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Review Article

A Review of Developments and Challenges of Pre-flight Preparation for Data Collection of UAV-based Infrastructure Inspection

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Abstract

As Unmanned Aerial Vehicles (UAVs) undergo rapid development, they have begun playing diverse roles across various industries, including infrastructure inspections. The evolution of UAV technology has addressed safety concerns for inspectors, offering efficient data collection capabilities. Furthermore, the development of advanced data processing algorithms enhances the appeal and viability of UAV-based infrastructure inspections. However, a pivotal challenge in UAV-based infrastructure inspection revolves around ensuring data quality, as it can be influenced by various factors. High-quality data serves as the cornerstone for effective and reliable UAV-based infrastructure inspections. Ensuring effective pre-flight preparation and planning for data collection is critical to achieving high-quality data. Addressing this issue will enhance the overall quality of UAV-based infrastructure inspections and maximize the benefits derived from UAVs. In this review, the progress and obstacles associated with pre-flight preparation for the data collection phase will be discussed from hardware selection and flight path planning perspectives.

Keywords: Unmanned Aerial Vehicle (UAV); Infrastructure inspection; Data collection; Flight path planning; Hardware selection; Sensors

Introduction

A significant portion of the vital infrastructure supporting modern dynamic society, including bridges, railways, tunnels, dams, buildings, power plants, and highways, was constructed decades ago and it is important to ensure the safety, resilience, and efficiency of these critical infrastructures. As an example, according to the report of the American Road and Transportation Builders Association (ARTBA) which is based on data from the Federal Highway Administration (FHWA) National Bridge Inventory (NBI) for 2022, from a total of more than 617,000 bridges across the United States, 36% of them (near 224,000) need repair work and more than 43,500 bridges are rated in poor condition and classified as structurally deficient. Due to these statistics, ARTBA estimated the cost of identified repairs for all 224,000 bridges, is approximately $260 billion [1]. These reports and statistics indicate the importance of monitoring, maintenance, and rehabilitation of aging civil infrastructures.

Infrastructure inspection is one of the important aspects and a key to identifying damage, preventing potential hazards, and optimizing performance. Civil infrastructure condition assessment is carried out by utilizing data from inspection/or monitoring. Traditional methods to evaluate the condition of civil infrastructure usually is done by visual inspection by the inspectors considering the related criteria (e.g., NBI standards for the bridges [2,3]. However, these methods for infrastructure inspection can be time-consuming, expensive, imprecise, and unsafe [4]. In recent years, to overcome these challenges, using Unmanned Aerial Vehicles (UAVs) also known as drones, has become one of the solutions, and it has attracted a lot of attention in civil engineering [5,6]. Due to UAV's key benefits, such as enhanced safety, cost efficiency, time efficiency, and easy repeatability, they are now widely used for civil infrastructure inspection and remote sensing [7].

As with most emerging technologies, challenges for UAV-based inspection remain, such as image distortion, massive data, image matching, lack of access to some parts of the infrastructure, instability of the UAV, vibration effects, etc. [6]. Recent advances in computer vision and image processing techniques, especially developments in Artificial Intelligence (AI) would be beneficial for UAV-based infrastructure inspection in different damage detection aspects. However, these methods heavily rely on the quality of collected data, and inaccuracies may arise without high-quality data. In this context, ensuring data quality is crucial for the success and reliability of UAV-based inspections. To harness the full potential of data processing techniques and enhance the overall efficiency of UAVs in infrastructure inspection, it is crucial to investigate pre-flight preparation and meticulous data collection to ensure high data quality. Regarding the importance of data quality and data collection, this study focuses on the recent developments and the challenges related to the pre-flight preparation for the data collection phase. For this purpose, the pre-flight preparation for the data collection phase is divided into two different categories: hardware selection and flight planning. The remainder of the paper is structured as follows: in section 2, developments and challenges of the hardware selection including UAV selection, payload selection, and camera calibration are discussed; Also, developments and challenges for flight planning are discussed in section 3, and section 4 delivers the conclusions of this paper.

Hardware (UAV Platform and Payload)

Before discussing the hardware selection, it is important to consider and define the inspection purpose. Without considering the purpose of inspection, suitable hardware may not be chosen and consequently, it may lead to some issues in other steps such as low data quality or inappropriate data collection. Five different purposes are defined in this study: crack detection, delamination, fatigue, 3D modeling, and corrosion. These purposes of inspection are discussed briefly below.

a. Crack Detection: Most of the studies mentioned crack detection as the basic and major application of infrastructure inspection using UAVs [8]. There are two primary steps in the image-based surface crack assessment method. Crack detection comes first, intending to remove noise and extract cracked objects from the images. The extraction of crack edges and the calculation of crack characteristics, such as crack width and length, make up the second stage of crack assessment [9]. For this purpose, mostly RGB cameras are used to find cracks in the surface of bridges, tunnels, and other structures. Using optical cameras, the UAVs can take high-quality pictures from difficult-to-reach regions [10].

b. Delamination: Deck delamination, also known as horizontal debonding in the deck's subsurface, is frequently a sign that the deck reinforcement has deteriorated due to corrosion [11]. The shape and depth of delamination, environmental factors like air temperature and solar intensity, which introduce feature variation of the same delamination, and surface textures like cracks, color differences, patching, and road painting, which add external noise, are the current challenges for the purpose of delamination profiling through thermography [12].

c. Fatigue: Fatigue cracks can have lengths less than 7 mm and diameters as small as 0.1 mm, and they are exceedingly difficult to discern. Inaccessible areas such as huge cross frames, welded stiffeners, or other complex geometries are typically where fatigue cracks develop in the superstructure. Commonly, RGB and IRT cameras are utilized to identify fatigue cracks. The effectiveness of UAV-based fatigue crack detection is greatly influenced by the platform that is used, the environment, and the lighting [13].

d. 3D Modeling: Inspectors can view geometric data, such as damage location, and surface condition, such as damage kind and amount, by using 3D models of the structures, which provide a base from which damage information can be compared. To create 3D models, RGB cameras and LiDAR sensors can be used [14]. Photogrammetry creates 3D points from a set of 2D photos collected from various angles and positions all around the structure, as opposed to LiDAR, which often contains more 3D points. Photogrammetry has a higher processing cost and lower accuracy than LiDAR because it compares image attributes to build the 3D points. However, UAV-based LiDAR systems need expensive LiDAR sensors and GPS systems, which reduce battery life by adding more payload to the system, whereas photogrammetry merely needs an optical sensor [15].

e. Corrosion: Due to the widespread usage of metals in construction infrastructure, corrosion is a constant risk. A positive charge is released during the electrochemical process of corrosion, which results in the formation of a stable compound. Despite some corrosion on the underlying metal components, such as the steel reinforcement used in bridge concrete, the surface of steel bridges experiences a great deal of corrosion [16]. The most popular cameras for detecting corrosion are RGB and IRT cameras. Although infrared thermography is a promising technique for measuring, mapping, and detecting corrosion, more study is required before it can be used perfectly in the field [17-19].

