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A Literature Survey of Unmanned Aerial Vehicle Usage for Civil Applications

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ABSTRACT

Unmanned vehicles/systems (UVs/USs) technology has exploded in recent years. Unmanned vehicles are operated in the air, on the ground, or on/in the water. Unmanned vehicles play a more significant role in many civil application domains, such as remote sensing, surveillance, precision agriculture and rescue operations rather than manned systems. Unmanned vehicles outperform manned systems in terms of mission safety and operational costs. Unmanned aerial vehicles (UAVs) are widely utilized in the civil infrastructure because of their low maintenance costs, ease of deployment, hovering capability, and excellent mobility. The UAVs can gather photographs faster and more accurately than satellite imagery, allowing for more prompt assessment. This study provides a comprehensive overview of UAV civil applications, including classification and requirements. Also encompassed with research trends, critical civil challenges, and future insights on how UAVs with artificial intelligence (smart AI). Furthermore, this paper discusses the specifications of several drone models and simulators. According to the literature review, precision agriculture is one of the civil applications of smart UAVs. Unmanned aerial vehicles aid in the detection of weeds, crop management, and the identification of plant diseases, among other issues, paving the path for researchers to create drone applications in the future.

Keywords: Drones; Altitude; Flight Mechanics; Applications; Artificial intelligence; Image processing; Machine learning.

INTRODUCTION

The manned system is utilized in challenging circumstances when there is limited control, autonomy or legal constraints. The introduction of modern military manned vehicles, such as aircraft, has narrowed the time when some personnel are at risk. Some defence experts believe that low-cost unmanned aerial vehicles (UAVs), which are now being developed, will eventually replace advanced manned military aircraft (Hildmann and Kovacs 2019). It is cost-effective to use UAVs in hazardous areas where human aircraft face a high risk of being turned away. Because an unmanned vehicle (UV) is without an aircrew, its range and endurance are limited, as is the potential of death.

An unmanned system (US) or UV is an electromechanical system that does not have a human operator on board. Unmanned vehicles can be controlled remotely or independently, depending on pre-programmed programs. A UV/US is used in several settings because of advancements in safety. As the spectrum of uses for drones widens, benefits such as improved mission safety and lower operational costs become available (Zhuo *et al.* 2017). There are three categories of unmanned vehicles/systems:

- Unmanned/Autonomous Aerial Vehicle (UAV/AAV) (Demir *et al.* 2015).
- Unmanned/Autonomous Ground Vehicle (UGV/AGV) (George Fernandez *et al.* 2019).
- Unmanned/Autonomous Underwater Vehicle (UUV/AUV) (Jain *et al.* 2015).

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Other UV classes do not share the broad popularity of UAVs.

In recent years, technology connected to UAVs has been consistently and swiftly advancing. Unmanned aerial vehicles, often known as drones, are the most prevalent type of US. Drone stands for "dynamic remotely operated navigation equipment". A UV can fly in the air, surveying large areas, and reaching human-hostile environments. Unmanned aerial vehicles with increasing degrees of autonomy can perform many functions, such as automated take-off, landing, obstacle avoidance, and course planning (Oubbati *et al.* 2019). Drones are transforming the world into a cyber-mechatronics environment. A drone is a one-of-a-kind aircraft comprised of advanced robotics, aeronautics, and electrical components. Drones have shown to be a legitimate alternative for obtaining information that would otherwise be transmitted faster and more cost-effectively by satellites (Alzahrani *et al.* 2020).

Unmanned aerial vehicles can capture outstanding aerial photographs, aerial films and collect vast amounts of correct data due to their excellent cameras equipped with top-notch sensors. In many domains, such as surveillance, transportation, farming, and disaster management, drones are a predictable and conspicuous provider of civil amenities. Unmanned aerial vehicle and drone words are used interchangeably in this paper.

Unmanned aerial vehicles are employed in various cities because of their positioning comfort, affordable maintenance, hover and high mobility. Figure 1 describes the structure of this survey paper. The earliest purpose of the survey is to analyse several UAV civil applications and identify the hurdles (Mohamed *et al.* 2020). Significantly, this survey consists of:

- Unmanned aerial vehicle classification and specifications based on their types, endurance, weight, payload, components, sensors, and applications;
- Description of drone models and simulators used in civil applications;
- An outline of research trends, vital challenges and future insights in the UAV usage in the civil application domain are summarized (Giordan *et al.* 2020).

