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Use of Unmanned Aerial Platforms in Brazil – a Ten-year Overview (2008-2018) of Academic Publications

Uso de Plataformas Aéreas Não Tripuladas no Brasil – um Panorama de Dez Anos (2008-2018) de Publicações Acadêmicas

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Abstract: The use of Unmanned Aerial Vehicles (UAVs) is increasingly consolidated in Brazil, incorporating applications previously attributed to satellites and traditional aerial surveys. According to the ANAC (National Civil Aviation Agency) there are 75,000 UAV registered, 40% for professional and/or academic activities. This article quantifies aspects of the use of UAV in obtaining remote sensing data by national scientific research, identifying products and services generated and methods and equipment used. A systematic literature review was carried out by combining the terms MONOGRAPH, DISSERTATION, THESIS, RPA, DRONE, UAV, PHOTOGRAMMETRY, REMOTE SENSING. Having established 2008 as the base year for the search, works between 2010 and 2018 were found. We selected 64 papers, including doctoral theses, master's dissertations and undergraduate course completion papers, in which 11 Boolean parameters and other 11 quanti-qualitative parameters were evaluated. There are works from all Brazilian regions: 21 from the Southeast; 19 from the South; 11 from the Midwest; 11 from the Northeast; and 2 from the North. The areas of Cartography, Geography, Civil Engineering, Forestry Engineering and Environmental Sciences concentrate more than 55% of publications. The generation and verification of digital models of surfaces and/or terrain (MDS/MDT) was the main application, present in 39% of the studies; next came the use of UAV for mapping and classification of vegetation cover, with 22% presence. The cartographic quality of the different products varied between PEC-PCD 'Class B' in a 1/10,000 scale and 'Class A' in a 1/1,000 scale.
Keywords: RPAS. UAV. Remote sensing. Systematic literature review.

Resumo: O uso de Aeronave Remotamente Pilotada (ARP) no Brasil é uma realidade cada vez mais consolidada, incorporando aplicações antes atribuídas aos satélites e aos levantamentos aéreos tradicionais. Segundo a ANAC (Agência Nacional de Aviação Civil), já são 75 mil ARPs registrados, sendo 62% para atividades profissionais e/ou acadêmicas. Esse artigo quantifica aspectos sobre o uso de ARP na obtenção de dados de sensoriamento remoto pela pesquisa científica nacional, identificando produtos, serviços gerados, métodos e equipamentos utilizados. Realizou-se uma revisão bibliográfica sistemática por combinação dos termos “monografia, dissertação, teste, rpa, drone, vant, fotogrametria, sensoriamento remoto”. Estabelecido 2008 como o ano base para a busca, encontrou-se trabalhos entre 2010 e 2018. Foram selecionados 64 trabalhos, entre teses de doutorado, dissertações de mestrado e trabalhos de conclusão de curso de graduação, nos quais avaliou-se 11 parâmetros booleanos e outros 11 parâmetros quanti-qualitativos. Há trabalhos de todas as regiões brasileiras: 21 do Sudeste; 19 do Sul; 11 do Centro-Oeste; 11 do Nordeste; e 2 da região Norte. As áreas de Cartografia, Geografia, Engenharia Civil, Engenharia Florestal e Ciências Ambientais concentram mais de 55% das publicações. A geração e verificação de modelos digitais de superfícies e/ou terrenos (MDS/MDT) foi a principal aplicação dos estudos, presente em 39% dos trabalhos; em seguida está a utilização de ARP para mapeamento e classificação da cobertura vegetal, com 22% de presença. A qualidade cartográfica dos diferentes produtos gerados variou entre o PEC-PCD 'Classe B' na escala 1/10.000 e o 'Classe A' na escala 1/1.000.
Palavras-chave: RPAS. ARP. Sensoriamento Remoto. Revisão bibliográfica sistemática.

1 INTRODUCTION

The acronym RPA comes from the English term "Remotely Piloted Aircraft" and is the focus of Brazilian regulations for use in professional activities involving "Unmanned Aerial Vehicles" (UAVs, generically known as drones*)*. Similarly, RPAS refers to "Remotely Piloted Aircraft System", adding to "RPA" all "the required command and control links and any other elements that may be required at any time during operation" (DECEA, 2017, p. 20). The term "UAV" (Unmanned Aerial Vehicle), in this document, refers to both the aircraft and the system.

In Brazil and worldwide, UAVs have been used for data collection for numerous purposes, such as filming, topographic surveys, construction inspections, and precision agriculture, among others. In some of these applications, the collected data is integrated with flows of Photogrammetry and/or Remote Sensing for the generation of their products.

In these activities, the UAV has been constituted as a true "disruptive technology", allowing the integration of global positioning systems to aerial filming and photographs, obtaining geospatial data of high spatial and temporal resolution, with low operational complexity and competitive costs. These are services, products and applications that, a short time ago, were restrictive due to the high costs involved in the construction of platforms and sensors, and which today are more accessible to professionals from various segments. Currently there are more than 75,000 pieces of equipment duly registered with ANAC, 62% of which are recording devices for professional activities (ANAC, 2020[1]).

Data collection via UAV, however, is not appropriate for every situation, as the authors MACLEAN (2015) and MATESE et al. present (2015), when they indicate the cost/benefit analysis in the use of such systems. For the former, the use of UAV may be feasible for data collection in areas up to 42 km^2, while for the second, the limit of the area would be 10 hectares (0.1 Km^2). The difference between the results is due to the variation in the equipment used, as well as to the different methods, sensors and purposes of the products generated by the authors. This brief comparison points to the wide variety of applications and possible methods for data generation and collection, analyzing the use of the system, successful cases and operational limits.

In this context, this research presents a systematic bibliographic review of national academic works on the collection of images via remote sensor embedded in UAVs, for the generation of geospatial data by flows of Photogrammetry and/or Remote Sensing, focusing on the understanding of the products and services generated, as well as on methods and equipment. It is expected, therefore, to contribute to the understanding of the potentialities of the use of such technology in the various areas of knowledge.

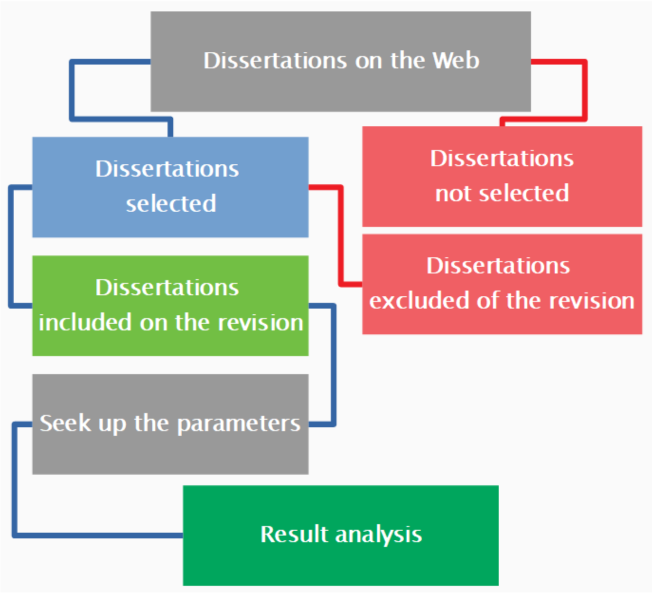
2 MATERIALS AND METHODS

According to Ravindran and Shankar (2015, p. 3), "systematic (bibliographic) reviews are characterized by an explicit question, defined as a matter for the screening and inclusion of studies and implications for future research."

For the search, carried out throughout May 2019, we used the public digital platform of CAPES (Coordination for the Improvement of Higher Education Personnel) and the open search engine Google Scholar. The combination of the terms adopted was "monograph, dissertation, thesis, rpa, drone, uav, photogrammetry, remote sensing", with a time frame of 10 years (2008-2018). The review methodology can be summarized by the flowchart in Figure 1.

1 According to https://www.anac.gov.br/assuntos/paginas-tematicas/drones/sisant_2020.csv , access on June 1, 2020.

Figure 1- Simplified flowchart of the method used in this review.



