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Review

Unmanned Aerial Vehicle classification, Applications and challenges: A Review

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Abstract: In past few years, unmanned aerial vehicles (UAV) or drones has been a hot topic encompassing technology, security issues, rules and regulations globally due to its remarkable advancements and uses in remote sensing and photogrammetry applications. This review paper highlights the evolution and development of UAV, classification and comparison of UAVs along with Hardware and software design challenges with diverse capabilities in civil and military applications. Further, safety and security issues with drones, existing regulations and guidelines to fly the drone, limitations and possible solutions have also been discussed.

Keywords: Drone, Remote Sensing, control station, Multispectral, Aviation, Regulations

1. Introduction

Technological amelioration has impacted significantly social, economic and personal life, from business approaches to international wars. These transformations can be visualized by getting benefited from these technological advancements. Unmanned aerial vehicle (UAV) also known as remotely operated aircraft is the best example to visualize the change. Unmanned Aerial vehicles do not need any pilot onboard and can be operated autonomously or remote pilot control [1, 2]. UAV is an integral part of the Unmanned aerial system which incorporates UAV, communication link and ground control station. UAV overcomes the limitation of the terrestrial system in terms of accessibility, speed and reliability [3]. UAV can provide cloud-free and high-resolution images to serve the commercial applications such as agriculture, mining and monitoring. UAV was originated in defense for reconnaissance and combat purpose. Perhaps in 1916 first ever semiautomatic aero plane was developed (aerial torpedo). In 1933 Royal Navy used the drones for the gunnery practices. Later on with the advent and integration of advanced navigation sensors UAV became an integral part of armed forces. The emergence of technology not only removed the limitations of UAV exercises in the military but expanded their wings in commercial applications related to agriculture, scientific activities, recreation, servile, delivering goods, photogrammetry and many more [4].

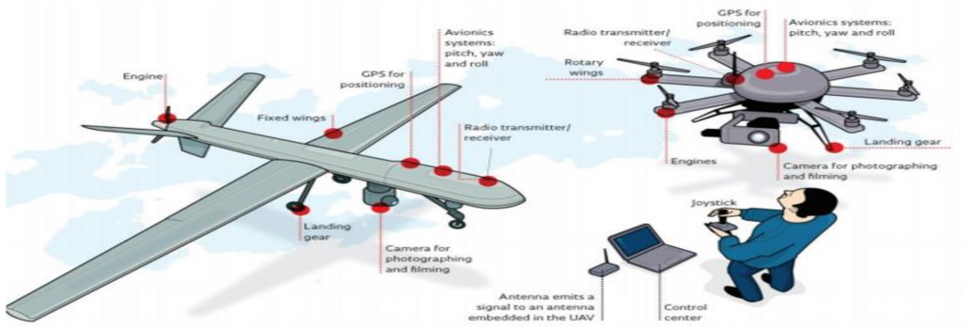

Figure 1: Fixed wing and Multirotor aerial systems [http://revistapesquisa.fapesp.br /en/2013/10/23/the-flight-of-the-falcon/]

Agriculture and Infrastructure cover the maximum share of unmanned aerial vehicle applications. The utilisation of autonomous UAV in agribusiness is reaching out at an energetic pace in Crop health monitoring, early cautioning frameworks, forestry, fisheries, and wildlife protection[5, 6]. Onboard Narrow band visible, near-infrared and thermal sensors administer the variability of the field from nutrient mapping to crop health monitoring, so that farmer makes smart farming decisions on time. [7][8].Latest PwC report (PwC, 2016) estimated the agriculture drone market to be worth USD 32.4 billion upto 2018.

2. Comparison of Satellite, Aircraft and UAV

Satellite and Aircraft based technologies are the conventional methods of remote sensing which have their benefits and hindrances in the form of Coverage area, spectral, spatial and temporal resolution with onboard sensors. Along with less revisit frequency, satellite suffers from cloud cover conditions where information beneath the clouds is shadowed entirely. Aircraft systems may sustain with higher payloads and speed, but the hovering at a place and maintaining high and low speeds are the challenges [7]. Several studies were performed by various researchers to compare the three technologies such as NDVI survey of larger farmland, soil and crop mapping, Land classification. Unmanned Aerial Vehicles somehow bridges the gap of conventional technologies regarding hovering capability, maintain low and high Speed, low elevation and more importantly higher spatial and temporal resolution of images.

