out on two important highways in the state of Paraíba and the results indicated pathologies such as interconnected cracks, alligator leather, landslides, longitudinal and transversal cracks, holes or pans and patches, indicating that the proposed methodology for inspection on highways through of the UAVs proved to be easy to apply and objective.

Keywords: Road Mesh, Asphalt Pavements, UAV, Inspection, Asphalt Pathology

1 Introduction

Asphalt pavements are structures composed of several layers, with the top covering, better known as asphalt, the layer that receives the most climatic actions and loads and overloads of vehicle axles in general. According to Bernucci et al. (2008, p.09) floors are classified into 2 types: rigid and flexible. Usually, the flexible pavements are correlated to the asphalt, however, its covering is supported on a base layer, another one of sub-base, reinforcement of the subgrade, and finally, it is supported on the subgrade.

According to the National Confederation of Transport (CNT) in Brazil, road transport is the most used in the transportation matrix, a factor that corroborates the flow overload in the existing road networks, which has caused premature wear of the networks, as well as increase traffic accidents and high transport costs. It is worth mentioning that cargo vehicles are the ones that most contribute to the premature deterioration of the pavements, due to the excess of shit on the vehicle axles.

Since Brazil is a country of continental proportions and an extensive road network, currently the inspection of highways requires a large technical body. Even so, it is known that all the effort made by the aforementioned professionals is not enough since the calamity situations that our roads face are reported daily in various media. In this sense, to carry out more efficient and effective inspections on highways, one can use technology such as Unmanned Aerospace Vehicles (UAVs).

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2 Objectives

To propose a methodology for road mesh inspections aiming at the identification of apparent pathologies, with the creation of Digital Surface Models (MDS), generated through the processing of the images collected with UAV, with the final result being an Orthomosaic.

3 Methods

The research is characterized by being qualitative, due to the natural environment being the direct source for data collection, with the researcher being the key element of the research. Data analysis is done inductively, with the process and its meanings as the main focus. According to Gil (2002), "Qualitative analysis depends on many factors, such as the nature of the data collected, the sample size, the research instruments and the theoretical assumptions that guided the investigation. However, this process can be defined as a sequence of activities, which involves reducing the data, categorizing that data, interpreting it and writing the report. The methodological sequence can be seen in Figure 1.

The research originated from the problems evidenced in most of the existing road network in the country. From the analysis of the maintenance and conservation procedures of the highways, regulated and inspected by the National Department of Transport Infrastructure (DNIT), with manuals available on the website of the local authority, and after consulting the current regulation for the use of UAV / RPA written by the Agency National Civil Aviation Agency (ANAC), the necessary methodology for road inspection was developed with the use of UAVs in the multi-engine category to optimize operational processes such as reducing operating time and costs, in addition to highlighting the causes and the effects generated by a delayed road network.
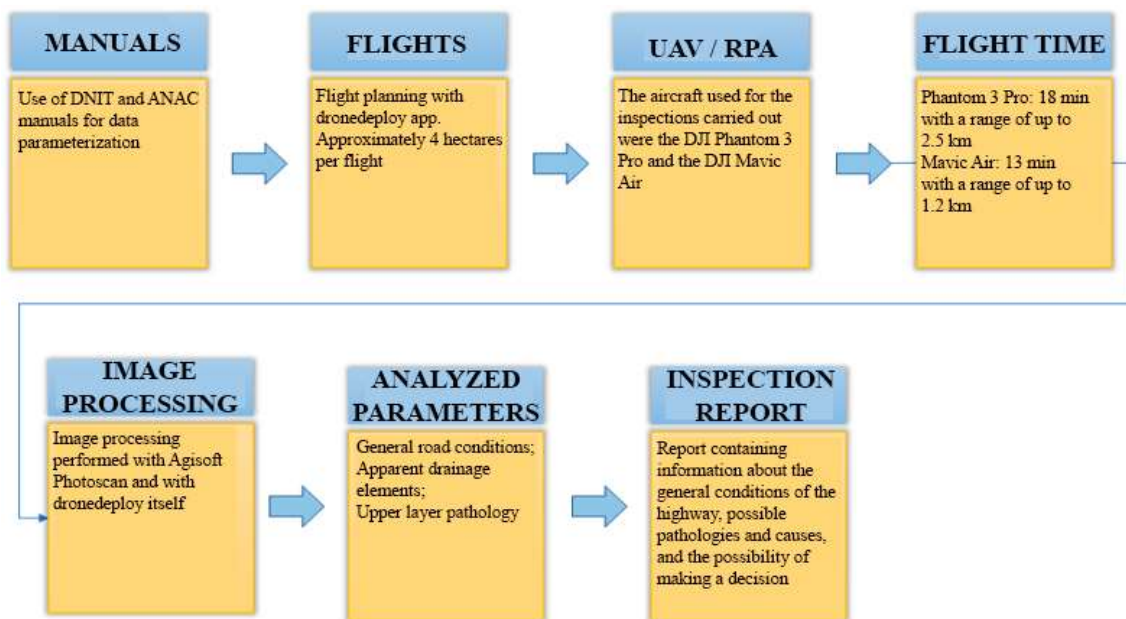