Source: The Authors (2020).

Monographs published by Brazilian educational and research institutions were selected, from 2008 (base year) included in the following categories: higher education (bachelor's, bachelor's degree or technology); master's degree (academic or professional); doctorate (academic or professional); who presented generation of geospatial data obtained by flows of Photogrammetry and/or Remote Sensing and who used UAV in data collection.

The base year was chosen with the limit of the publications up to 10 years (2008-2018), and the oldest publication found for the period is 2010.

The results were found, as a rule, in the 'Libraries of repository of publications' of the different universities; in the repository of the Brazilian Digital Library of Theses and Dissertations or in the catalog of dissertations and theses of CAPES.

Not all work published by university research centers was available for internet access. Only the online files that were available for download in the search period (27-31/5, 2019) were counted.

The selection of papers for inclusion in the review followed POPAY et al (1998), *apud* LOUREIRO et al. (2016), which indicates that the evaluation should verify that the papers meet the following points:

a) The study illuminates the subjective meaning, actions and context of what is being researched;
b) There is evidence of adaptation and response of the research project to needs and problems offered by real life;
c) The study produces the type of knowledge needed to understand the structure and the process in which it is located;
d) Sufficiently detailed descriptions are provided to allow the researcher to interpret the meaning and context of what is being researched;
e) How the research develops from the presentation and analysis of the data to the description of the results and conclusions;
f) Different sources of knowledge on the same issue are compared and contrasted;
g) Generalizations can be drawn from the conclusions offered for other areas of knowledge, or for different populations or groups;
h) The relevance of the search is clearly indicated.

The analysis of the studies resulted in three different levels of adequacy of the monographs, which were (1) adequate; (2) adequate in part and (3) inadequate.

The set of 'Monographs Included in the Review' was formed by the works identified as "Adequate" and "Adequate in part" (levels 1 or 2).

In this set, 11 Boolean parameters related to the generated products and methods used were evaluated. This evaluation was carried out in function of the presence or absence of the following topics (encoded by the acronyms in parentheses):

a) (BL) Indicates **the Legal Bases** for data collection via UAV;
b) (AF) Uses **'Fixed-wing'** aircraft for data collection;
c) (AR) Uses **'Rotating Wings' aircraft** to collect data;
d) (CL) **Applies Correction** of **Lens** distortions for photogrammetric processing;
e) (PC) **Plans** the collection in '**Corridors**' (instead of 'Blocs');
f) (NC) Uses **Cartographic Standards** to verify the products generated;
g) (PR) Implements **Reference Points** (control or verification) in UAV collection;
h) (TR) Uses **real-time** GNSS (RTK) relative positioning for UAV control;
i) (VC) Processes data by *SIFT* algorithm (Scale *Invariant Feature Transform*), SfM (*Structure from Motion*) or similar (Computer **Vision**);
j) (CT) **Compares** data obtained with **topography**, photogrammetry or terrestrial imaging;
k) (CA) **Compares** data obtained from **aerial**, orbital or similar images.

In addition to Boolean parameters, the following quantitative-qualitative data were collected from the studies included in the review:

a) (TYPE) Level of monograph work (Undergraduate, Master or Doctorate);
b) (YEAR) Year of publication;
c) (AREA) Concentration area of the center and publication research;
d) (STATE) Acronym of the Brazilian State in which the research center is located;
e) (INSTITUTIONS) Acronym of the University in which the research center is located;
f) (KEY) Grouping by the main application of the work;
g) (TITLE) Title of the monograph;
h) (AUTHOR) Last name and first name of the first author of the work;
i) (TRACK) Spectral range of the sensor used;
j) (GSD) Value, in centimeters, of the Ground Sample Distance (i.e., pixel size);
k) (BANDS) Number of spectral bands collected.

3 RESULTS AND DISCUSSIONS

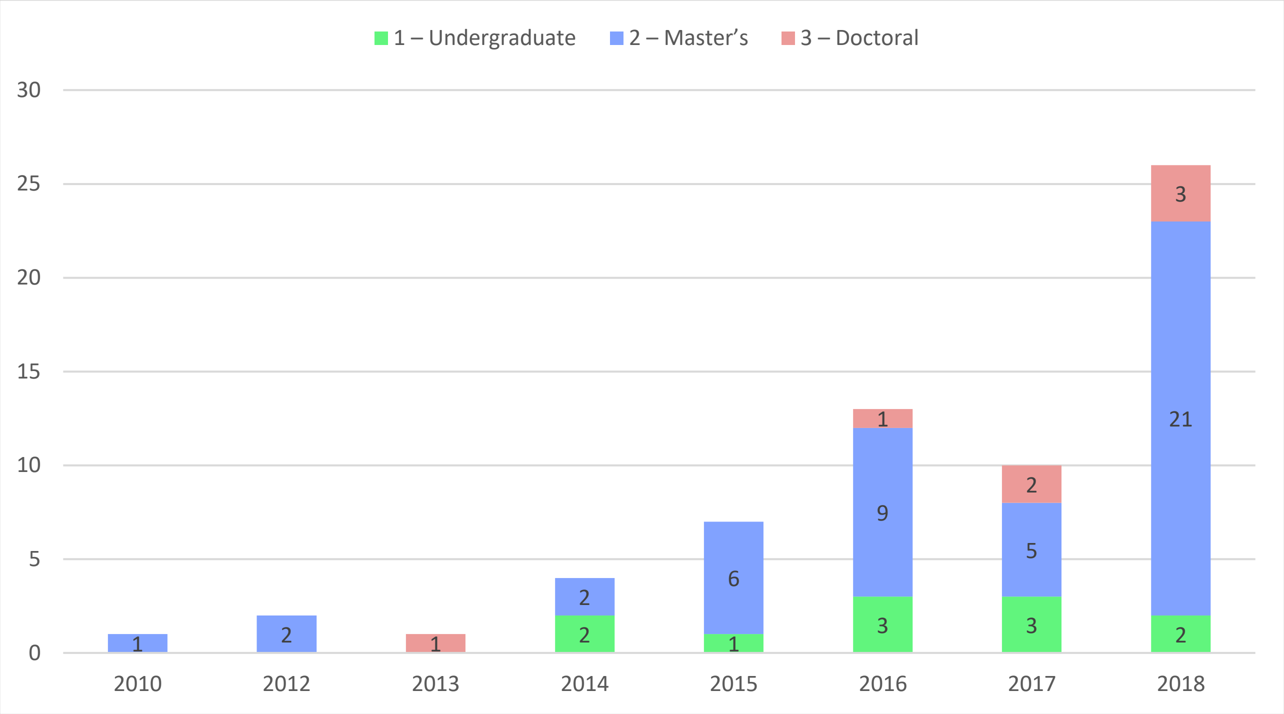
There was the recovery of 91 papers with the defined characteristics that were available for download, forming the set 'Selected Monographs'. From the analysis of this set, 64 studies were classified for the 'Monographs Included in the Review', 34 of which were 'Adequate' and 30 'Adequate in part'. The remaining 27 papers were excluded from the analyses because they were considered 'Inadequate' for the review.

With the base year set for 2008, the first work dates from 2010 and there is an increasing number over the years evaluated, reaching 26 works in 2018.

The distribution of the types of monographs reviewed presents a large concentration of master's publications, with 46 papers (~72%); followed by undergraduate studies, which totaled 11 (~17%) and doctoral theses, with 7 (~11%).

Figure 2 shows the distribution of the reviewed papers, reporting the types and years of publication.

Figure 2 - Distribution of the types of work reviewed in the period 2008 - 2018.