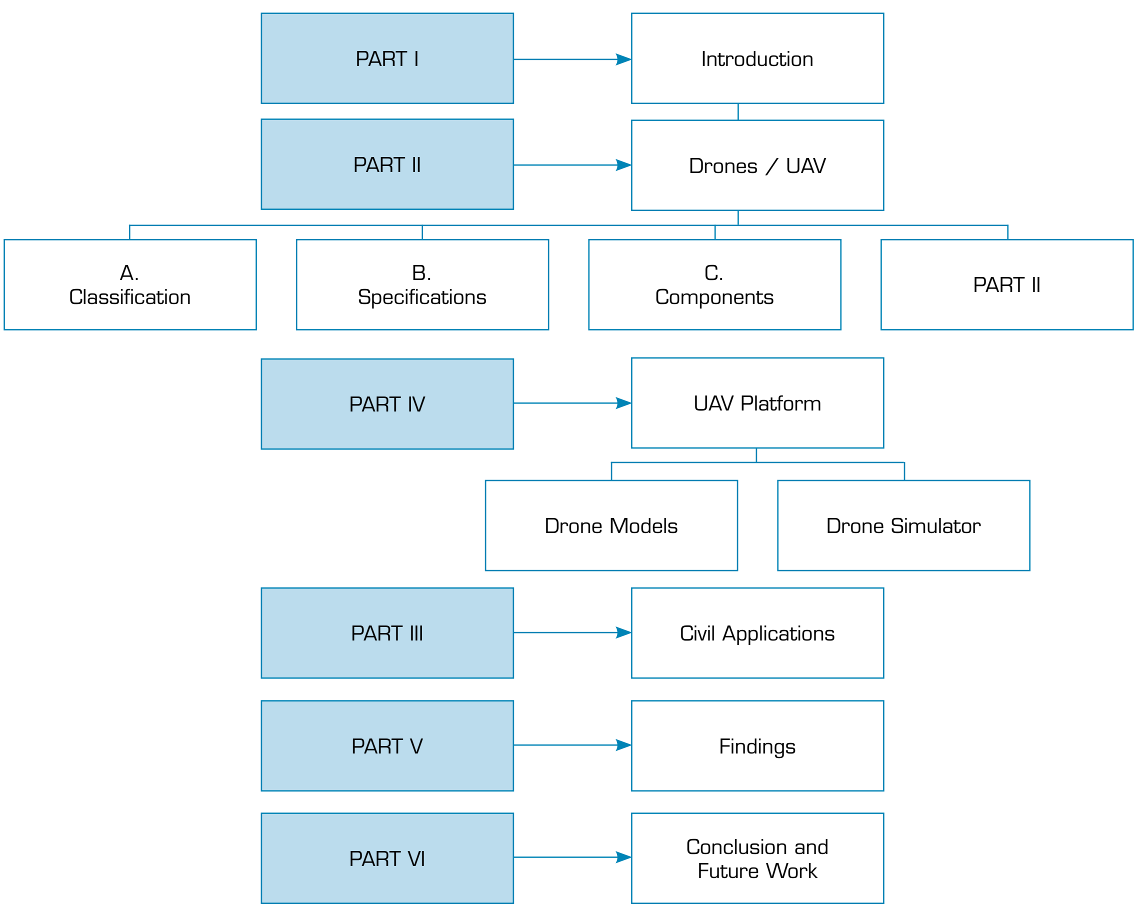

Figure 1. Detailed structure of the survey.

UNMANNED AERIAL VEHICLE HARDWARE

Unmanned aerial vehicle classification

A UAV can be operated remotely by pilots or pre-programmed to operate without the assistance of humans. The technical characteristics of drones play a significant role in their categorization, such as technology used, level of autonomy, size, weight and energy resources. Unmanned aerial vehicles are often equipped with a variety of sensors, including radars, television cameras, global positioning system (GPS) satellite communications, image intensifiers and infrared imaging technology (Shakhatreh *et al.* 2019). The primary feature used to keep the drone fly is the technology used. Drones are defined and differentiated based on flying mechanism and altitude, as shown in Fig. 2. The second prominent feature is the level of autonomy of the UAV, differ fully self-governing to and controlled entirely by a remote pilot.

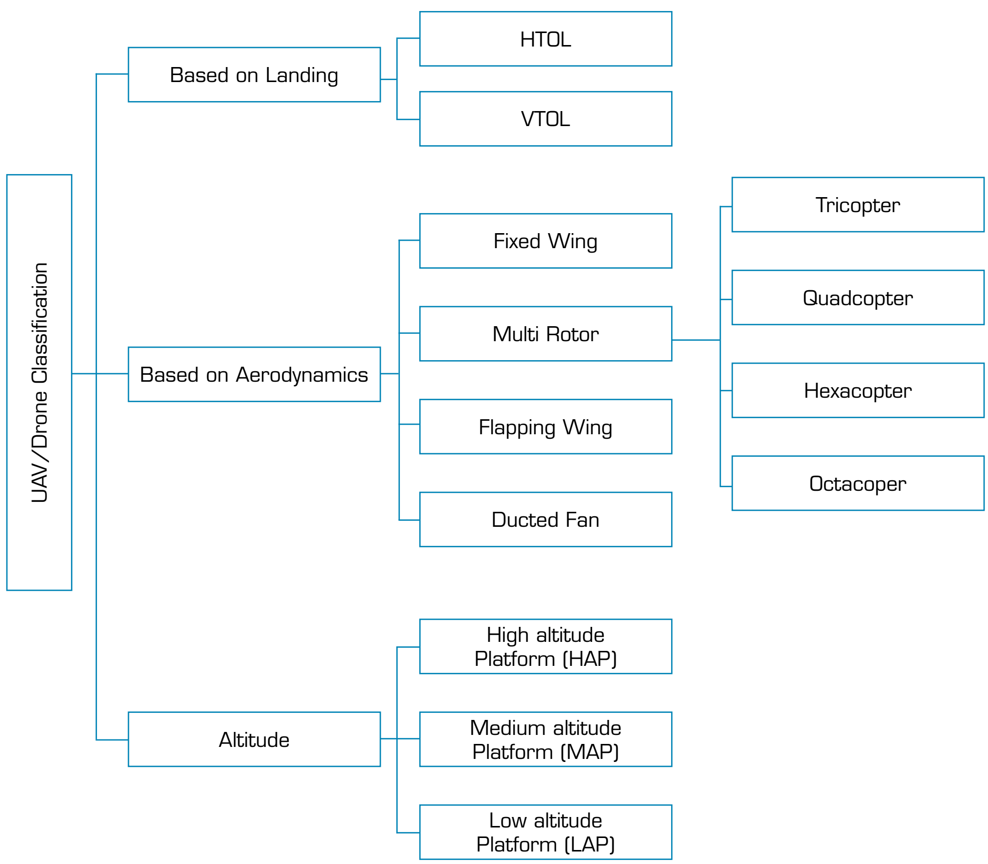

Figure 2. Classification of UAVs.

Unmanned aerial vehicle categorization

As shown in Fig. 3, drones are also graded based on their size and weight. The size of UAVs can vary from insect to aeroplane size and range from hundreds of grams to kilograms in weight. Drone governance is carried out remotely by radio waves or autonomously by a predefined path (Arfaoui 2017). For operational insight, a vehicle with a maximum take-off weight not exceeding 25 kg does not need a license, permit or insurance.

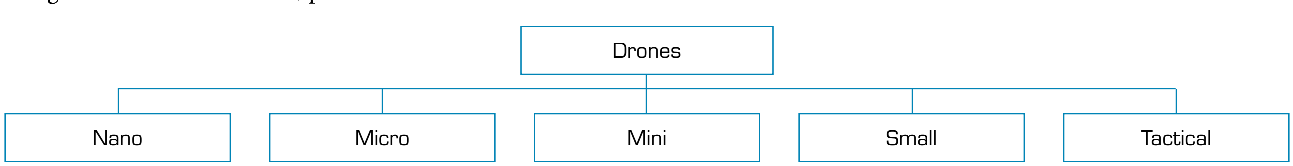

Figure 3. Categorization of UAVs based on size.

Drones are often characterized and differentiated based on their nano to mega applications. Large UAVs are mainly used for military applications (Vergouw *et al.* 2016), whereas more modest and smaller drones are for everyday society. The various standard distribution systems used drone weight and were classified into five drones: nano, micro, mini, small and tactical (Mitka and Mouroutsos 2017). Table 1 describes the properties of different types of drones, their weights, altitude range, flying mechanism and area that they can cover. The table also gives the information of example model, description and also applications. The payload field in the table gives how much weight that a drone is capable of carrying. Based on the application domain and the requirement the appropriate drone is selected (Singhal *et al.* 2018).

Table 1. Unmanned aerial vehicle classification based on size, range, properties and applications.