As mentioned above, different kinds of infrastructure inspections require different tools and considerations depending on the inspection's goal. The choice of appropriate equipment is the next stage, and it is covered below. The typical UAV is composed of a frame, motors, control unit, onboard sensors, communication system, and power supply. Many UAVs display a dual tube substructure to make it easier to mount various payloads [8]. Fixed-wing, rotorcraft, multi-rotor drones, and hybrid vertical take-off and landing (VTOL) vehicles are the four common UAV designs [20]. Figure 1 shows an example of these different types of UAVs and they are compared and discussed below. When it comes to operating characteristics and different airframes, fixed-wing drones are like conventional aircraft, they are usually bigger sized than other types and they can efficiently cover large distances. Similar to helicopters, rotorcraft UAVs have revolving propellers attached to the aircraft frame. Single-rotor drones are small-sized helicopter, which runs on gas or electricity. The multi-rotor UAV is a version of this type that has numerous propellers extending from the main body to increase the drone's flight. They are mostly used for common applications like aerial photography, aerial video surveillance, etc. Other kinds include the Tricopter (with three rotors), Quadcopter (with four rotors), Hexacopter (with six rotors), and Octocopter (with eight rotors). Multi-rotor UAVs can perform complex 3D mapping since they are quick and stable. Rotorcrafts, on the other hand, are more difficult to fly manually than multi-rotors since they are easier to control, have more lift, and have a backup plan in case of motor failure. Measurement Errors can be caused by the UAV's instability or increasing mobility. Finally, hybrid VTOL UAVs combine fixed-wing and multirotor designs, where the plane is propelled vertically before flying horizontally [10,21-23].

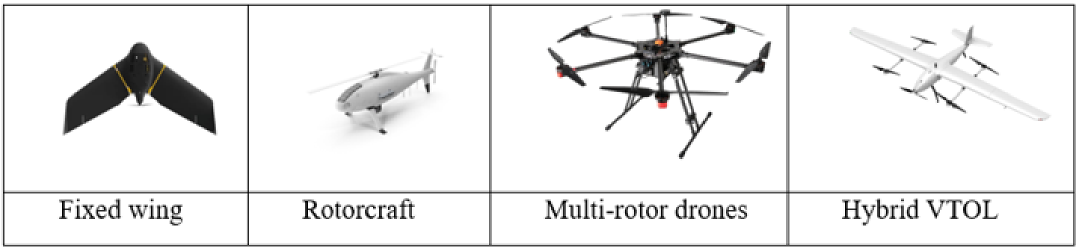

Figure 1: Common UAV types.

The choice of the appropriate UAV platform and sensors has proven to be a difficult problem due to UAV performance requirements related to flights close to the structure (e.g., turbulent flow characteristics around the bridge) and terrain characteristics (e.g., surface roughness, temperature, and humidity) [24]. This includes positioning and maneuvering the UAV around or under structures (operations prohibited by GPS) [25,26] and the stability of the platform in windy situations, where turbulence and other aerodynamic phenomena cause unpredictable wind effects [27,28]. One another major limitation of UAVs is the limited battery capacity or flight time. Moreover, it is not reasonable to increase battery sizes more than current battery sizes because it will affect the payload capacity and maneuverability of the UAV. A solution for this problem could be using wireless power transfer but still more investigation in this area seems crucial [29,30]. The main difficulty in maximizing the UAV for infrastructure inspections is striking a balance between payload capacity and compatibility, endurance, vehicle stability, navigational capabilities, and cost. These parameters play a pivotal role in UAV platform selection. By considering these parameters and inspection purposes, infrastructure inspections can be conducted with enhanced efficiency and data accuracy. A vehicle with a stabilizing gimbal that can change the camera pointing angle to any vertical angle, a camera with optical zoom for capturing high-resolution imagery while at a safe standoff distance, a vertical takeoff and landing capability, and the capacity to hover in place during the flight are examples of parameters and vehicle characteristics appropriate for infrastructure inspections [31].

The purpose of an infrastructure inspection mission is to collect data using designated sensors. UAV and payload selection should be done simultaneously because some UAVs come with fixed payloads while others can be customized with different payloads. Also, there are some UAVs that have fixed payloads, but other payloads can be added too. Therefore, considering the inspection purpose, UAV and payload selection are relevant to each other, and as mentioned before, if the UAV is customizable, payload capacity and compatibility of the drone are effective parameters for payload selection too [24]. Generally, the choice of the best sensors for infrastructure inspection depends on several factors, including cost, flight time, mission objectives, the UAV's payload capacity and compatibility, the payload's controllability, and navigational needs [31]. Although in the infrastructure inspection purposes section, the payloads are briefly described, Table 1 gives a summary of 3 commonly used payloads and some other information that is effective for the suitable payload selection. It is worth mentioning that if needed, using multi-sensors is possible if they are compatible with the UAV platform. Also, other than these three common payloads, there are other payloads such as Sound Navigation and Ranging (SONAR) sensors which can be used for surface mapping while flying UAVs and obstacle detection [32]. Moreover, magnetic sensors can be used to generate magnetic maps and defect maps for ferrous materials like steel girders [33]. One of the major challenges related to visual cameras is the rolling shutter issue. Usually, UAVs are equipped with low-cost rolling-shutter cameras. Unlike in global-shutter cameras, when the aircraft collects the data with a rolling-shutter camera, each row is exposed in turn and thus poses differently [36]. Consequently, moving roller-shutter cameras often produce more image distortion [37]. Also, global-shutter cameras are more expensive and may not be affordable for inspection which means that new methods are needed for the use of the rolling-shutter cameras or image distortion correction methods should be used during the data processing phase.

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Table 1: Specifics of different common payloads and their limitations [15,31,34,35].

Payload Type	Weight Range (kg)	Mission	Limitations
Visual Camera	0.1 - 1	-Crack Detection -Fatigue -Delamination -Corrosion -3D Modeling	- Vibration and wind effect - Lightning condition - GPS-deprived navigation
IRT Camera	0.2 – 1.5	-Fatigue -Delamination	- Low pixel resolution -Inspection time affects the results
LiDAR Sensor	1.3 – 2.8	-3D Modeling	- High weight - High price

Besides the impact of hardware on the data quality, safety regulations and pilot capabilities are two important factors at all steps of data collection. The pilot's ability and comfort level during flight operations have a significant impact on the quality of the data obtained [38]. Considering the above-mentioned parameters for hardware selection and the challenges of this process, some of the recent studies of data collection and hardware selection are represented in Table 2 considering the UAV and the payload that they have used [39-59]. These studies investigate the effect of hardware selection on infrastructure inspection or the effect of the hardware that they used for inspection case studies which can be beneficial for future research in this area. Also in Figure 2, the general effective considerations for UAV and payload selection are shown. Some of these parameters are common between UAV and payload selection. In addition, Figure 3 represents the above-mentioned challenges and limitations for hardware selection. Regarding payload selection, camera calibration is another area that has been studied in recent years. Camera calibration is necessary for UAV-based inspection due to the use of nonmetric, lightweight cameras that are not intended for photogrammetric accuracy [60]. Camera calibration is an essential step to extract metric data from 2D photos in 3D computer vision for correction of the image distortion [61]. In aerial images, pre-calibration or on-the-job calibration is frequently used to handle camera parameters, such as intrinsic parameters and lens distortion coefficients.

Table 2: Research related to hardware selection and data collection.