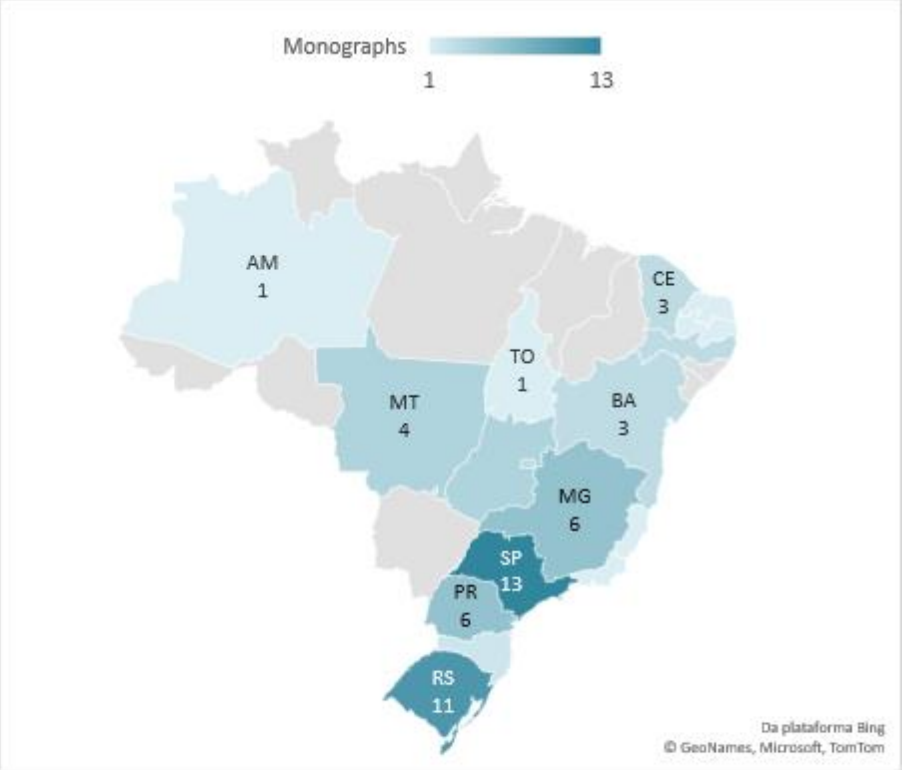


Source: The Authors (2020)

Monographs from all regions of Brazil were reviewed, 21 from the Southeast (~32%); 19 from the South (~21%); 11 from the Midwest (~17%); 11 from the Northeast (~17%); and 2 monographs from the North (~3%).

Figure 3 shows the number of studies evaluated in the states of Brazil.

Figure 3- Distribution of monographs evaluated throughout the national territory.

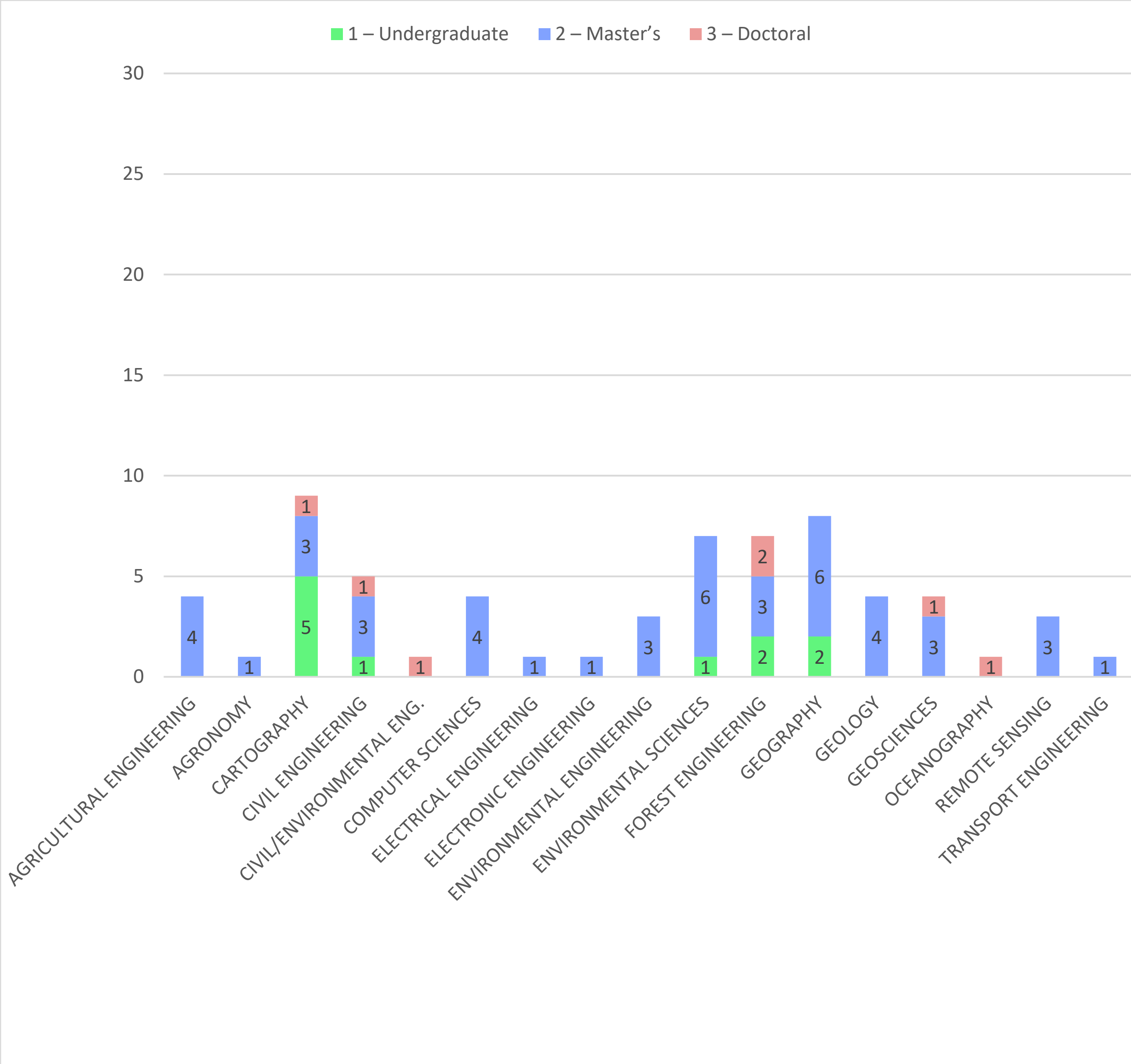


AM	BA	CE	DF	ES	GO	MG	MT	PB	PE	PR	RJ	RN	RS	SC	SP	TO
1	3	3	3	1	4	6	4	1	3	6	1	1	11	2	13	1

Source: The Authors (2020).

The analysis on the diversity of the areas of knowledge of the monographs highlights the areas of Cartography (9 monographs), Geography (8), Civil Engineering (5), Forestry Engineering (7) and Environmental Sciences (7) that, together, contained more than 55% of the reviewed papers, totaling 36 monographs. Figure 2 relates the classes of monographs to the areas of knowledge in which they are inserted.

Figure 4- Areas of knowledge and classes of the evaluated studies.



Source: The Authors (2020)

The main applications identified in the evaluation of monographs were grouped into 6 classes (KEY field):

a) **CADASTRE**, where monographs focus on studies for generation and application of data on a cadastral scale (1/10,000, or larger);
b) **GENERALITIES,** where monographs focus on studies that could not be classified in other groups;
c) **INSPECTION,** where the monographs focus on studies to perform inspections with the obtained products;
d) **MDS / MDT,** where monographs are similar to studies for the generation and verification of digital surface and/or terrain models;

e) **QUALITY,** where the monographs focus on studies to verify the quality of the products generated and/or the systems used;

f) **VEGETATION,** where the monographs focus on studies for data generation and application in the mapping and classification of vegetation cover.

The number of studies identified in each group is in Table 1.