Type	Max. weight	Operating altitude (m)	Range (km)	Payload (kg)	Flight time (min)	Example model	Flying mechanism	Description	Applications
Nano	200 g	50	5	< 0.2	6–8	Kogan Nano Model	Multirotor	Easily manoeuvred and reach remote locations	Recreation
Micro	2 kg	< 90	25	0.2–0.5	45	Parrot Disco	Fixed-wing	Operated on low altitudes with limited space for fuel and battery	Recreation, military, spying task.
Mini	20 kg	150 < 300	40	0.5–10.0	18	DJI Spreading Wings	Multirotor	Maintain line of sight between the aircraft and the ground station.	Hobbies such as photography and cinematography
Small	25 to 150 kg	< 1500	150	5.0–50.0	180	Scout-B330 UAV Helicopter	Multirotor	Operated at low to medium altitudes and longer loiter capabilities	Transferring goods, military, used in remote locations
Tactical	> 150 kg	< 3000	200	25.0–200.0	1800	Predator B	Fixed wing	Operated at high altitudes, provide tracking or monitoring	Armed investigation, target acquisition

Unmanned aerial vehicle components

Variations of UAVs are commonly used in different areas, including hazardous materials control or operation. Quadcopters seem to be used for all recent advancements in the field of small autonomous drones. Mechanical simplicity is the key reason why they are famous for small drones. A quadrotor refers to the UAV house; it also involves two pairs of counter-rotating rotors and propellers mounted at the top of a square frame (Nijim and Mantrawadi 2016). Vertical take-off and landings similar to traditional helicopters are capable of being achieved. Due to user safety and protection, the quadcopter is intended to allow either indoor or outdoor flights as a fundamental study parameter. At the appropriate time, the criterion for meeting the scheme should be fast, reliable and robust. X-copter is one of the most responsive drone constructions. Based on the number of propellers used, "X" was replaced with quad-, hexa- and octa-. Table 2 gives the overview of the most acceptable components used in quadcopter mounted in a cascade form to guarantee the endurance and reliability of the process (Gupte *et al.* 2012). The table also gives the component description. Drones are used to track the fitness of equipment, patrolling, transport, deliveries located in remote areas or at significantly high altitudes. They are used to collect the soil in areas where humans cannot live. Image recognition and mobile

3D mapping, where the UAV exerts photos or explores specific areas, are applied to the usage of the drones to create an implied model of the location chosen (Deepak and Singh 2016).

Table 2. Description of quadcopter components.

Quadcopter components	Description
Frame	It is the construction that endures or households all the components collectively. They are designed to be healthy and lightweight.
Motor	The design of motors is to rotate the propellers. Each rotor necessitates being controlled separately by a speed controller.
Speed controller	It checks the rapidity of the motor or expresses to the engines how fast it rotates at a given time.
Propeller	A quadrotor holds four propellers, two "regular" propellers that rotate counter-clockwise, and two "pusher" propellers that rotate clockwise to dodge body spinning.
Flight controller	It is the brain of the quadrotor. It houses the sensors before-mentioned as the accelerometers and gyroscopes, which conclude how quickly each of the quadrotor motors turn.
Radio transmitter and receiver	It enables the regulation of the quadrotor, and it necessitates four channels for a basic quadrotor.
Battery	Lithium polymer (LiPo) batteries are among the most frequent battery kinds for drones, as their size and weight benefit from high energy density with greater voltage per cell, which allows them to power drones on-board systems with less cells than other rechargeable systems.
Telemetry module	It is practiced to regain flight information of the quadrotor on a computer to follow several aircraft parameters on the ground.
Camera	It enhances the production of the quadrotor and adds value to its uses—the camera worked as an attachment with a USB to observe the images.
Video transmitter and receiver	The transmitter transforms the information into a radio signal and outputs it to the imputed antenna, which later sends it out. The receiver operates to turn the radio signal into explicit videos.

Sensors

A *sensor* is a system that differentiates changes in electrical, physical or other supplies and, thus, produces an output as an affirmation of the change in quantity (Ostojic *et al.* 2015). Figure 4 shows the basic sensors used in many UAVs.

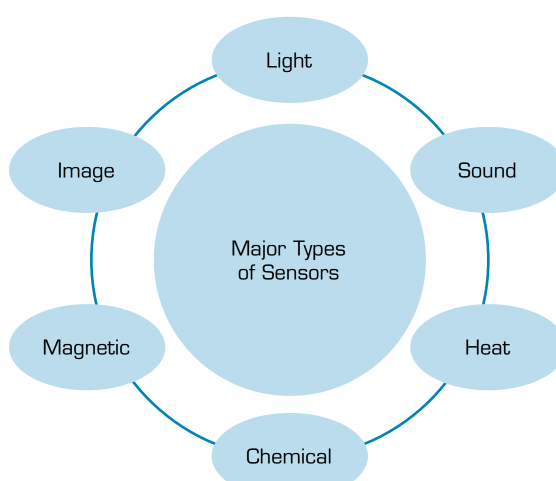

Figure 4. Major types of UAV sensors.

Besides this knowledge, UAVs can manage their situations, ascertain how quick they are, and evade barriers (Nagai *et al.* 2012). Here are some more sensors that are used in complex UAVs and their work.

- **Gyroscope:** Gyroscopes are a comprehensive tool used for measuring or maintaining orientation. This technology is massively operated to keep a steady hover. Gyroscope is so vital to the regular control of a UAV.
- **Barometer:** This sensor helps to regulate air pressure. It is seen in almost all UAVs and is frequently used to aid in sustain a stable altitude. Self-governing UAV missions with variations in height are necessary, also earn use of the citations from the onboard weatherglass. Although GPS technology can further be utilized to plot the elevation of a UAV, barometers provide much added accurate data and render quicker feedback, as long as they have precisely calibrated.
- **Accelerometer:** The accelerometer of a UAV goes collectively among its gyroscope to plot variations in its movement and location. Wherever the gyroscope practices understand rotational movements, an accelerometer does healthier in reading linear motion on any axis. Accelerometers, in sequence including GPS technology, allow the smartphone or fitness equipment to trace the route when running or travelling.
- **Global positioning system:** Depending upon the position of the satellite authorization, the time it needs for the UAVs GPS module to allow the call will vary. The accuracy of the site will depend on the power of the signal that the UAVs GPS module also bears the number of satellites inside its reach.
- **Magnetometer:** A magnetometer holds power and control of a magnetic field, so as the name. A UAV can eternally conclude the area of the magnetic north and modify its trajectory, respectively.
- **Range finder:** A rangefinder is to discover how far apart from the ground the UAV is. The standard rangefinders utilize sonar technology. By drawing sound waves from the land region, a sonar rangefinder can conclude the height of the UAV.
- **Inertial measurement unit (IMU):** An IMU is imprecisely a separate sensor of the drone, but is instead an association of several sensors. An IMU of the drone includes accelerometers, gyroscopes and magnetometers, a specific set of which acts in all three axes of action.
- **Current sensors:** In drones, power dissipation and performance are particularly important. Using current sensors, power loss may be monitored and regulated to a certain extent. Batteries throughout the house can be charged reliably, and faults in devices or other parts of the system can be identified and corrected (Sørensen *et al.* 2017).
- **Speed and distance sensors:** Certain sensors are used to identify the drone speed or measure the distance within the UAV and another article without actual physical contact with the item.
- **Infrared and thermal sensors:** For example, search and rescue, surveillance, leak detection, pipeline inspection and agricultural and forest health are all possible uses of infrared sensors depending on the accuracy of the sensor.
- **Image sensors:** By converting the volatile attenuation of light waves into electrical signals, an image sensor can identify and transfer information about whatever makes an image. As an example, it can be used to make multispectral photographs, thermography, X-ray sensors, as well as other extremely sensitive arrays for space observations.
- **Chemical sensors:** For example, it can be attached to a drone and offer information on the material balance of any situation.