Reference	Year	Content	UAV	Payload
[39]	2023	A survey of the limitations of using UAVs, data acquisition, and data processing considering accuracy and economy	Multiple fixed-wing and multi-rotor UAVs	Multiple rolling shutter and global shutter cameras
[40]	2023	A comprehensive review of UAVs, types, swarms, classifications, charging methods, regulations, application scenarios, potential challenges and security issues	Multiple UAVs	Multiple payloads
[41]	2023	A review of the challenges and future trends of UAV-based bridge and tunnel inspection	Multiple UAVs	Multiple payloads
[42]	2023	A study to ease the expenses and challenges related to sensor attachment for bridge inspection	Customized NASIMI II	Customized payloads and lasers
[43]	2023	A review of different robotics for inspection, their categorization, and comparison	Skydio 2+ and DJI Zenmuse L1	Different visual and non-visual sensors
[44]	2023	An overview of challenges and solutions for UAV application in underground space	Flyability Elios 3	LiDAR sensors
[45]	2023	The principle of optimized views photogrammetry for accurate image acquisition	DJI M300 and DJI Phantom RTK	PSDK 102S, DJI Zenmuse, PhaseOne iXM-RS150F, and DJI FC6310R
[31]	2022	An evaluation and review of the advantages and limitations of UAV application in various bridge inspections	Multiple UAVs	Multiple payloads
[46]	2022	A review of the benefits and limitations of UAV-based sensing systems in construction management and civil engineering	N/A	N/A
[47]	2022	UAS-based automatic damage detection and bridge condition evaluation on existing bridges for the entire bridge inspection process	Customized UAV	3D LiDAR
[48]	2022	A survey of major steps and challenges of UAV-based 3D mapping	N/A	N/A
[49]	2022	A method to safely guide the UAV along the tunnel axis while avoiding collisions with its walls.	Quadrotor UAV	Multiple payloads

[50]	2021	Recent advances in UAV technology and embedded hardware to develop ICARUS to integrate multiple sensors on the UAV for automatic data collection	DJI Matrice 300	DJI Zenmuse H20T, MicaSense Altum, and NVIDIA Jetson Xavier NX
[51]	2021	an automatic inspection method of building surface, especially for the inspection data collection, by integrating UAV and BIM	DJI Phantom 4	N/A
[52]	2020	An evaluation of the recent developments in the field of autonomous robotic platforms structural health monitoring of bridges.	Multiple UAVs	Multiple payloads
[53]	2020	A literature review and technical survey on (UAV) techniques for bridge inspection and damage quantification	N/A	N/A
[24]	2020	A framework to systematically select a commercially available UAS that is the most appropriate choice for bridge inspection.	Multiple UAVs	Multiple payloads
[8]	2020	A survey of the UAV-based civil structural health monitoring considering the literature over the last decade	N/A	Multiple payloads
[6]	2019	A review of the applications, challenges, developments, and future trends for all phases of UAV-based remote sensing	Multiple UAVs	Multiple payloads
[34]	2019	A framework for automated UAV-based inspections of large bridges to facilitate an automated condition assessment	N/A	N/A
[54]	2019	An artificial intelligence-powered UAV platform for underground spaces by collecting data from multiple payloads	Customized UAV	LiDAR, IR, and visible light sensors
[55]	2019	An evaluation of the drone platform, detecting and surveying system, and post-data processing system considering the challenges and opportunities	N/A	N/A
[56]	2018	The design and development of a smart UAV platform, Surveyor with Intelligent Rotating Lens (SWIRL), customized for autonomous operation in tunnels	Customized UAV	Customized payload
[57]	2018	A literature review of the state of practice for the United States bridge inspection programs considering applications, challenges, and future needs	Multiple UAVs	Multiple payloads
[58]	2018	A summary of the context for UAV inspection of power facilities and structures considering challenges and applications	Multiple UAVs	Multiple payloads
[59]	2018	An evaluation of the state-of-the-art methods in UAV spectral remote sensing considering and discussing the sensor technology	N/A	Multiple payloads

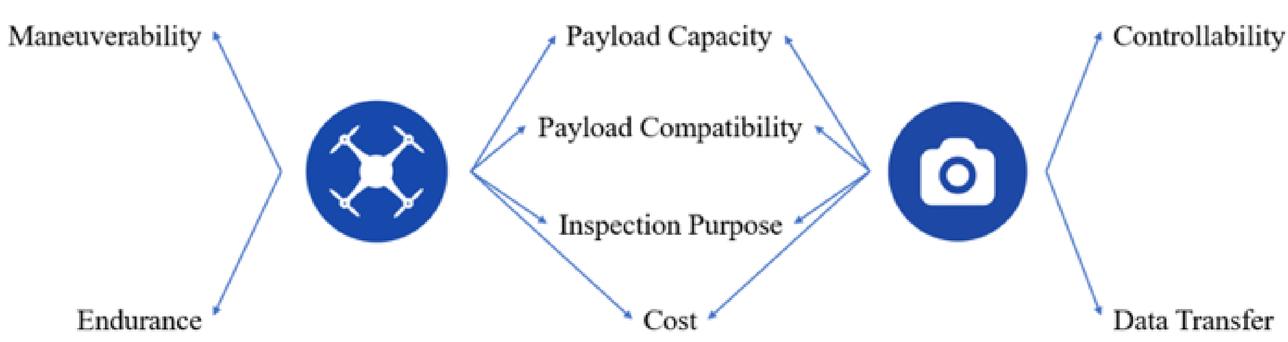

Figure 2: Effective parameters for UAV and payload selection.

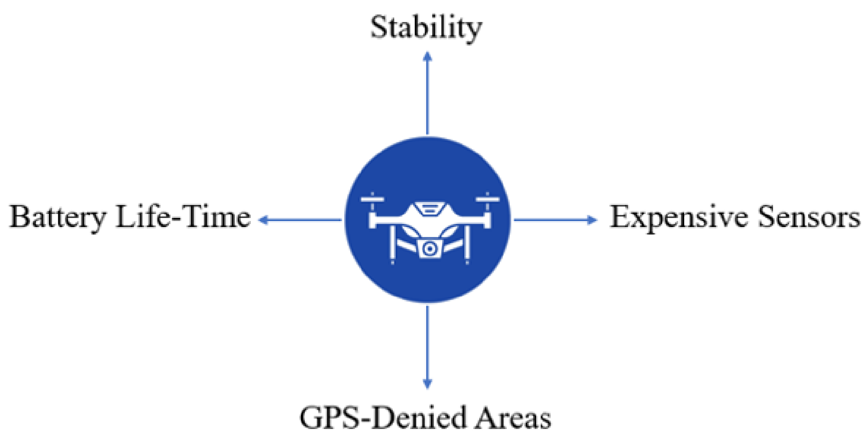

Figure 3: Hardware-related challenges and limitations of UAVs.

Also, generally, there are two methods of camera calibration: reference object-based calibration and self-calibration. Reference object-based calibration can be performed using 2D calibration benchmarks (such as checkboard patterns) or 3D physical calibration fields where coded markers are distributed in three dimensions with known coordinates [62]. 3D calibration is a highly accurate method, but costly and unsuitable for frequent recalibrations. On the other hand, 2D calibration is low-cost and it has been indicated that this method can achieve accurate results close to the 3D method [63]. For self-calibration, special calibration benchmarks are not required, and it depends on the structural information detected in images. Because of the flexibility and efficiency of this method, it has become a research area in recent years [6]. The goal of camera calibration is to establish the relationship between the 3D world coordinates of the object and their corresponding 2D image coordinates, forming the projection matrix. In Table 3, some of the studies that are related to camera calibration for RGB, thermal, and LiDAR cameras, especially for UAV applications are shown. After considering the inspection purpose, UAV and payload selection, and camera calibration, the next step for the preflight phase is to plan for the flight which is described and discussed in the next section.