Fig. 1 Sequence for data construction and final report

First, after the analyses, the flight maps were built, using the DroneDeploy tool, a free mobile application available on the DroneDeploy platform, which captures the images necessary to build the digital maps. In the aforementioned application, images are available via satellites, which allow the location of the points to be collected, as well as the customization of the flight settings desired by the UAV pilot. Parameters are defined on the application screen, which is essential for obtaining quality images, namely:

- **Altitude**: altitude at which the flight will be performed. The flight altitude has a direct influence on the aircraft's autonomy and the quantity and quality of the images to be captured;
- **Front Overlap**: rate of frontal overlap of images. It is recommended to always be 70% above to guarantee more reliable processing;

- **Side Overlap**: rate of lateral overlap of images. It is recommended that it be used at 65% for more reliable processing;
- **Flight Direction**: determines in which direction the aircraft will fly and capture images. This parameter is defined in degrees and varies from -180º to + 180º and also influences the number of images captured and the flight time.
- **Mapping Flight Speed**: defines the mapping speed. It also influences the flight range and the quality of the mapping. This parameter is limited according to the UAV model;
- **Starting Waypoint**: determines the starting and ending point of the aircraft.

In the mapping carried out for this case study, flight parameters defined after the performance of several test flights were used, in various types of environments, to which the best configuration was obtained taking into account the UAVs made available by the Operations Management Laboratories and Automation, Center for Sustainable Development of the Semi-Arid, Federal University of Campina Grande. The UAV used in this work was the DJI Mavic Air, of the multi-rotor type, classified in class 3, according to ANAC standards. The flight parameters for the UAV used in this case study can be seen in Table 1.

**Table 1** - Configuration parameters for flights with VANT Mavic Air Pro

DJI MAVIC AIR			MAPPING ESTIMATE	
Front Overlap	75%		Flight time (min)	38:28
Side Overlap	65%		Area (ha)	16
Fligth Direction	-128°		Images	358
Mapping Flight Speed	6 m/s		Batteries	3
Starting Waypoints	1			

Figure 2 shows the DroneDeploy configuration of the mapping to be performed. The red rectangle indicates the flight parameters shown in Table 1. The yellow rectangle shows the area selected for mapping through the UAV. The range of photos taken by the UAV during mapping is taken along the perimeter of the green crossbands.
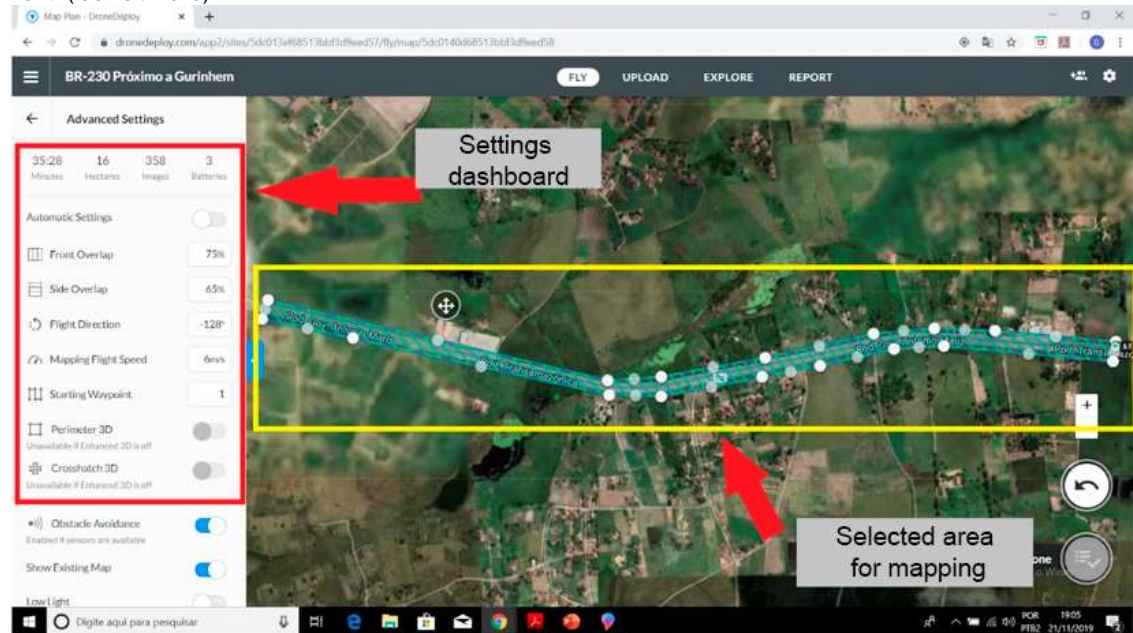
Fig. 2 Mapping configuration on the application plataform