UNMANNED AERIAL VEHICLE MODELS AND DRONE SIMULATOR

Broadly used UAV models

Numerous drone models are already in use, as they are developing fast. In a short period, many new models are formed for the developing demand in drone technology. Therefore, models which are extensively available for civil applications are described here.

- **DelFly Explorer:** DelFly Explorer is the main flapping-wing MAV capable of solo flight (Croon *et al.* 2012). Onboard stereo vision is used to avoid impediments. In addition, it is equipped with a barometer to help it maintain its height. DelFly Explorer can fly for up to 9 min without external control thanks to a collection of sensors. Testing has proven successful in numerous indoor areas, including laboratories and lecture halls, as well as outdoor spaces. As a result of the battery, the current record is limited to 9 min.

- **Hubsan X4 drone:** Hubsan X4 drone was developed by a Chinese company named Hubsan (2015). Despite its modest size and weight (28 g without the battery), this drone is incredibly fast and offers a high degree of manoeuvrability. It is not as important as the palm of a human hand, but it is still a lot of fun. It has a maximum flight time of 9 min when completely charged. A built-in camera is included in some X4 drone versions for taking photos and recording video. It is designed largely for leisure goals.
- **Parrot AR drone:** The Parrot AR is a drone primarily manufactured for entertaining commitments. This drone can fly for about 12–18 min when fully charged. The weight of the parrot AR drone is approximately 400 g. Drones can go up to 18 km•h^{-1} and have a range of roughly 50 m. This drone is equipped with Bluetooth, wi-fi, two cameras, and GPS instructions to hover over a preprogrammed course. Some applications of Parrot AR drone are film, photography and gaming, emphasizing recreation more clearly. The customer can set a new assignment and settings, such as maintaining a particular altitude, before it automatically leads out the specified charge. This Parrot AR drone is one of DJI's most popularly used recreational drone models (Cheema *et al.* 2016).
- **Phantom:** The DJI Phantom UAV is a four-rotor multirotor UAV primarily designed for entertainment purposes. A smartphone or a wi-fi controller with a camera may control the DJI Phantom UAV. The smartphone can also move and capture pictures or record video with the drone camera. The DJI Phantom has a top speed of 54 km•h^{-1} and a battery life of about 25 min. The user can simply preprogram the flight height and waypoints, and the UAV will automatically take off, land, document, and respond (Hovhannisyan *et al.* 2018; Sagitov and Gerasimov 2017).
- **Raven:** In 2002, fixed-wing UAV Raven was developed. The essential idea of the Raven is inspection, and it can be controlled preprogrammed for self-governing operation. The Raven weighs 2 kg, has a diameter of 1.4 m, and has a range of 10 km. It can stay operational for 60–90 min. It is primarily comprised of an optic and an infrared camera. Heaving the Raven into the air propels it forward. It arrives by gliding towards a preprogrammed docking point and can compensate for the impact by falling apart as it hits the ground (Bratanov *et al.* 2017; O'Young and Hubbard 2007).

Drone simulator

A UAV simulator is what it seems like: it is a software program developed to reproduce the action of operating a drone by using an actual UAV controller compared to the cooperative device (Oubbati *et al.* 2020). Most UAV simulators can work on either a computer or a Mac. Some drone flight simulators allow to customize them for specific flying scenarios. Due to the complicated environment, including various variables, a simulation model of the UAV system serves to design more reliable and achieve a drone fleet (Fernando *et al.* 2013). The network function virtualization (NFV) and software-defined network (SDN) are two prominent technologies for managing and improving UAV assistance in future mobile networks. Unmanned aerial vehicle system simulation enhances resolution-making in these sectors (La *et al.* 2017). The best simulators used in many civil applications are tabulated in Table 3.

CIVIL APPLICATIONS

Unmanned aerial vehicles can be practised in various civilian uses due to their low preservation cost, deployment efficiency, high mobility and ability to hover (Kardasz *et al.* 2016). Several civil applications are listed here and also summarized in Fig. 5.

- **Disaster management:** assessing the damage, locating victims, care of public safety, search and rescue actions and delivering aids (Hayat *et al.* 2016).
- **Construction and infrastructure inspection:** creating accurate 2D and 3D data, maps and models, conducting surveys before, during and after construction, monitoring gas, oil and water pipelines (Greenwood *et al.* 2019).
- **Agriculture and remote sensing:** planting crops, disease finding, monitoring, irrigation, water quantity nursing, yield approximations, deficiency monitoring (Norasma *et al.* 2019).
- **Healthcare:** delivering medical services in remote areas (Wulfovich *et al.* 2018).
- **Waste management:** identifying garbage sites (Leizer 2018).
- **Utility inspecting:** telecommunication towers, tracking oil spills (Johnsen *et al.* 2020).
- **Urban planning:** providing instant mapping and ready to use data for planning (Noor *et al.* 2018).

- **Wildlife conservation:** monitoring the number of animals, species, collecting samples for conservationists to track porches (Ivosevic *et al.* 2015).
- **Geographic mapping:** acquiring high-resolution data, downloading imagery in challenging to reach locations like coastlines (Yavaşlı 2020).
- **Weather forecasting:** accessing weather trends to understand imminent dangers (Balaji *et al.* 2018).
- **Mining:** measuring minerals, surveying operations (Park and Choi 2020).
- **Law enforcement:** monitoring large crowds, tracking illegal activities (Stelmack 2015).
- **Real-time monitoring of road traffic flow:** field provision sides, rescue teams, traffic police, road inspectors, hovering roadside unit and hovering dynamic traffic signals (Elloumi *et al.* 2018).
- **Commercial photography:** images and videos are both popular outcomes from commercial drone jobs. These could be for wedding and commercial photography/videography, real estate marketing photography, or even filming with big-budget motion pictures.

Table 3. Drone simulator used in civil applications.