Table 3: Research related to UAV camera calibration.

Reference	Year	Content	Camera Type
[64]	2023	A review of automatic targetless LiDAR-camera calibration methods by dividing these methods into four categories	LiDAR
[65]	2022	A stereo camera calibration method using the UAVs as feature points, combined with the high-precision position information and suitable for large scene field environments and some complex field scenes	High-speed
[66]	2021	A study to find the optimum method to calibrate the Nikon EOS 6D camera – adaptable as a potential UAV sensor and mounted on a DJI S1000 UAV in this research	Non-metric
[67]	2020	A literature review of existing calibration methods for a LiDAR camera system mounted on a UAV platform and a new versatile automatic and targetless calibration method of this system	LiDAR
[68]	2020	An ambient temperature-dependent radiometric calibration function that enables more accurate surface temperature retrievals to support field and UAV-based data collection efforts	Thermal
[69]	2018	A 3D calibration field for the digital cameras mounted on UASs in terms of accuracy and robustness with case studies to show the efficiency of the method	Digital
[70]	2017	An overview of the current scenario of cameras, often used in UAV applications with focus on the geometrical calibration of these cameras and testing 9 cameras	Different types
[71]	2016	A brief theoretical introduction and camera calibration process, details of the calibration methods and models	RGB
[72]	2015	Addressing the issues of small consumer-grade digital cameras by conducting calibration tests using two kinds of consumer-grade digital cameras	Digital
[73]	2013	A camera calibration system, AprilCal, that yields more accurate calibration and applies to a variety of lenses	Different types
[74]	2009	An algorithm to perform the calibration without any user interaction whatsoever, which works under almost all possible conditions and just uses some pictures of a checkerboard taken with the camera as the input	Different types
[63]	2000	A flexible technique to easily calibrate a camera and only requires the camera to observe a planar pattern shown at a few different orientations	Different types

Flight Planning

A good flight path is a crucial need for the use of UAS for inspection operations. Only if the mission is carefully planned to accomplish every inspection target can its full potential be used [75]. Path planning is challenging for UAV-based infrastructure inspection to find the optimal or near-optimal path. The flight path is a set of camera positions in which the images will be captured from these positions. Camera positions consist of the horizontal and vertical distance from the object, and the angle of the camera. The purpose of the flight path computation is to specify a collection of camera positions and viewing angles that are arranged in such a way that the structure being inspected is entirely covered by overlapping images at the specified resolution. The control of the UAS will then use those viewpoints as waypoints to automatically capture images [75]. In the process of selecting camera positions, one of the key considerations is the Ground Sampling Distance (GSD). The Ground Sampling Distance refers to the distance between two consecutive pixel centers measured on the ground. It plays a crucial role in determining the spatial resolution of the image and the level of visible details. A larger GSD value corresponds to lower spatial resolution, resulting in fewer visible details in the captured images.

For the selection of appropriate GSD, Debus et al. propose three distinct levels of interest for conducting the inspection, [75]. 2.0 mm/pixels, 1.0 mm/pixels, and 0.1 mm/pixels are defined as level 1(for rough geometry), level 2 (for detailed geometry), and level 3 (for crack detection) of interest respectively, which provides valuable guidance for tailoring the GSD and camera positions to effectively meet the inspection objectives. Also, according to the Specifications for the National Bridge Inventory 2022 (SNBI), the following quantitative standards are considered to categorize the cracks by their width and GSD can be selected based on the required crack detection:

a) Insignificant - crack width less than 0.004 inches (prestressed) or 0.012 inches (reinforced), or medium width cracks that have been sealed.

b) Medium - crack width ranging from 0.004 – 0.009 inches (prestressed) or 0.012 to 0.05 inches (reinforced).

c) Wide - crack width wider than 0.009 inches (prestressed) or 0.05 inches (reinforced).

To ensure comprehensive coverage and accurate data collection, it is generally recommended to have at least a 50% overlap of images between consecutive camera positions, as suggested by various studies [9]. This overlapping ensures that critical details are captured redundantly, minimizing the risk of missing essential information. For Infrastructure inspection using UAVs, there are two major methods for flight path planning: Manual Flight and Autonomous Flight. Also, an inspector may prefer to inspect with a combination of these methods. The principles for both methods are almost similar but it's worth noting that in the past years, some research has explored autonomous flight path planning [27,34,76,77]. Obstacle avoidance especially in urban environments, multi-UAV path planning, and coverage path planning in 3D space are some of the challenges related to auto flight and some studies focused on addressing these issues [78-80]. Online or real-time path generation is another challenging area where the path is generated dynamically based on the data collected from the sensors and it is hard to ensure a sub-optimal path for this type of path generation. Some real-time path planners generate and modify their path while the dynamic obstacles are detected [81]. Another challenging area for path planning is to optimize flight path planning, especially for coverage problems and path planning for 3D flights because finding the shortest path in a 3D environment is NP-hard [82]. This task poses a challenging optimization problem, as it involves minimizing the objective cost function considering all relevant parameters such as obstacle avoidance. Most of the studies define path length as the objective function [83]. However, some studies define flight time or energy consumption [84], or flight altitude [85] as the objective cost function. Different optimization methods such as graph theoretical methods and meta-heuristics can be used for this purpose. Meta-heuristic algorithms excel at handling complex optimization problems by simulating natural phenomena and efficiently exploring large search spaces but they can be computationally costly [86].

Some studies applied these algorithms for flight path optimization. Qu et al. presented two methods for UAV path planning during the multi-thread circumstance. The first method is based on genetic algorithms and is suitable for offline path planning. The other method is fit for computing in real-time on UAV and is based on A-star heuristically search [87]. In another research, Phung et al. studied the inspection path planning using the traveling salesman problem and then optimization was applied by using discrete particle swarm optimization [88]. Table 4 shows the studies related to flight path planning, especially for flight path optimization which is an area that gained more attention during the last years as illustrated in the table below. Also, Figure 4 shows the above-mentioned challenges for flight path planning [89-114].

Table 4: Flight path planning-related studies.