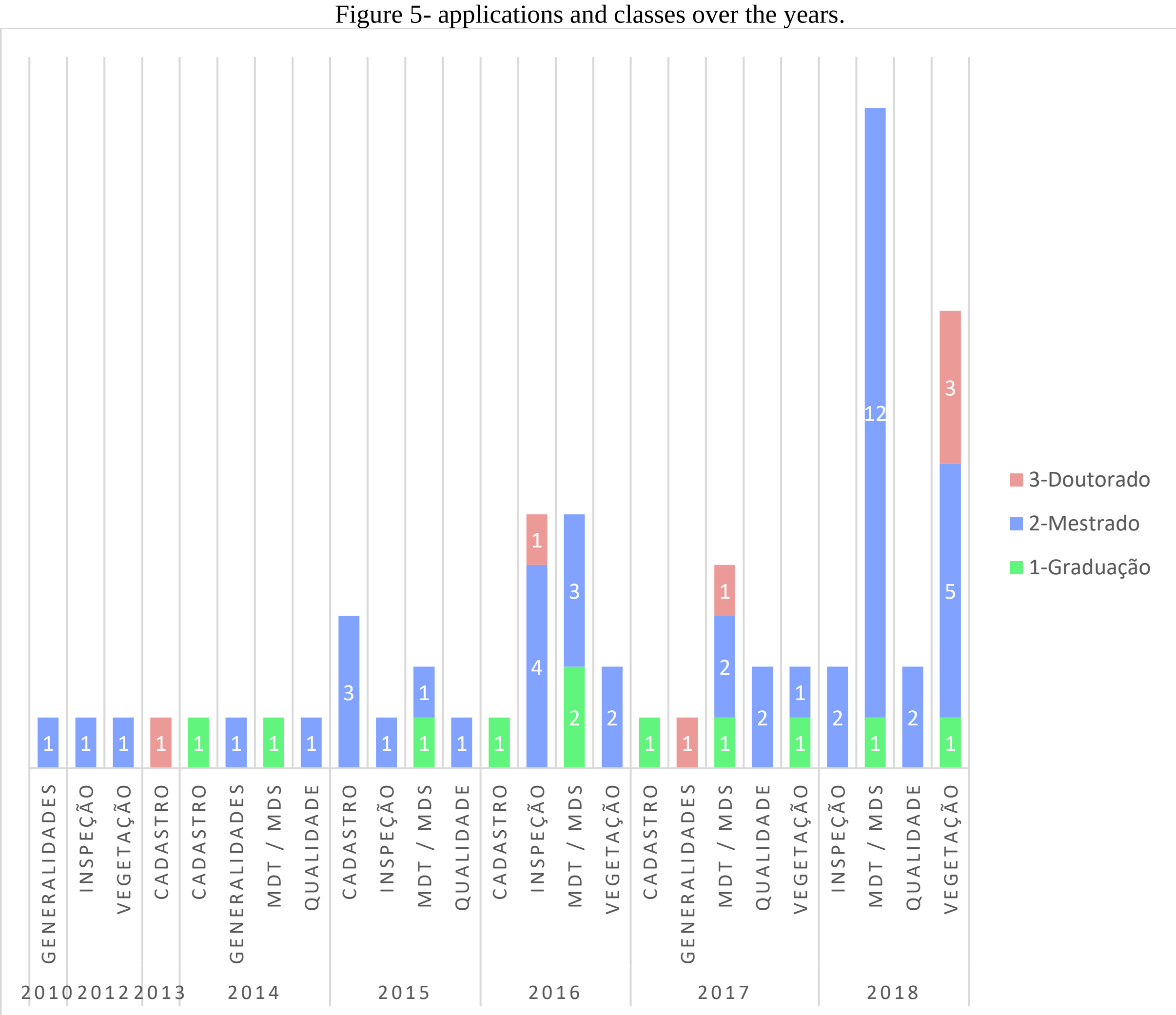
Table 1 - Number of papers according to the applications of the studies.

KEY Applications	Percentage of total	Count
Registration	10.94%	7
General	4.69%	3
Inspection	14.06%	9
MDT / MDS	39.06%	25
Quality	9.38%	6
Vegetation	21.88%	14

Source: The Authors (2020)

The distribution over the years relating to the key applications of the works, following the classes of monographs, is presented in Figure 5.

Figure 5- applications and classes over the years.



Source: The Authors (2020).

3.1 Evaluation of parameters

3.1.1 (BL) INDICATES LEGAL BASES FOR DATA COLLECTION VIA UAV

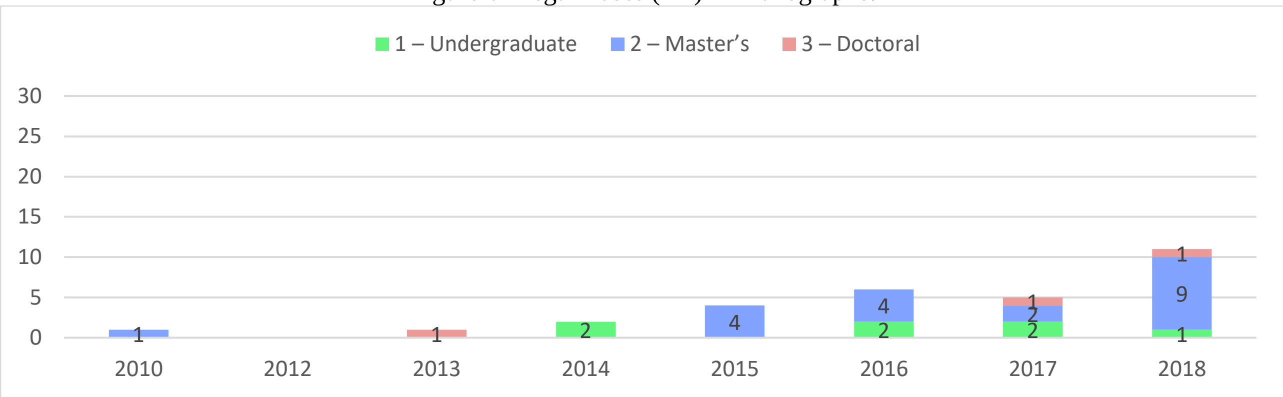
About 46% of the papers (30 monographs) have the legal basis for the use of UAVs. The papers cite the requirements and deliberations of 3 bodies for the use of UAVs in Brazil:

a) ANATEL, for the registration and homologation of the UAV communication system;
b) DECEA, for registration and access to airspace in the use of UAVs;
c) ANAC, for the registration and/or homologation of the aircraft.

These laws have undergone changes over the last few years, and each monograph presents laws one that was in force at the time of its elaboration.

Figure 6 shows the distribution of studies with (BL) in the classes of monographs over the years.

Figure 6- Legal Bases (BL) in monographs.



Source: The Authors (2020).

3.1.2 (AF) AND (AR) INDICATE THE TYPE OF AIRCRAFT USED IN THE COLLECTION OF DATA

Only one work, from 2018, for evaluation of androde with the generation of MDT / MDS, presented results with simultaneous use of fixed wing aircraft (AF) and rotary wing (AR) – all others had used one or another type of aircraft. The lack of data collected by one or another type of aircraft was perceived only in one monograph from 2010 – which presented, generally and theoretically, the possible applications for both types of aircraft. The distribution presented 26 monographs 'AF' (~41%) and 38 monographs 'AR' (~59%).

All equipment used fits class 3 of ANAC legislation, with maximum takeoff weight less than or equal to 25 kg (ANAC, 2017). This class is known as microvants; class 2 refers to platforms with total weight between 25 and 150 kg, while class 1 is intended for platforms with a total weight of more than 150 kg. The massive presence of Class 3 equipment can be explained by the lower cost of acquiring the equipment, by the operating facilities that such equipment presents and by the simplification that there is in the legislation for the legalization of the use of such equipment.

In the case of the use of aircraft with rotary wing (multi-rotor), most of the works present the use of quadcopters with battery power and flight autonomy ranging between 15 and 35 minutes.

The wingspans of fixed-wing aircraft were not greater than 2.5 meters long, with battery power or combustion and autonomy, presented by the authors, between 30 minutes and 2 hours of flight time.