Drone simulator	Description	Example application domains
DJI drone simulator	DJI UAV flight simulator has an energetic set of flight situations such as high-quality visuals and realistic flight experience (Mairaj *et al.* 2019).	Search and rescue, power line inspection
Zephyr drone simulator	It arises with a continually increasing library of both exercise modules and UAV platforms with different modes and styles of flying available (Roder *et al.* 2018).	Drone farming, precision agriculture, fire departments
droneSimPro drone simulator	It is a custom-built flight engine, which permits the simulator to imitate the real-world physics of drone flight (Intaratep *et al.* 2016).	Real-world physics, agriculture and pilot training
USBsim	It allows the user to create imaginary drone-networks by adjusting parameters like as the number of hosts and attackers, as well as mobility and radio propagation models (Pleban *et al.* 2014).	Gaming and future drone traffic controllers
Heli-X simulator	It is designed to enhance operator abilities prior to flying a specific UAV and to aid in the practise of flight settings and training modes (Akturk and Altunel 2019; Peacock and Johnstone 2013).	Film making, fire departments, security
AVENS simulator	It is mainly developed for communications and integrated with both X-Plane and the OMNeT++ (Erbil *et al.* 2009; Marconato *et al.* 2017).	UAVNet Security
RAVEN simulator	It has a good prototype for a controlled environment and manages the network for SWARM (Gerdes *et al.* 2014).	Agriculture, military, drone farming
AirSim simulator	It is a beneficial tool for artificial intelligence research concentrating on various autonomous drones and generates exercised data for machine learning models (Shah *et al.* 2018).	Kaggle datasets, elite data science
Real drone simulator	It enhances the career in virtual reality and the real world using Google Earth (Burnham 2019; Nguyen *et al.* 2019).	Film making, precision agriculture
D-MUNS	Distributed multiple UAVNet simulator can effectively reduce simulation time and effort (Kok and Chahl 2015; Van Hoydonck and Pavel 2007).	UAVNet security, academic curriculum

Unmanned aerial vehicles are declaring to be highly propitious in places where a person cannot move or is incapable of performing in an exceedingly reasonable and sufficient practice. Improving work performance and potency, minimizing workload and merchandise cost, refining service and customer relations, increasing precision, and fixing security problems on a broad scale is the first UAV uses that give industry globally. The rapid mobility of UAVs, frequent packet losses and weak connectivity between UAVs are addressed to affect data delivery reliability (Oubbati *et al.* 2019). The drones maintain the flexibility to achieve the significant isolated areas with little to no human resources required and wish the smallest amount of energy, effort, and time. It is one of the most important goals of being embraced worldwide, especially by these four sectors: disaster management, precision agriculture, construction and infrastructure inspection and healthcare, as shown in Fig. 6. The detailed description of the four sectors is presented below.

Figure 5. Unmanned aerial vehicle civil applications.

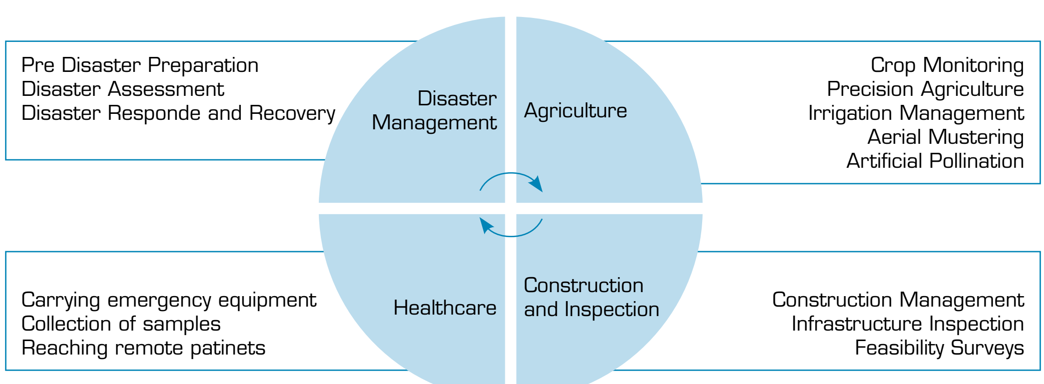

Figure 6. Categorization of civil applications.

Disaster management

A disaster is an event caused by a natural or man-made hazard that occurs over a short or extended period of time. It results in significant physical harm or destruction, as well as mortality or a big alteration in the environment. The disaster management team supports search and rescue operations, such as public safety, locating victims, assessing damage, and delivering aids

(Oubbati *et al.* 2020). Drones can step in for relief workers and manned vehicles in situations when they are needed. Drones can be easily used to access hard to reach areas. Drones are used to enable communication coverage during natural or man-made disasters such as floods or terrorist attacks, as well as essential infrastructure like water and electrical utilities (Tanzi *et al.* 2016). Drones provide timely disaster warnings as well as assistance in restoring public communication networks that have been interrupted. It can also supply medical aids to classified inaccessible areas and search missing persons/animals in disastrous situations like poisonous gas leakage, forest fires, and avalanches (Restas 2015). These are the main areas where drones help to improve search and rescue missions.

- Use of mapping and imaging technology to provide quick situational awareness;
- Help rescuers locate hot spots and examine property damage;
- Capture imagery for communications and news coverage;
- Search for survivors;
- Assess utility and infrastructure damage;
- Create before/after maps of the affected region (Erdelj and Natalizio 2016).

Unmanned aerial vehicles have been applied in a wide variety of disaster management applications, but the following are the most common (Chowdhury *et al.* 2017):

- **Predisaster planning:** refers to incidents linked to surveying that occur prior to the calamity.
- **Evaluation of disasters:** provide real time situational awareness of the event and complete logistic damage studies.
- **Disaster response and recovery:** Search And Rescue (SAR) missions, building the communications backbone, and insurance-related field surveys are just a few examples.

Agriculture

The rapid improvement and growth of UAVs as a remote sensing platform, as well as advances in device downsizing and data systems, have resulted in increased adoption of this technology in metropolitan areas and remote sensing social networks. Drones can be used to collect data from ground sensors and distribute it to ground base stations. Drones with sensors can be used to create an aerial sensor network for disaster management and environmental monitoring (Tsouros *et al.* 2019). Drones, remote sensing applications from tree species, water quality monitoring, disease detection, crop monitoring, yield predictions, and drought monitoring are just few of the data sources. Some of the applications of drones in agriculture are:

- **Crop monitoring:** The crop fields are vast and challenging to monitor volatile weather conditions, increasing the field risk and labour costs. Unmanned aerial vehicles equipped with RGB or multispectral cameras helps to eliminate these challenges (Hassan-Esfahani *et al.* 2015).
- **Precision agriculture:** Vegetation that focuses on crop diseases, nutrient deficiencies, and pest infestation reduces productivity. Crop data is collected by UAVs and processed with AI techniques to address these challenges (Radoglou-Grammatikis *et al.* 2020).
- **Irrigation management:** UAVs assist in obtaining critical irrigation data at any time and at a low cost (Kim *et al.* 2019).
- **Aerial mustering:** Aerial stock mustering occurs when a UAV is used to locate, direct, and concentrate livestock while flying below 500 ft above ground level. It is utilised to supplement the employment of horses and motorcycles in traditional mustering tactics (Katke 2019). Mustering operations are defined as activities linked to the aerial monitoring and control of livestock that is handled by helicopter and fixed-wing aircraft and include: animal culling, aerial stock mustering and aerial stock spotting (Barbedo *et al.* 2020).
- **Artificial pollination:** The decrease in the honeybee population has gained immense concern worldwide. Hence, UAVs act as pollinators to transport pollen from flowers using hair coated with gel (Potts *et al.* 2018).