Reference	Year	Content	Path Optimization
[89]	2023	A novel hybrid optimization algorithm namely HC-SAR for UAV path planning and a real-time path adjustment strategy to optimize the individuals	Yes
[90]	2023	A multi-UAV cooperative path planning algorithm based on co-evolution optimization considering the cost function of multiple UAVs with the penalty function method to deal with multiple constraints	Yes
[78]	2023	A general approach to compute energy optimal flight paths UAVs in urban environments by exploiting local wind phenomena, i.e., upwind and tailwind areas from the airflow around buildings	Yes
[91]	2023	Addressing the gap between UAV inspection planning and risk-informed inspection optimization by a novel physics-informed framework for planning UAV inspections of deteriorating infrastructure and connecting UAV mission planning to structural inspection goals	Yes

[83]	2023	A review of path-planning algorithms for drones to compute an optimal or near-optimal path considering limitations and some solutions	Yes
[92]	2023	A new UAV flight path planning algorithm based on a version of the White Sharks Optimization (WSO) for complex 3D flight Environments	Yes
[93]	2023	A new method based on Q-learning as a reinforcement learning technique that aims to reduce the power consumption of UAV missions in disaster scenarios to circumvent the negative effects of wind variations	Yes
[94]	2022	A novel hybrid particle swarm optimization (PSO) algorithm, namely, SDPSO, to access the optimal path rapidly in the complicated field	Yes
[95]	2022	A methodology for bridge inspections in communication routes using images acquired by UAV flights and a systematized image/video acquisition method	No
[96]	2022	A summary of the most recent work and an overview of the trend in the use of AI algorithms in UAV swarms for path planning problems considering four groups of AI techniques	No
[97]	2022	A review of different meta-heuristic algorithms for UAV optimum collision-free flight path planning and a method for less transportation cost	Yes
[80]	2022	Minimization techniques to optimize the coverage path planning task for multiple UAVs with real-world experiments using RGB and thermal cameras	Yes
[98]	2022	An area coverage path planning method for a fixed-wing unmanned aerial vehicle (UAV) based on an improved genetic algorithm by using the good point set algorithm to generate a high-quality primary population for GA	Yes
[99]	2022	A survey of the studies of motion planning for UAVs that use bio-inspired algorithms considering contributions and limitations of each study	Yes
[100]	2022	A systematic review of 115 journal articles published from 2007 to 2021 to understand the level of automation (LoA) of existing UAV-enabled bridge inspection approaches considering challenges, and to guide future research	No
[101]	2022	A UAV path planning algorithm based on improved Harris Hawks Optimization (HHO) with a 3D mission space model and a flight path cost function to transform the path planning problem into a multidimensional function optimization problem	Yes
[102]	2022	A survey of UAV path planning approaches classified into five main categories including classical methods, heuristics, meta-heuristics, machine learning, and hybrid algorithms	Yes
[103]	2021	A new modification of the Bat Algorithm based on the characteristics of the standard BA and the artificial bee colony algorithm (ABC) for an accident-free, shorter, and safer flight path between the starting point and the endpoint in the complex three-dimensional battlefield environment	Yes
[75]	2021	A multi-scale flight path planning procedure, enabling higher resolution requirements for areas of special interest, while reducing the number of required images to a minimum.	Yes
[104]	2021	an improved adaptive grey wolf optimization algorithm (AGWO) based on the grey wolf optimization algorithm (GWO) aiming at the three-dimensional path planning of unmanned aerial vehicle (UAV) in a complex environment	Yes
[105]	2021	An analysis and study of the UAV route optimization method based on the two goals of confidence and ambiguity, and optimizing the method of drone route	Yes
[106]	2021	A path planning algorithm based on A∗ and DWA to achieve global path optimization while satisfying security and speed requirements for UAVs to shorten the path length, reduce the planning time, improve the UAV path smoothness, and enhance the safety of UAV path obstacle avoidance	Yes
[107]	2020	A study on the path planning problem and an improved A* algorithm to produce the optimal flight path for UAVs	Yes
[108]	2019	A study for generating 3D flight paths for a swarm of cooperating UAVs flying in a formation having a prespecified shape, in the presence of polygonal obstacles, no-fly zones, and other non-cooperative aircraft	No
[109]	2019	A study on Dijkstra's algorithm and a heuristic algorithm for the path planning of a UAV and comparing the results under different configurations	Yes
[110]	2019	A framework of autonomous bridge inspection using a UAV which consists of a six-step process and uses several sensors, cameras, and LiDAR	No
[111]	2018	A method to find the optimal path for a UAV flight considering 3 cost functions: path security cost, length cost, and smoothness cost	Yes
[112]	2018	A survey on computational-intelligence-based UAV path planning considering offline and online planning, and 2D and 3D models	No
[113]	2018	A method for autonomous tracking using radar to provide real-time feedback on target position, and then to perform dynamic path planning by combining the feedback data and the state estimation result	Yes
[114]	20 18	An improved particle swarm optimization (PSO) algorithm, named GBPSO, to enhance the performance of three-dimensional path planning for fixed-wing UAVs	Yes

Conclusions

With advancements and the expanding scope of research on Unmanned Aerial Vehicles (UAVs), addressing the issues and challenges associated with this platform holds considerable benefits, especially in fields like infrastructure inspection. The effectiveness of UAV-based inspections heavily relies on data quality, it becomes crucial to overcome challenges and limitations in pre-flight planning for optimal data collection. This review study delves into the pivotal phase of UAV-based infrastructure inspection, discussing the progress and remaining challenges related to the selection of hardware (UAV and payload), camera calibration, and flight path planning for UAVs. The increasing interest among researchers in achieving these advancements and addressing challenges is thoroughly explored. Furthermore, each challenge highlighted in this study presents an opportunity for future research endeavors aimed at optimizing UAV-based infrastructure inspection by resolving these issues.