A comparison of satellite, aircraft and UAV is depicted in table 1.

Table 1: UAV, Airborne and Satellite System Comparison

System	Resolution	Degree of Availability	Operation mode	Payload capacity	Operating cost
UAV	Cm to meters	High	Autonomous or remote control	Limited	Low
Helicopters	100 meters	High	Human Pilot	Limited	Medium
Airborne	Up to 50 meters	Moderate	Human Pilot	Much more than helicopters	High
Satellite	10m-1Km	Poor	Autonomous	Limited	Too high

3. Classification of UAV

3.1 Based on Aerodynamics

A variety of UAV system has been developed and in the advancement phase, some of them includes the Fixed-wing aircraft [9-11], chopper [12, 13], multi-copter [14], motor parachute and glider [15-17], UAV with Vertical takeoff and landing [18-20], congregating ready-made parts [21] and commercialized UAV [22, 23].all of them are specified for a specific mission and have their zeros and ones.

Fixed wing drones are very simple but saturated in designing and manufacturing, because of successful generalisation of larger fixed-wing planes with slight modifications and improvements. Fixed wings are the main lift generating elements in response to forward accelerating speed. The velocity and steeper angle of air flowing over the fixed wings controls the lift produced. Fixed wing drones require a higher initial speed and the thrust to load ratio of less than 1 to initiate a flight [24, 25]. If fixed wing and Multirotor are compared for a same amount of payload, fixed-wing drones are more comfortable with less power requirement and thrust loading of less than 1. Rudder, ailerons and elevators are used for yaw, roll and pitch angles to control the orientation of aircraft. Figure 2 shows the force applied on fixed-wing aircraft.

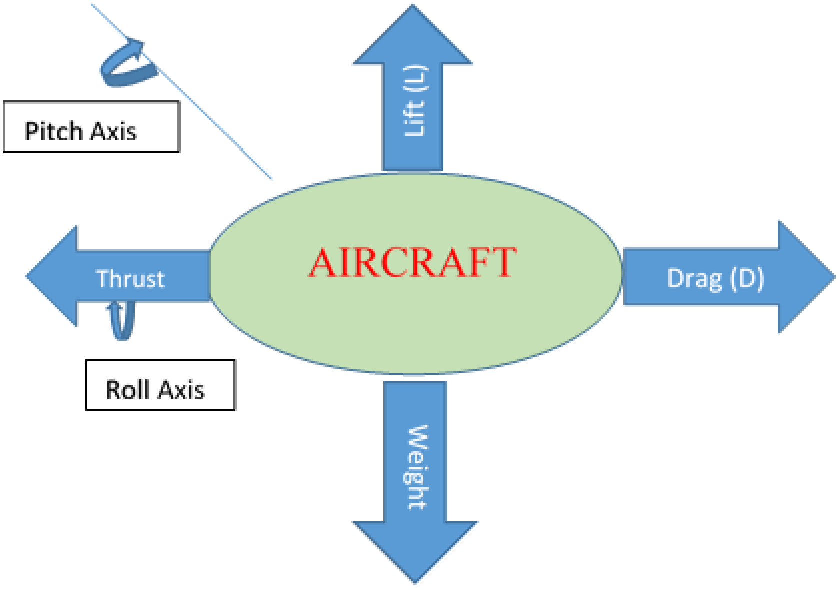

Figure 2: Fixed Wing UAV Aerodynamics

Fixed wing drones cannot hover at a place, and they cannot maintain their low speed. Subsequently, it can be seen that lift to drug ratio denotes the lift generated by a wing counter to drag generated. Fixed wing drones are more compatible with larger L/D ratio and with higher Reynolds number. Unfortunately, fixed-wing drones are less noticeable for L/D <10 for the reason that Reynolds number and efficiency decreases for smaller drones.

Flapping wing drones are primarily inspired by insects such as small hummingbirds to large dragonflies [26, 27]. The lightweight and flexible wings are inspired from the feathers of insects and birds which demonstrate the utility of weight and flexibility of wings in aerodynamics. However, these flapping wings are complex because of their complicated aerodynamics. Flapping drones can support stable flights in a windy condition, unlike fixed-wing drone. Light, flexible and flapper wings provide the flapper motion with an actuation mechanism. Intensive research on flapping wings has been carrying out by drone community and biologist because of their exclusive manoeuvrability benefits [28].