After configuring the parameters, the UAV pilot must check the flight conditions to carry out safe and quality mapping. The battery level of the equipment, calibration of the GPS, weather conditions, altitude and wind speed must be taken into account. To obtain higher quality images, it was observed that the mappings should preferably take place between 10:00 am and 2:30 pm.

The next step is to download the images to the computer and process the images in the Agisoft PhotoScan trail version. After uploading the images to the software, a sequence of tasks begins that will result in the MDS. Figure 3 illustrates the task flow for creating an MDS in Agisoft Photoscan.
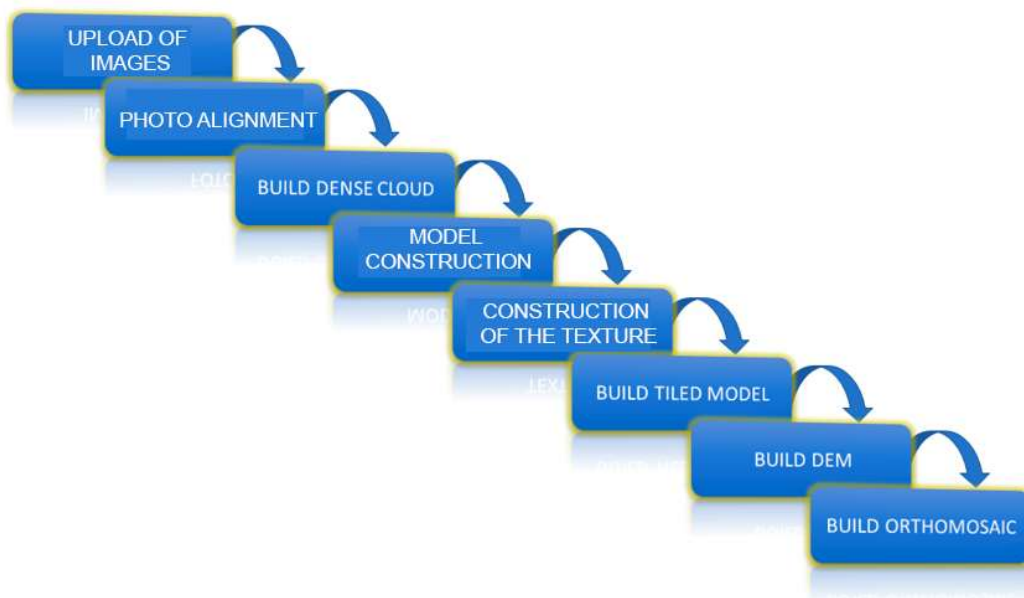

Fig. 3 Task flow creating the MDS in Agisoft Photoscan

The images processed and generated in PhotoScan will make it possible to carry out the analyzes relevant to the actual conditions of the pavements, their elements and the like, which in turn will characterize the use of the tool as a direct aid in the inspection, maintenance, and conservation of road networks.

After the generation of the MDS, the analysis of the images generated to identify the conditions of the mapped highway is carried out, to identify pathologies of the upper layer of the asphalt pavement structure, called Hot Machined Bituminous Concrete (CBUQ), usually used in the construction of flexible asphalt pavements, as well as drainage and horizontal signage elements that are visible in the images, as shown in Figure 4.

Fig. 4 MDS generated after image processing

4 Results

Mappings were carried out on the BR-230 / PB and BR-412 / PB highways, which have a continuous flow, and therefore present some type of degradation in the upper coating (asphalt). In both stretches evaluated, pathology was identified in the asphalt, namely: interconnected cracks of the alligator leather type, slip, longitudinal and transversal cracks, holes or pans and patches, as shown in (Figure 5).