Construction and infrastructure inspection

Unmanned aerial vehicles used in real-time monitoring development project sites and examining high voltage of power synchronized lines. Drones are used to recognize the buildings near the power lines and the location of trees (McCabe *et al.*

2017). Small UAVs are deployed, observe the facilities, infrastructure, including water, gas, oil pipelines. The gas controller unit is deployed in UAVs to identify gas, air leaks and content. Drone inspection applications throughout the construction cycle (Anwar *et al.* 2018) are mentioned below:

- **Monitoring project progress:** Project maps are built using drone data for regular monitoring and planning, avoiding delays and additional expenses. Progress monitoring helps the projects to move according to their plan with no deviations. Construction/deconstruction sequences, crane positions, perimeter security, and many other aspects are evident due to UAV-based progress monitoring (Shahmoradi *et al.* 2020).
- **Construction site mapping:** The creation of drone maps has become more straightforward, inexpensive and results in less intense civil engineering work than older methods. Drones may now easily access any location using topographic surveys to create visual representations for evacuations, stockpile measurements, and correct transport prices. For real-time computer mapping of information, Pix 4D software is used (Getsov *et al.* 2017).
- **Volumetric measurement:** To keep records of the onsite raw materials used during construction to improve efficiency and reduce stock waste. In stockpiles volume estimates, 99% accuracy is achieved by incorporating state-of-the-art technology, such as machine learning. Volumetric measurements are high speed, precise, and cost-effective using Equinox drones (Fan and Saadeghvaziri 2019).
- **Buildings surveillance:** Inspections of buildings can be dangerous and challenging for humans to carry out independently. Building UAV surveillance helps lower personal safety risks and boosts productivity by recording vast and essential data. Drone surveillance or aerial surveillance helps in finding potentially risky scenarios for better decisions more efficiently. Drones equipped with thermal sensors are popular amongst building surveillance projects to evaluate roofs for faults without actually going there.

Health care

Drones have the potential to collect real-time data and deliver payloads at a low cost, and they have sped up the development of various industrial, commercial, and recreational applications. Telecommunication drones are used for diagnosis and treatment, perioperative evaluation, and telemetering in remote locations (Rosser Junior *et al.* 2018). Microbiological and laboratory samples, drugs, vaccines, emergency medical supplies, and patient transportation can all be delivered using drones. Drones have a variety of practical applications that have much potential and are listed below:

- **Emergency supplies or medications on board:** EpiPens, poison antidotes, and oxygen masks are just a few types of life-saving kit (Thiels *et al.* 2015).
- **Blood and tissue sample collection:** Drones may be able to provide goods and services while also allowing for speedier return transit to labs that are adequately prepared, eliminating human work and time (Konert *et al.* 2019).
- **Performing search and rescue missions:** People that have gone missing or been injured can be rescued at sea, in the mountains, in the desert, or in the bush (Fotouhi *et al.* 2019).
- **Accessibility to far-flung patients:** People are typically found in situations where the infrastructure for efficient emergency or continuity of care is lacking. Drones are being used to provide telemedicine, vaccinations, prescription drugs, and medical supplies to people at home.
- **Integration of cloud and internet of things (IoT):** It presents a cost-effective way to connect heterogeneous devices and address rising data demands in healthcare applications, including seamless application deployment and rendering service (Malleswari and Vadivu 2019).

DISCUSSION

This section summarizes recent applications in which UAVs with AI for civil purposes are presented. The following Tables 4–7 summarize types of sensors, recent trends and critical challenges, and how they are addressed using UAVs in civil applications (Maghazei and Netland 2020).

Table 4. Summary of disaster management applications.

Continuation

Reference	Applications/ Goals/Scenarios	Method adopted	Type of sensors	Drone Model Used	Future Insights
Erdelj *et al.* (2016)	Pre-disaster management; Disaster assessment; Disaster response and recovery.	Using unmanned aerial vehicles as data mules enhance WSN data collecting and processing to determine the severity of future disaster occurrences. Use heterogeneous unmanned aerial vehicle networks made up of fixed-wing unmanned aerial vehicles to scan the region and identify key moments to be covered and inspected by rotary-wing unmanned aerial vehicles. Maximize data provided by the WSN to improve the efficiency of search and rescue missions conducted out by unmanned aerial vehicles.	Thermal sensors; Optical camera; Thermal IR camera; LiDAR; Multispectral cameras; Particle sensor.	DJI Phantom 4 PRO: search and rescue missions; Zipline: fast medical interventions; AuxDron: life guard drones; Aerones: firefighting missions; DJI Mavic PRO: police search and crime prevention.	Self-learning approaches employing repeated trials may not be appropriate for using unmanned aerial vehicles to survey disaster areas. Unified situational awareness can direct unmanned aerial vehicles to specified places and reduce data forwarding requirements, saving more energy for flight. The charging points are located, and the energy transmission mechanisms must be properly adjusted.
Kamilaris and Prenafeta-Boldú (2018)	Deep learning for calamity detection.	Unmanned aerial vehicle-captured aerial photographs are used to identify disasters using deep learning techniques. A VGG-based deep learning model was created to demonstrate the potential of the technique for automatically and accurately identifying disasters.	Optical remote sensing; Multispectral cameras.	PrecisionHawk; Terra Drone; SenseFly unmanned aerial vehicle; Swinglet CAM.	Limited computational capability. Low energy resources. Issues with flight allowance regulations impede real-time data processing, geographical coverage, and flexibility of use. Unmanned aerial vehicles with deep learning techniques are significant, providing high-accuracy event identification in real-time without requiring much processing capacity.
Xu *et al.* (2019)	Autonomous unmanned aerial vehicle navigation based on airborne vision and deep learning: Mapping locations; Delivering urgent supplies; Extinguishing fires; Airlifting victims.	Unmanned aerial vehicle path-finding using a rotatable camera and onboard processing module in the midst of a tragedy.	HD FPV Camera; GPS; Thermal infrared images; Laser scanner; GIS.	DJI Mavic Mini; DJI Mini 2 Fly; Holy Stone HS110D FPV RC Drone; Contixo 4K GPS Quadcopter Drone.	There is a greater emphasis on precision in navigation; Lack of real-world verification.
Software used for disaster management		DisasterLAN: DisasterLAN (DLAN) disaster management software gives your team everything they need to plan for, respond to, and report on problems—anytime, anywhere, and on any device. SiteRecoveryManager: VMware Site Recovery Manager Disaster Recovery Software Discover the industry-leading disaster recovery software that uses policy-based administration, nondisruptive testing, and automated orchestration to provide application availability and mobility across sites in private cloud settings. TapeTrack: their software, which is based on their five pillars of tape management design philosophy, will help manage the tape assets, chain of custody, library management, disaster recovery, and quality control. ENOv8 environment management: Enov8 is a one-of-a-kind software engineering firm that specializes in enterprise IT environment management, such as IT disaster recovery, enterprise release management, and test environment management. Tpgroup is a prominent provider of cutting-edge artificial intelligence and machine learning-driven solutions for complex issues in a variety of domains. This includes a software that provides safe and secure autonomous navigation for single or multiple manned and unmanned platforms, such as unmanned surface vessels, unmanned aerial vehicles, and unmanned ground vehicles.			