References

1. AP Black (2022) 2022 Bridge Report American Road & Transportation Builders Association.
2. Federal Highway Administration (2004) National Bridge Inspection Standards..
3. BF Spencer, V Hoskere, Y Narazaki (2019) Advances in Computer Vision-Based Civil Infrastructure Inspection and Monitoring. Engineering 5(2): 199-222.
4. S Abu Dabous, S Feroz (2020) Condition monitoring of bridges with non-contact testing technologies. Auto. Constr 116: 103224.
5. Q Zhang (2023) Automated Unmanned Aerial Vehicle-Based Bridge Deck Delamination Detection and Quantification. Transp Res Rec J Transp Res Board pp. 036119812311554.
6. TZ Xiang, GS Xia, L Zhang (2019) Mini-Unmanned Aerial Vehicle-Based Remote Sensing: Techniques, applications, prospects. IEEE Geosci. Remote Sens 7(3): 29-63.
7. L Duque, J Seo, J Wacker (2018) Bridge Deterioration Quantification Protocol Using UAV. J Bridge Eng 23(10): 04018080.
8. S Sreenath, H Malik, N Husnu, K Kalaichelavan (2020) Assessment and Use of Unmanned Aerial Vehicle for Civil Structural Health Monitoring. Procedia Comput Sci 170: 656-663.
9. Y Liu, X Nie, J Fan, X Liu (2020) Image-based crack assessment of bridge piers using unmanned aerial vehicles and three-dimensional scene reconstruction. Comput Aided Civ Infrastruct Eng 35(5): 511-529.
10. S Feroz, S Abu Dabous (2021) UAV-Based Remote Sensing Applications for Bridge Condition Assessment. Remote Sens 13(9): 1809.
11. N Gucunski (2013) National Research Council (US), Second Strategic Highway Research Program (U.S.), Eds., Nondestructive testing to identify concrete bridge deck deterioration. in SHRP 2 report, no. S2-R06A- RR-1. Transportation Research Board, Washington, DC, USA.
12. C Cheng, Z Shang, Z Shen (2020) Automatic delamination segmentation for bridge deck based on encoder-decoder deep learning through UAV-based thermography. NDT E Int 116: 102341.
13. S Dorafshan, LE Campbell, M Maguire, RJ Connor (2021) Benchmarking Unmanned Aerial Systems-Assisted Inspection of Steel Bridges for Fatigue Cracks. Transp Res Rec J Transp Res Board 2675(9): 154-166.
14. S Chen, DF Laefer, E Mangina, SMI Zolanvari, J Byrne (2019) UAV Bridge Inspection through Evaluated 3D Reconstructions. J Bridge Eng 24(4).
15. BJ Perry, Y Guo, R Atadero, JW van de Lindt (2020) Streamlined bridge inspection system utilizing unmanned aerial vehicles (UAVs) and machine learning. Measurement 164: 108048.
16. A Rahman, ZY Wu, R Kalfarisi (2021) Semantic Deep Learning Integrated with RGB Feature-Based Rule Optimization for Facility Surface Corrosion Detection and Evaluation. J Comput Civ Eng 35(6): 04021018.
17. Q Chen, X Wen, S Lu, D Sun (2019) Corrosion Detection for Large Steel Structure base on UAV Integrated with Image Processing System. IOP Conf Ser Mater Sci Eng 608(1): 012020.
18. P Pfändler, K Bodie, U Angst, R Siegwart (2019) Flying corrosion inspection robot for corrosion monitoring of civil structures - First results. p. 8.
19. G Pryor (2021) Utilizing Unmanned Aerial Vehicles (UAVs) for the Estimation of Beam Corrosion of Steel Bridge Girders.
20. WW Greenwood, JP Lynch, D Zekkos (2019) Applications of UAVs in Civil Infrastructure. J Infrastruct Syst 25(2): 04019002.
21. A Ellenberg, A Kontsos, F Moon, I Bartoli (2016) Bridge deck delamination identification from unmanned aerial vehicle infrared imagery. Autom Constr 72: 155-165.
22. A Khaloo, D Lattanzi, K Cunningham, R Dell'Andrea, M Riley (2018) Unmanned aerial vehicle inspection of the Placer River Trail Bridge through image-based 3D modelling. Struct Infrastruct Eng 14(1): 124-136.
23. F Jalinoos, M Amjadian, AK Agrawal, C Brooks, D Banach (2020) Experimental Evaluation of Unmanned Aerial System for Measuring Bridge Movement. J Bridge Eng 25(1): 04019132.
24. S HekmatiAthar, N Goudarzi, A Karimoddini, A Homaifar, D Divakaran (2020) A systematic evaluation and selection of UAS-enabled solutions for bridge inspection practices. in 2020 IEEE Aerospace Conference, Big Sky, MT, USA: IEEE pp. 1-11.
25. J Chen, J Wu, G Chen, W Dong, X Sheng (2016) Design and Development of a Multi-rotor Unmanned Aerial Vehicle System for Bridge Inspection. in Intelligent Robotics and Applications, vol. 9834, N Kubota, K Kiguchi, H Liu, T Obo (Eds.,) in Lecture Notes in Computer Science, Cham: Springer International Publishing pp. 498-510.
26. F Vanegas, KJ Gaston, J Roberts, F Gonzalez (2019) A Framework for UAV Navigation and Exploration in GPS-Denied Environments. in 2019 IEEE Aerospace Conference, Big Sky, MT, USA: IEEE, pp. 1-6.
27. N Bolourian, A Hammad (2020) LiDAR-equipped UAV path planning considering potential locations of defects for bridge inspection. Autom. Constr 117: 103250.
28. B Hubbard, S Hubbard (2020) Unmanned Aircraft Systems (UAS) for Bridge Inspection Safety. Drones 40(3): 40.
29. T Campi, S Cruciani, M Feliziani (2018) Wireless Power Transfer Technology Applied to an Autonomous Electric UAV with a Small Secondary Coil. Energies 11(2): 352.
30. Ramin Babazadeh Dizaj, Nastaran Sabahi (2023) Optimizing LSM-LSF composite cathodes for enhanced solid oxide fuel cell performance: Material engineering and electrochemical insights. World J Adv Res Rev 20(1): 1284-1291.
31. Z Ameli, Y Aremanda, WA Friess, EN Landis (2022) Impact of UAV Hardware Options on Bridge Inspection Mission Capabilities. Drones 6(3): 64.
32. I Sa, S Hrabar, P Corke (2014) Inspection of pole-like structures using a vision-controlled VTOL UAV and shared autonomy. in 2014 IEEE/RSJ International Conference on Intelligent Robots and Systems, Chicago, IL, USA, IEEE, pp. 4819-4826.
33. G Pajares (2015) Overview and Current Status of Remote Sensing Applications Based on Unmanned Aerial Vehicles (UAVs). Photogramm Eng Remote Sens 81(4): 281-330.
34. G Morgenthal (2019) Framework for automated UAS-based structural condition assessment of bridges. Autom Constr 97: 77-95.
35. CV Dung, H Sekiya, S Hirano, T Okatani, C Miki (2019) A vision-based method for crack detection in gusset plate welded joints of steel bridges using deep convolutional neural networks. Autom Constr 102: 217-229.