Fig. 5 Pathologies BR-230/PB

Also in Figure 5, it is possible to notice that in a single section of the survey, it is possible to identify the structural impairment of the highway, being evident several types of pathologies resulting from the intense flow of heavy cargo vehicles, which increasingly can carry more cargo. , and, conversely, travel on an "obsolete" pavement, in addition to the lack of preventive and, often, even corrective maintenance.

In turn, BR-412 / PB has less intense traffic, however, no less important, and it also shows signs of wear and tear due to the flow of passenger vehicles (and cargo) and the lack of maintenance, as shown in (Figure 6).

Fig. 6 Pot-type pathology BR-412/PB

As already mentioned, the equipment used for the mapping was the DJI Mavic Air. Technical specifications regarding the equipment are contained in the user manual that can be consulted on the manufacturer's web site (Appendix, pages 53, 54 and 55).

During the flights performed, MAVIC Air was stable, managing to maintain the qualities of the images, but reduced its flight time by about 35% due to the need for stabilization in the air due to the wind. Thus, it was identified that the flights are more durable in the moments when the air displacement is milder. There is also a maximum range limitation both horizontally and vertically. Due to the regulations in force in Brazil, the UAV navigation application itself limits the maximum altitude to 300 meters, a factor that does not influence the mapping carried out in question because it uses, in its configurations, the altitude of 60 meters to maintain a better quality in capturing images.

The image processing was carried out in Agisoft PhotoScan and its methodology has been previously described. The software offers a wide choice of tools that made it possible to make an Orthomosaic capable of providing sufficient clarity for the analyses proposed by the work. See figure 7.
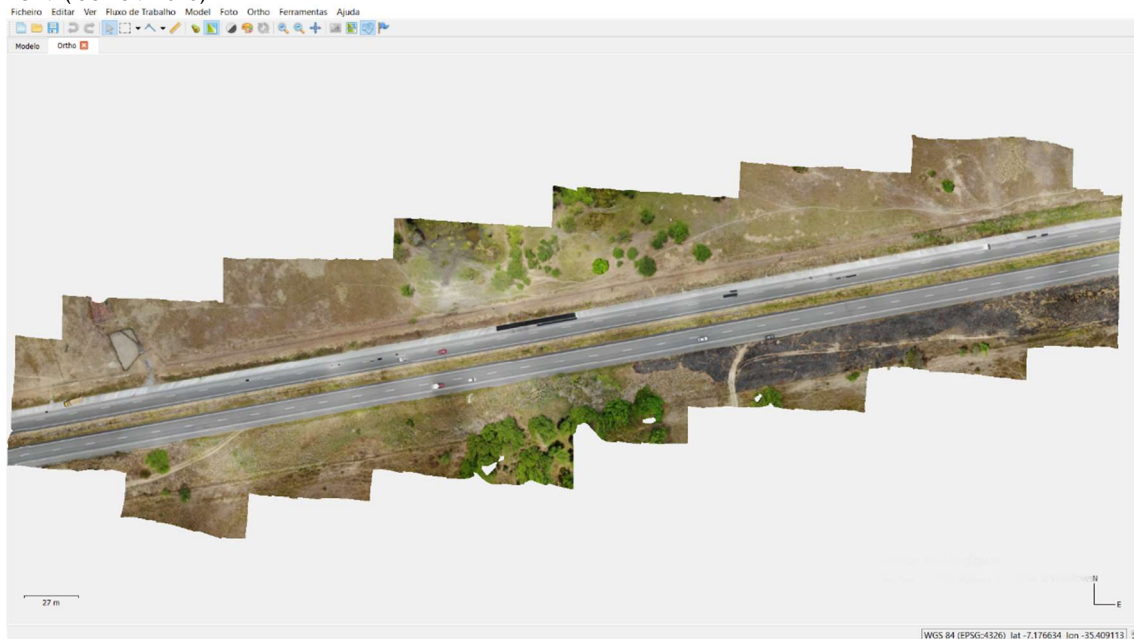
Fig. 7 Image Processing Performed on Agisoft Photoscan