Table 5. Summary of precision agriculture applications.

Author and year	Applications/ Goals/Scenarios	Method adopted	Type of sensors	Drone model used	Future insights
Yinka-Banjo and Ajayi (2019)	Crop monitoring	The development of a framework to analyse unmanned aerial vehicle images and create mosaic images that can be matched with maps for GIS integration is centred on establishing a framework to analyse unmanned aerial vehicle photos and create mosaic images that can eventually be matched with maps for GIS integration.	Digital; Hyperspectral cameras; Multispectral cameras; GPS Receiver; Wireless temperature and humidity sensors	Lancaster 5; AgBot.	Advances in computer intelligence, particularly in navigation, automated sensing, and actuation. Techniques for data gathering, data mulling, and, most crucially, transforming these data into valuable information must be developed. The flying time of an unmanned aerial vehicle is mostly determined by its battery capacity. Most unmanned aerial vehicles are unable to carry a large amount of cargo at once due to their small size.
Radoglou-Grammatikis *et al.* (2020)	Precision agriculture	The vegetation indices are calculated using unmanned aerial vehicle photos, allowing farmers to track crop variability and other unusual situations. The normalized difference vegetation index (NDVI) helps extract information on biomass levels, which can then be used to get essential insights on crop diseases, pest infestations, nutrient deficits, and other factors that affect productivity.	RGB cameras; Hyperspectral cameras; Multispectral cameras; Thermal cameras; GPS receiver; Wireless temperature and humidity sensors.	Sentera PHX; AgEagle RX-60.	Designing a decision support system (DSS) capable of handling both a FANET and a ground-based WSN for crop monitoring and spraying.
Cancela *et al.* (2019)	Irrigation management	Using proximal and remote sensing to determine crop water requirements and monitor crop water status to improve irrigation efficiency. Exploring novel approaches to better irrigation management and a more accurate estimate of crop water requirements.	Digital cameras; Micro hyperspectral cameras; Multispectral cameras; GPS receiver; Wireless temperature and humidity sensors.	eBee SQ; HoneyComb; DJI Matrice 210.	Improving model predictions at larger scales aims to address information gaps and obtain consistent hydraulic space-temporal input data to be used in artificial intelligence networks. Unmanned aerial vehicles allow researchers and water managers to collect large amounts of data in a safe, cost-effective, and more accessible way than previous techniques. As unmanned aerial vehicle and sensing technology evolve, new processing tools and algorithms will be developed.

Continue...

Table 5. Summary of precision agriculture applications.

Author and year	Applications/ Goals/Scenarios	Method adopted	Type of sensors	Drone model used	Future insights
Yaxley *et al.* (2021)	Aerial livestock mustering	It combines a deep learning algorithm for imprecise animal location with pixel modification to boost animal contrast.	RGB cameras; Hyperspectral cameras; Multispectral cameras; Thermal cameras GPS receiver; Wireless temperature and humidity sensors.	AgEagle; DJI Matrice 600 Pro; Lancaster 5.	It is not optimal to consider several features of the same animal; new techniques will be explored for animal tracking. New approaches to collect photographs with the purpose of increasing the useful space in each image.
Chen and Li (2019)	Artificial pollination	It includes flower recognition using computer vision techniques and a robotic MPR system, as well as an unmanned aerial vehicle pollinating system. A six-configuration MPr architecture has indeed been presented for autonomous artificial pollination.	OpenMV Camera	QWinOut DIY F450	Experimental verification and validation of unmanned aerial vehicle pollination, Create a CIAD framework for intelligent unmanned aerial vehicle pollination. New artificial intelligence algorithms are being developed, such as the heredity algorithm (HA).
Iost Filho *et al.* (2019)	Biological control	Changes in leaf reflectance are caused by physiological defence responses that are triggered by arthropod pests that damage plants and cause biotic stress. Advanced imaging technologies allow noninvasive crop monitoring by detecting changes such as these.	Temperature sensor; Humidity sensor; Light intensity sensor; CO_2 sensor; Water level sensor; EC and pH sensor.	eBee SQ; Sentera PHX; AgBot.	To employ drones for precision agriculture, you will face financial issues, such as the expenses of drones and associated sensors and material, a restricted flight time and payload, and rules that will constantly be changing. There will be an increased demand for multidisciplinary research partnerships among agronomists, ecologists, software developers, and engineers as a result of this new trend.

Table 6. Summary of construction and infrastructure inspection applications.