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36. B Klingner, D Martin, J Roseborough (2013) Street View Motion-from-Structure-from-Motion. in 2013 IEEE International Conference on Computer Vision, Sydney, Australia: IEEE, pp. 953-960.
37. L Deng, Z Mao, X Li, Z Hu, F Duan, et al. (2018) UAV-based multispectral remote sensing for precision agriculture: A comparison between different cameras. ISPRS J. Photogramm. Remote Sens 146: 124-136.
38. Y Xu, Y Turkan (2019) BrIM and UAS for bridge inspections and management. Eng Constr Archit Manag 27(3): 785-807.
39. K Pargieła (2023) Optimising UAV Data Acquisition and Processing for Photogrammetry: A Review. Geomat Environ Eng 17(3): 29-59.
40. SAH Mohsan, NQH Othman, Y Li, MH Alsharif, MA Khan (2023) Unmanned aerial vehicles (UAVs): practical aspects, applications, open challenges, security issues, future trends. Intell Serv Robot 16(1): 109-137.
41. FY Toriumi, TN Bittencourt, MM Futai (2023) UAV-based inspection of bridge and tunnel structures: an application review. Rev. IBRACON Estrut. E Mater 16(1): e16103.
42. R Nasimi, F Moreu, GM Fricke (2023) Sensor Equipped UAS for Non-Contact Bridge Inspections: Field Application. Sensors 23(1): 70.
43. AJ Lee, W Song, B Yu, D Choi, C Tirtawardhana, et al. (2023) Survey of robotics technologies for civil infrastructure inspection. J Infrastruct Intell Resil 2(1): 100018.
44. R Zhang, G Hao, K Zhang, Z Li (2023) Unmanned aerial vehicle navigation in underground structure inspection: A review. Geol J 58(6): 2454-2472.
45. Q Li, H Huang, W Yu, S Jiang (2023) Optimized Views Photogrammetry: Precision Analysis and a Large-Scale Case Study in Qingdao. IEEE J Sel Top Appl Earth Obs Remote Sens 16: 1144-1159.
46. S Guan, Z Zhu, G Wang (2022) A Review on UAV-Based Remote Sensing Technologies for Construction and Civil Applications. Drones 6(5): 117.
47. IH Kim, S Yoon, JH Lee, S Jung, S Cho, et al. (2022) A Comparative Study of Bridge Inspection and Condition Assessment between Manpower and a UAS. Drones 6(11): 355.
48. S Jiang, W Jiang, L Wang (2022) Unmanned Aerial Vehicle-Based Photogrammetric 3D Mapping: A survey of techniques, applications, challenges. IEEE Geosci Remote Sens. Mag 10(2): 135-171.
49. T Elmokadem, AV Savkin (2022) A method for autonomous collision-free navigation of a quadrotor UAV in unknown tunnel-like environments. Robotica 40(4): 835-861.
50. A. Savva et al. (2021) "ICARUS: Automatic Autonomous Power Infrastructure Inspection with UAVs. in 2021 International Conference on Unmanned Aircraft Systems (ICUAS), Athens, Greece: IEEE, pp. 918-926.
51. Y Tan, S Li, H Liu, P Chen, Z Zhou (2021) Automatic inspection data collection of building surface based on BIM and UAV. Autom. Constr 131: 103881.
52. H Ahmed, HM La, N Gucunski (2020) Review of Non-Destructive Civil Infrastructure Evaluation for Bridges: State-of-the-Art Robotic Platforms, Sensors and Algorithms. Sensors 20(14): 3954.
53. E Jeong, J Seo, J Wacker () Literature Review and Technical Survey on Bridge Inspection Using Unmanned Aerial Vehicles. J Perform Constr Facil 34(6): 04020113.
54. DH Hennage, JR Nopola, BD Haugen (2019) Fully Autonomous Drone for Underground Use. presented at the 53rd U.S. Rock Mechanics/ Geomechanics Symposium, p. ARMA-2019-2028.
55. J Fan, M Ala Saadeghvaziri (2019) Applications of Drones in Infrastructures: Challenges and Opportunities.
56. CH Tan (2018) A smart unmanned aerial vehicle (UAV) based imaging system for inspection of deep hazardous tunnels. Water Pract Technol 13(4): 991-1000.
57. S Dorafshan, M Maguire (2018) Bridge inspection: human performance, unmanned aerial systems and automation. J Civ Struct Health Monit 8(3): 443-476.
58. S Jordan (2018) State-of-the-art technologies for UAV inspections. IET Radar Sonar Navig 12(2): 151-164.
59. H Aasen, E Honkavaara, A Lucieer, P Zarco Tejada (2018) Quantitative Remote Sensing at Ultra-High Resolution with UAV Spectroscopy: A Review of Sensor Technology, Measurement Procedures, Data Correction Workflows. Remote Sens 10(7): 1091.
60. H Aasen, A Burkart, A Bolten, G Bareth (2015) Generating 3D hyperspectral information with lightweight UAV snapshot cameras for vegetation monitoring: From camera calibration to quality assurance. ISPRS J Photogramm. Remote Sens 108: 245-259.
61. G Wang, QM Jonathan Wu, W Zhang (2008) Kruppa equation-based camera calibration from homography induced by remote plane. Pattern Recognit. Lett 29(16): 2137-2144.
62. A Tommaselli, M Galo, M De Moraes, J Marcato, C Caldeira, et al. (2013) Generating Virtual Images from Oblique Frames. Remote Sens 5(4): 1875-1893.
63. Z Zhang (2000) A flexible new technique for camera calibration. IEEE Trans Pattern Anal Mach Intell., 22(11): 1330-1334.
64. X Li, Y Xiao, B Wang, H Ren, Y Zhang, J Ji (2023) Automatic targetless LiDAR-camera calibration: a survey. Artif Intell Rev 56(9): 9949-9987.
65. Y Zhang (2022) Camera Calibration for Long-Distance Photogrammetry Using Unmanned Aerial Vehicles. J Sens 2022: 1-7.
66. S Sobura (2021) Calibration of Non-Metric UAV Camera Using Different Test Fields. Geod Cartogr 47(3): 111-117.
67. Q Pentek, P Kennel, T Allouis, C Fiorio, O Strauss (2020) A flexible targetless LiDAR-GNSS/INS-camera calibration method for UAV platforms. ISPRS J. Photogramm. Remote Sens 166: 294-307.
68. B.Aragon (2020) A Calibration Procedure for Field and UAV-Based Uncooled Thermal Infrared Instruments. Sensors 20(11): 3316.
69. VE Oniga, N Pfeifer, AM Loghin (2018) 3D Calibration Test-Field for Digital Cameras Mounted on Unmanned Aerial Systems (UAS). Remote Sens 10(12): 2017.
70. M Cramer, HJ Przybilla, A Zurhorst (2017) UAV Cameras: Overview and Geometric Calibration Benchmark. Int. Arch. Photogramm. Remote Sens Spat Inf Sci pp. 85-92.
71. A Fryskowska, M Kedzierski, A Grochala, A Braul (2016) Calibration of Low Cost RGB and Nir UAV Cameras. Int Arch Photogramm Remote Sens Spat Inf Sci 817-821.
72. H Yanagi, H Chikatsu, (2015) Camera Calibration in 3d Modelling for UAV Application. Int. Arch. Photogramm. Remote Sens Spat Inf Sci 223-226.
73. A Richardson, J Strom, E Olson (2013) April Cal: Assisted and repeatable camera calibration. in 2013 IEEE/RSJ International Conference on Intelligent Robots and Systems, Tokyo: IEEE, pp. 1814-1821.
74. K Douterloigne, S Gautama, W Philips (2009) Fully automatic and robust UAV camera calibration using chessboard patterns. in 2009 IEEE International Geoscience and Remote Sensing Symposium, Cape Town, South Africa IEEE, p. II-551-II-554.
75. P Debus, V Rodehorst (2021) Multi-scale Flight Path Planning for UAS Building Inspection. in Proceedings of the 18th International Conference on Computing in Civil and Building Engineering, vol. 98, E Toledo Santos, S Scheer (Eds.,) Lecture Notes in Civil Engineering, vol. 98, Cham: Springer International Publishing pp. 1069-1085.
76. K Hidaka, D Fujimoto, K Sato (2019) Department of Mechanical Engineering, Faculty of Science and Engineering, Saga University 1 Honjo-machi, Saga-shi, Saga 840-8502, Japan, Autonomous Adaptive Flight Control of a UAV for Practical Bridge Inspection Using Multiple-Camera Image Coupling Method. J Robot Mechatron 31(6): 845-854.

77. AE Jimenez Cano, PJ Sanchez-Cuevas, P Grau, A Ollero, G Heredia (2019) Contact-Based Bridge Inspection Multirotors: Design, Modeling, Control Considering the Ceiling Effect. IEEE Robot Autom Lett, 4(4): 3561-3568.

78. H Rienecker, V Hildebrand, H Pfifer (2023) Energy optimal 3D flight path planning for unmanned aerial vehicle in urban environments. CEAS Aeronaut J 14(3): 621-636.

79. M Torres, DA Pelta, JL Verdegay, JC Torres (2016) Coverage path planning with unmanned aerial vehicles for 3D terrain reconstruction. Expert Syst Appl 55: 441-451.

80. MA Luna, MS Ale Isaac, AR Ragab, P Campoy, P Flores Peña, et al. (2022) Fast Multi-UAV Path Planning for Optimal Area Coverage in Aerial Sensing Applications. Sensors 22(6): 2297.