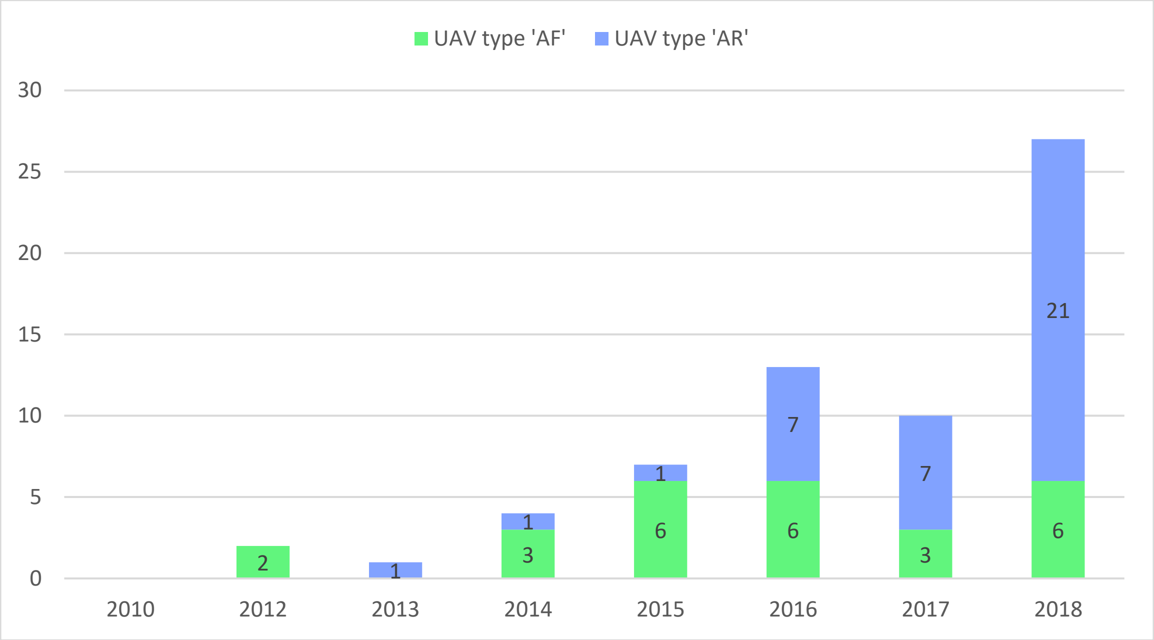
The manufacturer of equipment most mentioned in the monographs, for the case of rotary wings (AR), was the Chinese 'DJI', present in 26 works (~68% of the AR). Another 8 studies (~21% of the AR) presented the data collected by generic equipment – developed by the authors themselves or by a company without a trademark.

For fixed wings (AF), the manufacturer 'SenseFly' was the most cited, in twelve works (~44% of THE).

The use of equipment developed by the authors themselves or by companies without a trademark was identified in 7 other studies (~21% of the PA). There is also the presence of equipment developed by national companies, such as Xmobots; AGX (now extinct) and NuvemUAV, adding another 8 monographs (~29% of PA).

Figure 7 distributes the types of aircraft used over the years (in 2018 there is a single work that used both 'AR' and 'AF', and in 2010 the only work that did not use any type).

Figure 7- Types of aircraft used in monographs over the years.



Source: The Authors (2020).

3.1.3 (CL) CORRECTION OF LENS DISTORTIONS FOR PHOTOGRAMMETRIC PROCESSING

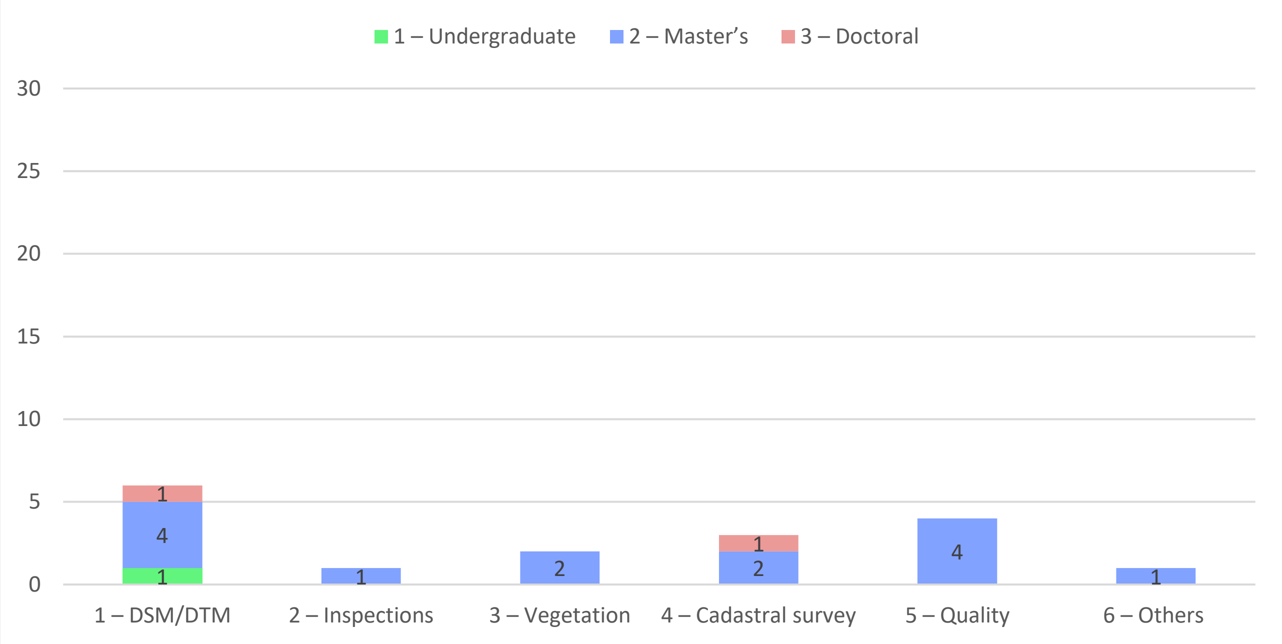
All the studies reviewed pointed out the use of small format cameras, not metrics, in data collection. These characteristics suggest the use of techniques of systematic error corrections, caused by lens distortions, in the photogrammetric processing itself (CÔRTES, 1998; 2010).

As for the spectral range of the sensors, most of the studies used passive image sensors in the visible spectrum (RGB) to obtain the data. There were cases of studies that used hyperspectral cameras; others that used multispectral cameras, with access to the infrared range, and still others that took advantage of active LASER emission sensors, with LIDAR (Light Detection and Ranging) equipment to obtain data.

From the set of reviewed monographs, 18 papers (~28%) pointed out some pre-calibration to obtain the orientation parameters of the lenses, aiming to correct errors caused by the lenses in the data processing.

Figure 8 indicates the distribution of the works that mention the correction of the lenses (LC) for the purposes of the work.

Figure 8- Works that mention the correction for the distortion of the lenses (LC).



Source: The Authors (2020).

3.1.4 (PC) COLLECTION PLANNED IN 'CORRIDORS' (IN CONTRAST TO 'BLOCS')