Author and year	Applications/ Goals/Scenarios	Method adopted	Type of sensors	Drone model used	Future insights
Shaw and Vimalkumar (2020)	Construction monitoring and reporting of a residential apartment	A framework used to establish a fully automated intelligent building surveillance and reporting system based on real-time drone data. Data for drone photographs from numerous locations (by the 3D scan of the sites) and point clouds can be used to create a 3D model using photogrammetry techniques.	Laser scanner; Global positioning satellite; Thermal sensor; Real-time thermography; Kinect RGB-D sensors; Infrared or LiDAR.	DJI Phantom 4 RTK drone; Zero V-Cptr Falcon.	Use of unmanned aerial vehicle swarms for inspection tasks. Exploring techniques and developments in automated by the deep learning techniques applied in the cloud. More data are a significant challenge, despite multiple advanced algorithms. The sharpness or clarity of the image is another crucial challenge that prevents drones from further use in infrastructure.
Kim *et al.* (2020)	Drones deliver construction prefabricated unit	An effective operational design for a drone-based parcel shipment is suggested on the rooftops of town buildings. It is suggested that solutions (i.e., delivery timetables) should be produced swiftly and efficiently, even for significant difficulties often present in congested metropolitan regions. With experimental tests, the proposed optimization model and heuristic are validated.	Laser scanner; Global positioning satellite; Thermal sensor; Real-time thermography; Kinect RGB-D sensors; Infrared or LiDAR; Reflector prism.	DJI Inspire 2; 3DR H520-G.	When the actual validation work of the planned delivery system begins later, more accurate data should be obtained and used for model parameters. Since the location of the drone operations centre can impact the planning of drone operations, it is necessary to examine the location problem. In order to evaluate the proposed heuristic performance, metaheuristics such as genetic algorithms must be compared.
Hegeir *et al.* (2017)	Drones used in placing pilot lines of suspension bridges	In each clamp, the drone was used to measure the slip value; from the video captured by the drone, high-definition images had been taken; and AutoCAD was used to adjust the image size using the well-known image dimension.	Laser scanner; Global positioning satellite; Thermal sensor; Real-time thermography; Kinect RGB-D sensors; LiDAR; Infrared thermography.	DJI Matrice 600; Equinox's; Zero V-Cptr Falcon.	The investigations include using monitoring devices and analysing drone videos and field investigations to determine the cause of the slip. Augmented and virtual reality used in autonomous inspections are another potential development.
Software used for construction and infrastructure inspection		Pragmatic insight: Drone data and artificial intelligence are used by pragmatic insight to make construction monitoring, mine management, and infrastructure inspections easier. The estimator: Appia is a web platform that organises daily reporting, funding, items, change orders, and payments for capital improvement and infrastructure projects while allowing for real-time collaboration. SmartFlow: With smart data collection, integrated process flows, and relevant insights, Smartflow is presenting the next generation of connected workers. Smartflow is a cloud-based solution for the oil, gas, and petrochemical industries, as well as Maritime, Construction & Infrastructure, Industrial Manufacturing, Energy & Utilities, and Food, Beverage, and FMCG. Businesses can use this solution to digitise inspections and certifications, to digitise and automate quality control processes, to improve operational excellence with mobile workflows in health, safety, and the environment, to manage asset performance, to digitise turnarounds and plant maintenance, and to digitise requirements verification and validation. Ramco is a prominent provider of end-to-end enterprise resource planning (ERP) software for drones, UAS, and electric vertical take-off and landing (eVTOL) aircraft. Teledyne CARIS is a major geospatial software provider for the maritime GIS community, offering high-efficiency resource optimization and data processing solutions for mapping and surveying platforms, such as autonomous underwater vehicles (AUVs) and unmanned surface vehicles (USVs).			

Table 7. Summary of healthcare applications.

Reference	Applications/ Goals/Scenarios	Method adopted	Type of sensors	Drone model used	Future insights
Bogle *et al.* (2019)	The case for drone-assisted cardiac arrest response	By specifying the number of stations and the target automated external defibrillators arrival time, a mathematical optimization model selects drone stations from existing infrastructure.	Digital barometric pressure sensor; Accelerometer; Gyroscope; Pulse rate sensor; Temperature sensor.	Automated external defibrillators (AED) drones: TU Delft, Flirtey Drone	Airbag defibrillators and other life-saving technologies can be delivered quickly via drone networks to wide and diverse geographic regions.
Jalal *et al.* (2018)	Using a continuous anaesthetic sensor in the style of a watch, a model for safe transport of critical patients in unmanned drones has been developed.	Volatile anaesthetics (isoflurane) are the only anaesthetic agents that can be monitored closely with infrared spectroscopy (IR) equipment, but they are undesirable for transport, so a safe unmanned aerial vehicle transport protocol incorporating novel gas monitoring technology was devised.	Anaesthesia sensor; Digital barometric pressure sensor; Pulse rate sensor; Temperature sensor; Glucometer.	AtraxM; TU Delft; Seattle VillageReach; EHang.	Its limited sensitivity limits its ability to isolate signals for minute variations.
Kim *et al.* (2017)	Chronic disease patients' drone-assisted healthcare in rural areas.	It is a multidepot vehicle routing problem with pickup and delivery requests. To improve the computing performance of the proposed models, a preprocessing strategy, a partition method, and a Lagrangian Relaxation (LR) method are devised.	Digital barometric pressure sensor; Pulse rate sensor; Temperature sensor; Glucometer.	TU Delft; Seattle VillageReach; Flirtey Drone.	Increasing varied flight periods are related with a distinct battery consumption rate.
Software used for health care		NextGen Healthcare: NextGen Healthcare is a prominent healthcare software and services provider that enables ambulatory care transformation. Ambulatory clinics can use this smart, electronic health record solutions to save paperwork, improve clinical outcomes, link with other health systems, improve provider and patient satisfaction, streamline the revenue cycle, and build healthier communities. Definitive healthcare: definitive healthcare supplies hospitals, physicians, and other healthcare professionals with comprehensive, up-to-date, and integrated data. Allscripts Healthcare: Allscripts (NASDAQ: MDRX) is a leading provider of healthcare IT solutions that improve clinical, financial, and operational outcomes.			

CONCLUSION

Unmanned aerial vehicles are now being built with highly versatile technology, continually developing creative ways to provide more outstanding service. This paper provides a detailed systematic literature analysis of the context classification, UAVs specification, and applications to the respective models. The study also presents various aspects of drones such as technological requirements, drone models, parts, possible payloads and sensors. The use of UAVs is rapidly increasing in substantial civil application domains. Compared to other studies, this paper comprehensively analyses existing literature and UAV uses that accurately represented their particular civil applications while further analysing the research trends, key challenges, and potential perspectives for each category. This analysis covers the different types of drone models currently being used, their configuration and applications, and the imminent technical enhancement of UAV technology. Unmanned aerial vehicles are widely employed in precision agriculture for crop management and tracking, weed detection, irrigation scheduling, disease detection, pesticide spraying, and field sensor data collection. Artificial intelligent pollinators are a wonder in precision agriculture. In the future, UAVs will play a vital role in precision agriculture by incorporating image processing techniques such as georeferencing, mosaicking, classification algorithms, and collecting high-resolution images. The key research challenges in precision agriculture raise the opportunities and further pave the way for researchers to develop future drone applications.

AUTHORS' CONTRIBUTION

Conceptualization: Mithra Sivakumar, TYJ.Nagamalleswari**; Survey Analysis:**Mithra Sivakumar, TYJ.Nagamalleswari**;Writing-Original Draft:**Mithra Sivakumar**;Writing-Review and Editing:**Mithra Sivakumar, TYJ.Nagamalleswari**; Supervision:** TYJ. Nagamalleswari.

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Data sharing is not applicable to this article as no new data were created or analyzed in this study.

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