81. Y Lin, S Saripalli (2014) Path planning using 3D Dubins Curve for Unmanned Aerial Vehicles. in 2014 International Conference on Unmanned Aircraft Systems (ICUAS), Orlando, FL, USA: IEEE, pp. 296-304.

82. J Canny, J Reif (1987) New lower bound techniques for robot motion planning problems. in 28th Annual Symposium on Foundations of Computer Science (sfcs 1987), Los Angeles, CA, USA: IEEE, pp. 49-60.

83. G Gugan, A Haque (2023) Path Planning for Autonomous Drones: Challenges and Future Directions. Drones 7(3): 169.

84. F Morbidi, R Cano, D Lara (2016) Minimum-energy path generation for a quadrotor UAV. in 2016 IEEE International Conference on Robotics and Automation (ICRA), Stockholm, IEEE, pp. 1492-1498.

85. X Zhang, H Duan (2015) An improved constrained differential evolution algorithm for unmanned aerial vehicle global route planning. Appl. Soft Comput 26: 270-284.

86. A Kaveh, P Almasi, A Khodagholi (2023) Optimum Design of Castellated Beams Using Four Recently Developed Meta-heuristic Algorithms. Iran J Sci Technol Trans Civ Eng 47(2): 713-725.

87. Yao-hong Qu, Quan Pan, Jian-guo Yan (2005) Flight path planning of UAV based on heuristically search and genetic algorithms. in 31st Annual Conference of IEEE Industrial Electronics Society, 2005. IECON 2005., Raleigh, NC, USA IEEE, p. 5.

88. MD Phung, CH Quach, TH Dinh, Q Ha (2017) Enhanced discrete particle swarm optimization path planning for UAV vision-based surface inspection. Autom. Constr 81: 25-33.

89. C Zhang, W Zhou, W Qin, W Tang (2023) A novel UAV path planning approach: Heuristic crossing search and rescue optimization algorithm. Expert Syst. Appl 215: 119243.

90. Y Wu, M Nie, X Ma, Y Guo, X Liu (2023) Co-Evolutionary Algorithm-Based Multi-Unmanned Aerial Vehicle Cooperative Path Planning.

91. Z Wu, J Zeng, Z Hu, MD Todd (2023) Optimization of unmanned aerial vehicle inspection strategy for infrastructure based on model-enabled diagnostics and prognostics. Mech Syst Signal Process 204: 110841.

92. R Zhang, X Li, H Ren, Y Ding, Y Meng, et al. (2023) UAV Flight Path Planning Based on Multi-strategy Improved White Sharks Optimization. IEEE Access, pp. 1-1.

93. A Souto, R Alfaia, E Cardoso, J Araújo, C Francês (2023) UAV Path Planning Optimization Strategy: Considerations of Urban Morphology, Microclimate, Energy Efficiency Using Q-Learning Algorithm. Drones 7(2): 123.

94. Z Yu, Z Si, X Li, D Wang, H Song (2022) A Novel Hybrid Particle Swarm Optimization Algorithm for Path Planning of UAVs. IEEE Internet Things J 9(22): 22547-22558.

95. M Cano, JL Pastor, R Tomás, A Riquelme, JL Asensio (2022) A New Methodology for Bridge Inspections in Linear Infrastructures from Optical Images and HD Videos Obtained by UAV. Remote Sens 14(5): 1244.

96. A Puente-Castro, D Rivero, A Pazos, E Fernandez-Blanco (2022) A review of artificial intelligence applied to path planning in UAV swarms. Neural Comput. Appl 34(1): 153-170.

97. Z Qadir, MH Zafar, SKR Moosavi, KN Le, MAP Mahmud (2022) Autonomous UAV Path-Planning Optimization Using Metaheuristic Approach for Predisaster Assessment. IEEE Internet Things J 9(4): 2505-12514.

98. J Yuan (2022) Global Optimization of UAV Area Coverage Path Planning Based on Good Point Set and Genetic Algorithm. Aerospace 9(2): 86.

99. A Israr, ZA Ali, EH Alkhammash, JJ Jussila (2022) Optimization Methods Applied to Motion Planning of Unmanned Aerial Vehicles: A Review. Drones 6(5): 126.

100. C Zhang, Y Zou, F Wang, E Del Rey Castillo, J Dimyadi, et al. (2022) Towards fully automated unmanned aerial vehicle-enabled bridge inspection: Where are we at? Constr Build Mater 347: 128543.

101. R Zhang, S Li, Y Ding, X Qin, Q Xia (2022) UAV Path Planning Algorithm Based on Improved Harris Hawks Optimization. Sensors 22(14): 5232.

102. A Ait Saadi, A Soukane, Y Meraihi, A Benmessaoud Gabis, S Mirjalili, et al. (2022) UAV Path Planning Using Optimization Approaches: A Survey Arch Comput Methods Eng 29(6): 4233-4284.

103. X Zhou, F Gao, X Fang, Z Lan (2021) Improved Bat Algorithm for UAV Path Planning in Three-Dimensional Space. IEEE Access 9: 20100-20116.

104. W Zhang, S Zhang, F Wu, Y Wang (2021) Path Planning of UAV Based on Improved Adaptive Grey Wolf Optimization Algorithm. IEEE Access 9: 89400-89411.

105. H Zhang (2021) Research on UAV Route Optimization Method Based on Double Target of Confidence and Ambiguity. Front Neurorobotics 15: 694899.

106. X Bai, H Jiang, J Cui, K Lu, P Chen, M Zhang (2021) UAV Path Planning Based on Improved A ∗ and DWA Algorithms. Int J Aerosp Eng 2021: 1-12.

107. J Chen, M Li, Z Yuan, Q Gu (2020) An Improved A* Algorithm for UAV Path Planning Problems. in 2020 IEEE 4th Information Technology, Networking, Electronic and Automation Control Conference (ITNEC), Chongqing, China: IEEE, pp. 958-962.

108. E D'Amato, M Mattei, I Notaro (2019) Bi-level Flight Path Planning of UAV Formations with Collision Avoidance. J Intell Robot Syst 93(1-2): 193-211.

109. K Danancier, D Ruvio, I Sung, P Nielsen (2019) Comparison of Path Planning Algorithms for an Unmanned Aerial Vehicle Deployment Under Threats. IFAC-Pap 52(13): 1978-1983.

110. S Jung (2019) Toward Autonomous Bridge Inspection: A framework and experimental results. in 2019 16th International Conference on Ubiquitous Robots (UR), Jeju, Korea (South): IEEE, pp. 208-211.

111. Z Fu, J Yu, G Xie, Y Chen, Y Mao (2018) A Heuristic Evolutionary Algorithm of UAV Path Planning. Wirel Commun Mob Comput 2018: 1-11.

112. Y Zhao, Z Zheng, Y Liu (2018) Survey on computational-intelligence-based UAV path planning. Knowl. Based Syst 158: 54-64.

113. B Wang, J Bao, L Zhang, Q Sheng (2018) UAV autonomous path optimization simulation based on radar tracking prediction. EURASIP J Wirel Commun Netw 2018(1): 239.

114. C Huang, J Fei (2018) UAV Path Planning Based on Particle Swarm Optimization with Global Best Path Competition. Int. J. Pattern Recognit. Artif. Intell 32(6): 1859008.

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