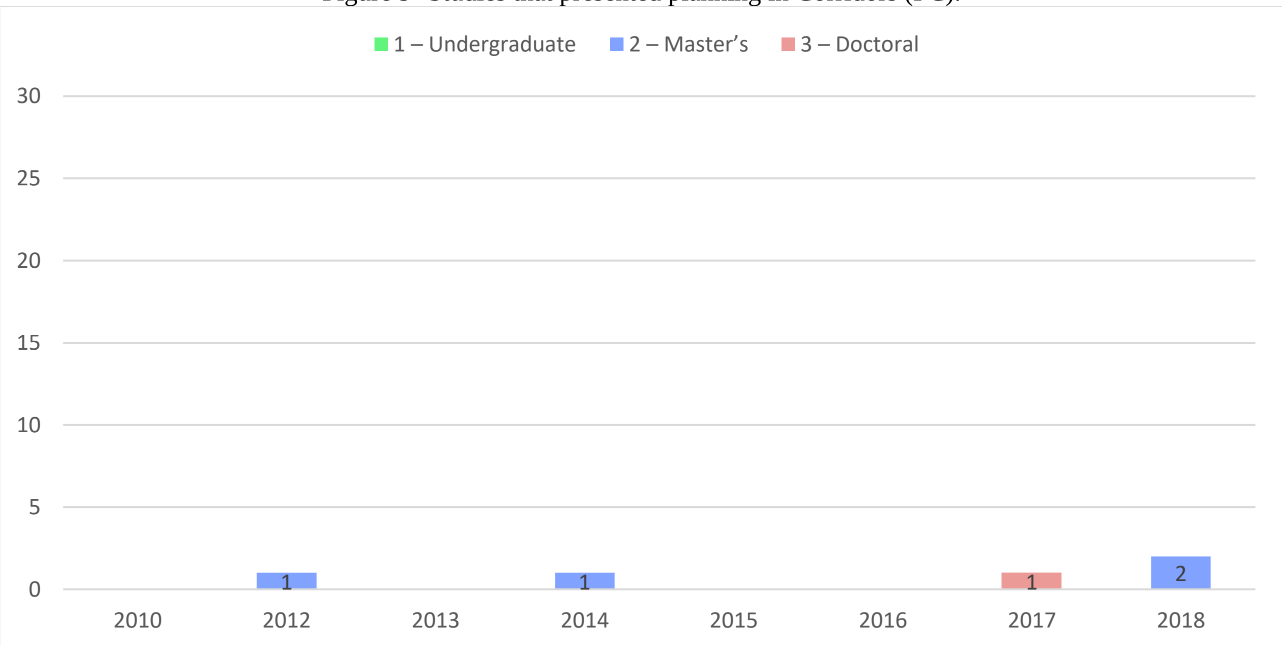
The 'PC' works predominantly showed data collected in small stretches, with flight lines in hundreds of meters, covering areas of up to a few tens of hectares.

There have been cases where flight lines have reached a few kilometers (maximum of 5 km), covering areas of up to a dozen square kilometers.

'Corridor' collections were those that are planned to have one to three flight ranges and that the length of the coverage area was at least 4 times greater than the width – forming the outline of a linear figure.

Five papers were identified (~8%) that presented this type of planning for collection. Figure 9 shows the types and years of these works.

Figure 9- Studies that presented planning in Corridors (PC).



Source: The Authors (2020).

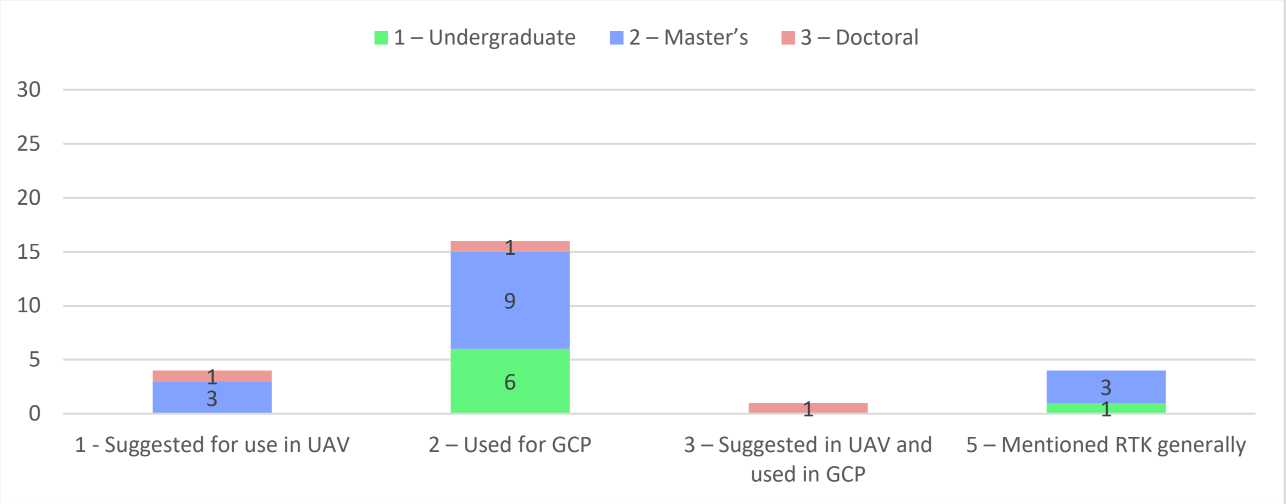
3.1.5 (TR) USES RELATIVE REAL-TIME GNSS (RTK) POSITIONING TO CONTROL RPA

No monograph used the relative kinematic GNSS positioning in real time (RTK - Real Time Kinematic) for the control of the UAV.

The vast majority of the papers, 40 monographs (~62%), do not even mention the term RTK. Nevertheless, 5 studies were identified in which the authors suggested this investigation; there were 4 in which this type of collection is generically mentioned; and 17 in which the RTK technique was used in the collection of control points.

Figure 10 shows the distribution of the studies in which RTK positioning is mentioned, suggested or used for the control points in the types of monographs in which they were identified.

Figure 10- Monographs quoting the term 'RTK'.



Source: The Authors (2020).

3.1.6 (NC) USES CARTOGRAPHIC STANDARDS TO VERIFY THE PRODUCTS GENERATED AND (PR) IMPLEMENTS REFERENCE POINTS

The quality of the cartographic products (NC) of the monographs was verified by the "Cartographic Accuracy Standard", PEC (BRASIL, 1984) or by the "Standard of Cartographic Accuracy of Digital Cartographic Products", PEC-PCD (EB, 2011), sometimes for one or the other, sometimes for both.

Most of the coordinates of the reference points were determined by relative GNSS positioning, using double frequency receptores (L1/L2) that were occasionally compatible with the RTK positioning method.

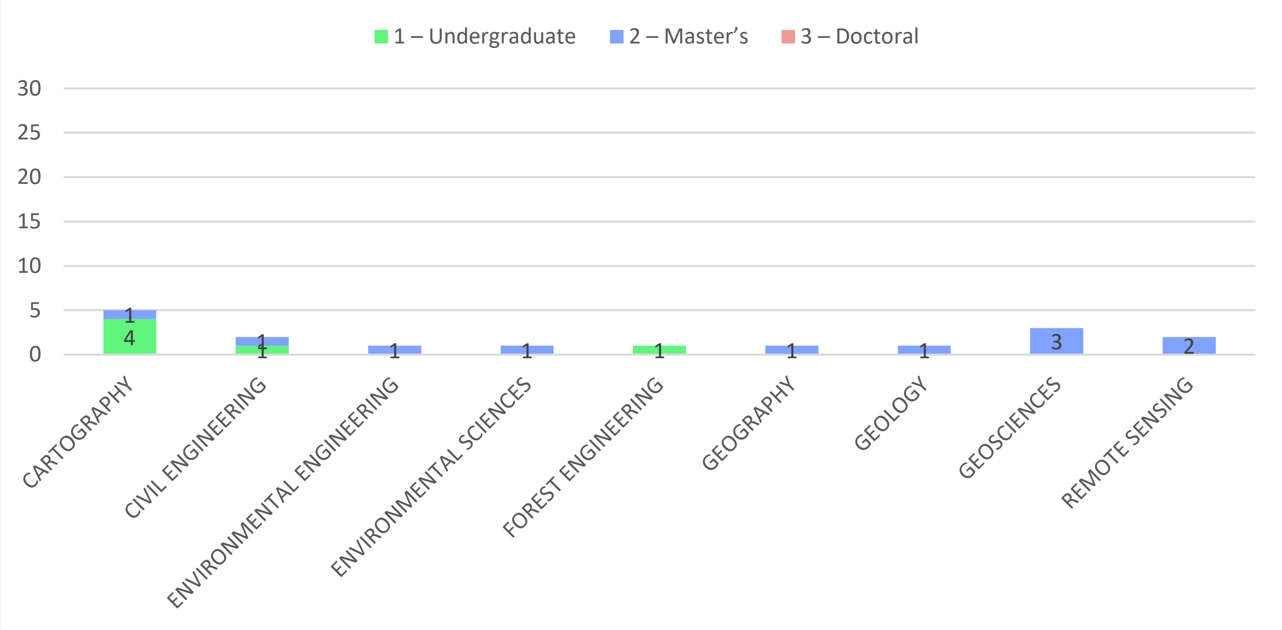
Works were found that implemented control points and / or verification through the Service of Precise Point Positioning (PPP) from IBGE, and others that determined the coordinates of their points of interest through absolute positioning, with navigation receivers.