In figure 8, there are evident pathologies of pavement wear due to overloads and intense flow. Cracks of the "alligator leather" type appear in great frequency throughout the stretch, which reinforces the issue of the lack of preventive maintenance.
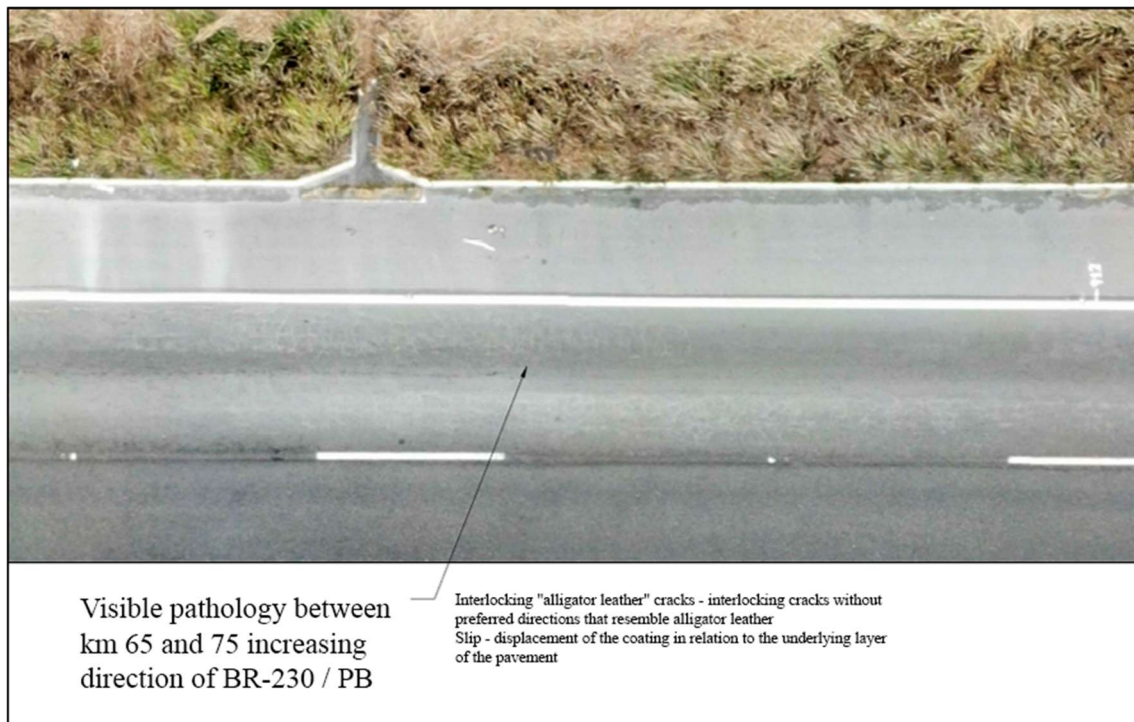

Fig. 8 Cracks like "alligator leather" - BR-230/PB

Some stretches of the mapped highways present different pathologies, among them, are the type: longitudinal cracks, transversal cracks, cracks and wear in general, including remnants of probable maintenance by a patch that is also already compromised. Recurrently the most likely causes are overloads and lack of maintenance, in addition to climatic variables.

In addition to the weather, which the pavements are subjected to, the change in the configuration of heavy vehicles in recent years may have a greater contribution to the degradation of the pavements, because of a possible poor distribution of loads by vehicle axles, which in turn instead, they cause severe damage to the pavements over time, thus decreasing their useful life.

Also, there is a deficit of scales on the entire road network in the country, a factor that limits the inspection of heavy vehicles that most travel over the permitted weight. Another contributing factor is the exponential growth of the entire vehicle fleet in the country and the low investment in transport infrastructure.

There is still the possibility of inspecting other elements of the highway that were not mentioned in the work, but that is easily visible in the mappings performed, such as some drainage elements, domain range and some horizontal signaling information, which can become additional elements generated reports.

5 Conclusion

Inspections carried out on road networks via UAV indicated pathologies such as interconnected cracks, alligator leather, slipping, longitudinal and transversal cracks, holes or pans and patches, indicating that the proposed methodology for road inspection through UAVs proved to be easy to apply and objective.

The Digital Surface Map, generated by the mapping of the UAV, allowed a better aerospace visualization of the surface state of the elements that comprised the evaluated highways, in this case, the Hot Machined Bituminous Concrete, an aggregate compound that after machined and applied, forms the analysis of these elements, it was possible to identify the most evident problems of the highways mapped, which enabled a more assertive decision-making regarding the maintenance/conservation issues or even the elaboration of new road implantation projects, for offering a greater ability to identify specific or recurring problems of the sections submitted to analysis.

The innovative methodology for road network inspection via UAV proposed in this work directly impacts the way public spending can be directed, in decision-making time, in reducing costs, in accident risks, in addition to increasing the degree of assertiveness in pathological diagnoses and improves the proposals for maintenance/conservation, restoration, and implantation of new highways.

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