The 17 monographs (~26%) that presented the verification of the products by cartographic standards (NC) implemented their control and/or verification points through relative positioning and use of dual frequency GNSS receivers, and in 7 of these the RTK method was used.

Another 23 monographs programmed reference points for other purposes or did not present the quality of the products by cartographic standards, totaling 40 works (~63%), where there is the presence of the parameter 'PR'.

Figure 11 presents the 17 studies that verified the products according to the guidelines of the cartographic standards (NC), co-related the types of monographs and their areas.

Figure 11- Monographs in which the quality of products is verified by cartographic standards (NC).



Source: The Authors (2020).

3.1.7 (VC) PROCESSES DATA BY SIFT, SFM, OR SIMILAR ALGORITHM (COMPUTER VISION)

The use of software equipped with computer vision algorithms for data generation (VC) was presented in approximately 82% of the monographs evaluated (53 studies).

Most authors used the agisoft photoscan computational application (currently marketed as METASHAPE) in the processing, and the use of the PIX4D Mapper program was also observed in some monographs.

Both types of program used the SIFT (Scale Invariant Feature Transform) algorithm to obtain the distances between the center point of the camera lens and the points of an imaged object.

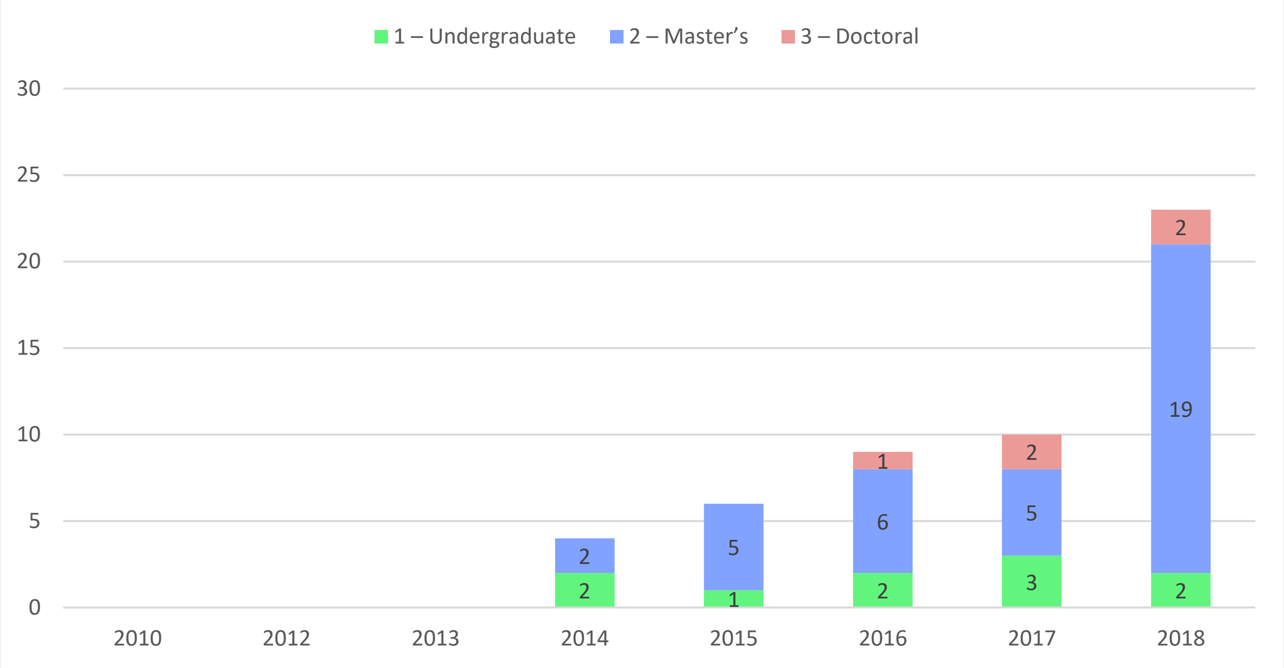
The technique used to determine these distances is that of the field of computer vision, known by the acronym SfM (Structure from motion), a "passive way to determine multiple three-dimensional points of objects that are in areas overlapped by two sequential two-dimensional images" (adapted from MOONS, 2008); that is, it follows the principle of stereoroscopy, used by traditional aerophotogrammetry.

While the majority of the studies performed automated processing through the default parameters of the programs, some authors applied filters to the images and used advanced options in generating the results.

Figure 12 shows the evolution of the presence of this topic over time.

 DOI: http://dx.doi.org/10.14393/rbcv72nespecial50anos-56503

Figure 12- Use of computer vision in monographs.



Source: The Authors (2020).

3.1.7.1 (CT): Connotes data obtained with topography, photogrammetry or terrestrial imaging; and (CA): Combines data obtained with aerial, orbital, or similar images.

Most of the products generated by the authors are raster imaging, and the spatial resolution of the final products (pixel size) ranged between 1.5 cm and 1.9 m. Two studies were observed in which the type of output was exclusively vector.

Most used passive-type imaging sensors, capturing the spectral range of the visible and, in some cases, near infrared. A few cases of use of hyperspectral passive sensors with capacity and capturing data in hundreds of bands in the range of 400 to 900 nm and also of active sensors, of the type LIDAR (Light Detection and Ranging) were noticed.

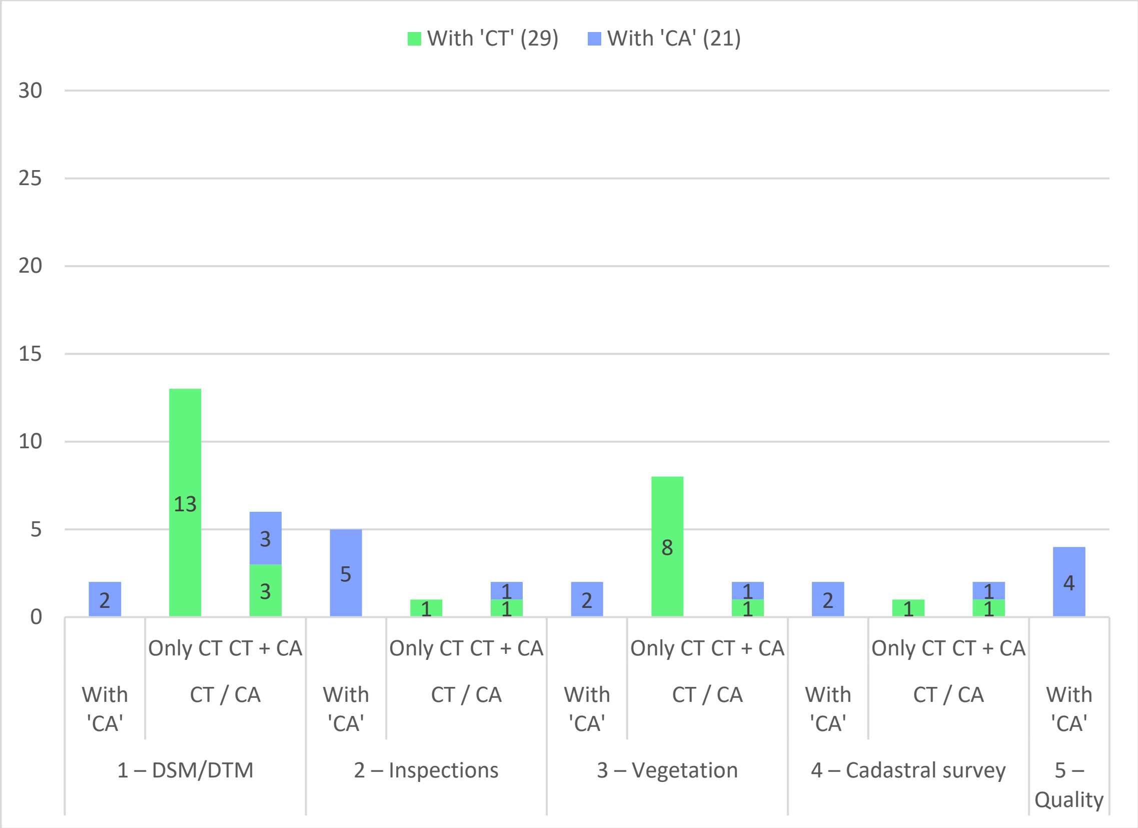
Of the 21 monographs (~32%) that compared the data generated to aerial or similar images (CA), 6 also compared the data with information on topography, photogrammetry or terrestrial imaging (TC). Another 23 studies compared their data only with information collected on land, totaling 29 studies (~46%), with the presence of the parameter 'CT'. In all, there were 44 (~69%) studies that presented CA or CT.

In the case of 'CA' monographs, the images of the Google Earth platform, *landsat* series images, and relief images of the Shuttle Radar Topography Mission (SRTM) are highlighted by the number of times they were mentioned. No data collected by manned flights were included, especially with the use of LIDAR sensors.

In comparisons with data from terrestrial surveys (TC), most monographs used the topography associated with GNSS positioning, obtaining features of the terrain and/or buildings that were compared to those generated by the processing of the data obtained by UAV.

Table 12 presents the distribution of studies with the parameter 'CT' by the areas of knowledge and main purposes of the reviewed monographs.

Figure 13- Compared with other data in monographs (CA/CT) in their applications.



Source: The Authors (2020).

4 CHALLENGES AND FUTURE PROSPECTS

As future perspectives of the solutions obtained by Remotely Piloted Aircraft (RPA), we highlight its continuous development in Brazil, both of the platforms themselves, which improve flight efficiency every day. The embedded technology, favored by sensor instruments (imagers or not) more sophisticated, with significant cost reduction. All of this is associated with a possible improvement in the data transmission infrastructure, especially in rural areas, from a more excellent coverage of 4G cellular technology, with the forecast in the next decade of implementing 5G cellular technology. Such technologies will enable processing solutions already embedded in the aircraft, with online support from manufacturers and mapping service providers, allowing them to obtain more accurate information and less time.

In addition to the improvements and cost savings for multispectral, hyperspectral, and thermal imager, a popularization of active sensors, such as LIDAR (Light Detection and Ranging), is foreseen, integrated with smaller and more accurate IMU/INS (Internal units for measuring the attitude and position of the aircraft in flight), as well as GNSS positioning sensors, which are gradually offered with multiple frequencies (geodetic pattern).

All this evolution should also require the development of a new line of processors embedded in the aircraft, which, together with computer systems based on machine learning and artificial intelligence, will process images in real-time, with battery consumption compatible with the demands of the activity.

Understanding that electrical RPAs are a trend, the battery itself is a significant challenge to be overcome; with the equipment increasingly demanding flight autonomy and processing capacity, they should be able to maintain the load for a longer time without over-competing with the payload (payload) of the platforms, especially those of the rotary-wing type (or multi-rotor).

With the growing interest in RPA-based data collection solutions (as well as other remotely piloted systems - terrestrial and aquatic), regulatory institutions (civil and military) must be prepared to increase demand, both in terms of personnel, computational capacity, and inspection tools, which is a challenge to be faced by the government, especially at the federal level. It includes updating the rules that guide the production and application of RPAs in the national market.

In this sense, it would be urgent to update the technical standards of National Cartography, dating from the mid-1980s, which could support the updating of numerous technical standards of organs and institutes that generate geospatial data. Among many public administration bodies, a good example is the DNIT (National Department of Terrestrial Infrastructure), which bases the projects on regulations in 2006 - a time when aerophotogrammetry was analogous and overly restrictive in its costs - and which currently has outlined an update to technical requirements to accept data collected by RPA in its project flows.

5 FINAL CONSIDERATIONS

This research presents an academic overview of the different uses of UAV for Photogrammetry and Remote Sensing in Brazil over 10 years (2008-2018). These studies, both at the undergraduate and graduate levels, indicate a growing trend in the use of this technology, as well as the areas of knowledge and most sought-after purposes in the country, reflecting the level of learning and investments in public and private universities. Of course, a considerable portion of these studies were published in specialized journals, national and international, helping to disseminate knowledge and scientific advances.

There are a wide variety of applications for UAVs, with the use of equipment that must be chosen according to the intended purposes and the resources available for their acquisition. The costs of acquiring the equipment used in the evaluated surveys range from approximately US$ 500.00 to those that easily exceed US$ 100,000.00.

Regulatory agencies for professional use of UAVs in Brazil, namely the National Agency of Telecommunications (ANATEL), National Civil Aviation Agency (ANAC), Ministry of Defense (MD), and Department of Airspace Control (DECEA), have invested in the simplification and modernization of processes, legislation and systems.

In this context, it is worth mentioning the initiatives of ANAC, with the Unmanned Aircraft System (SISANT) for the registration of equipment, and DECEA, in the implementation of the Remotely Piloted Aircraft Access Request (SARPAS) system, for the use of airspace (aka NOTAM). These bodies have made efforts to update the legislation, with the recent edition and publication of the "Compendium of legislation and technical and legal issues on aerosurvey" (MD, 2020) by the Ministry of Defense and by updating, since July 1, 2020, the legislation on access to airspace by DECEA[2].

The control of aircraft through GNSS systems, which use the RTK positioning method, did not appear in any of the evaluated studies, although some authors point to this method as a possible way of improving positional quality in data processing, implementing the direct georeferencing technique. As an example, one can mention PIX4D, the software manufacturer for photogrammetric processing of UAV data, offering 3 positioning solutions: RTK implementation; use of control points; and post-processing of receiver data (PPK) (PIX4D, 2018).

Most of the studies analyzed were done in a planned flight coverage of the 'Bloc' type, and not in a 'Corridor'. The few works that collected data in 'Corridors' did not exceed flight lines of 5 km.

The studies that evaluate the cartographic quality of the products generated are not conclusive, because it is not possible to verify consistency or a pattern in the methodologies of the analyses performed by the authors. There are indications that quality would not be higher than 'Class B', in scales 1/10,000, even with products similar to those generated by authors who classified mappings as 'Class A' (PEC-PDC) in scales from 1/1000 to 1/2500.

In most of the studies reviewed, there was no variation between the spatial resolution of data collection (Ground Sampling Distance - GSD) value and the spatial resolution of the generated raster product (pixel size). Only five studies indicated the geometric degradation of the GSD for the generation of the final product, reaching up to a factor of 1/21 in the data generation (i.e., a collection with GSD of 9 cm and pixel of the evaluated product of 189 cm).

2 The latest legislation is available in https://www.decea.gov.br/drone/, access on 02/07/2020.

6 LIST OF REVIEWED MONOGRAPHS

Alphabetical order of the monographs reviewed in this work, composed of the data: AUTHOR; YEAR; TITLE; TYPE; AREA; INSTITUTION; STATE > <u>*GENERAL*</u>.

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9. CALOU, Vinícius; 2018; **USO DE VANTs NO MONITORAMENTO DA SIGATOKA-AMARELA DA BANENEIRA;**2-Master; AGRICULTURAL ENGINEERING; UFC; EC > *VEGETATION*
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Authors' Contribution

Fábio Lobo (UFC/IBGE) contributed with the original idea, initial data collection and tabulation, generating a first version of the text. Carlos Uchôa (UFC/LAG) and Manuel E. Ferreira (UFG/LAPIG) contributed to the revision of the first version of the text, guiding the final form and content. João Vitor S. Costa (UFG/LAPIG) assisted in the final collection and final tabulation of the data presented in this article.

Conflicts of Interest

The authors declare no conflicts of interest.

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