Fixed/flapping-wing: Integrated effect of the fixed and flapping mechanism is used where fixed wings are used to generate lift whereas flagging wings are used for generation of propulsion [29]. These type of drones are inspired by dragonfly which uses two pairs of wings in order to increase the lift as well as thrust forces. Hybridisation using fixed and flapping wing increases overall efficiency and aerodynamic balance [29].

Multirotor: Main rotor blade produces a forceful thrust, which is used for both lifting and propelling. Multirotor unmanned aerial vehicles are capable of vertical takeoff and Landing (VTOL) and may hover at a place unlike fixed-wing aircraft [30, 31]. Multirotor are designed by number and location of motors and propellers on the frame. Their hovering capability, ability to maintain the speed makes them ideal for surveillance purpose and monitoring. The only concern with Multirotor is that they need more power consumption and makes them endurance limited. Abott equations are used for exact calculation of power and thrust requirements in multirotor aircraft.

$$Power\ [W] = Pitch\ X\ (Diameter)^4\ X\ (RPM)^3\ X\ (5.33\ X\ 10^{-15}) \tag{1}$$

$$Thurst\ [OZ] = Pitch\ X\ (Diameter)^3\ X\ (RPM)^2\ X\ (10^{-10}) \tag{2}$$

Multicopter is divided into specific categories based on number and positioning of motors, each category belongs to a specific type of mission[32], and based on the mission requirement they are classified in various configurations such as Monocopter, Tricopter, quadcopter, hexacopter (X, + configuration) Mode, Octacopter (X, + configuration).

3.2 Based on Landing

Horizontal takeoff and landing (HTOL) and vertical takeoff and Landing (VTOL): HTOL may be considered as the extension of fixed-wing aircraft. They have high cruise speed and a smooth landing. VTOL drones are expert in flying, landing and hovering vertically [33], but they are limited by cruise speed because of the slowing down of retreating propellers [32].

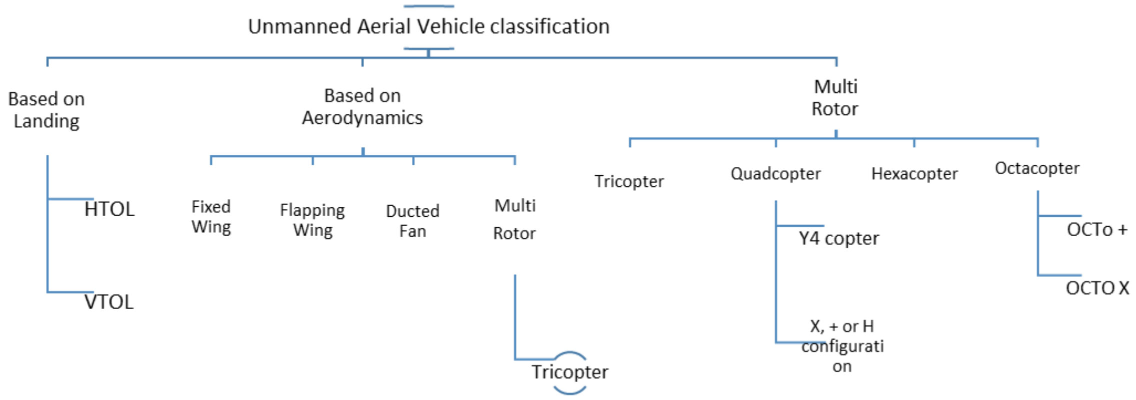

Figure 3: Classification of UAV based on Landing, Aerodynamics and weight

3.3 Based on Weight and Range

Some researchers and organisations have classified the drones based on weight and range. Table 2 presents the list of the unmanned aerial vehicle based on the weight and range.

Table 2: Unmanned aerial Vehicles classification based on weight and range [5, 34-36]

Type	Maximum Weight	Maximum Range	Category
Nano	200 gms	5 Km	Fixed wing, multirotor
Micro	2 Kg	25Km	Fixed wing, multirotor
Mini	20 Kg	40 Km	Fixed wing, multirotor
Light	50 Kg	70 Km	Fixed wing, Multirotor
Small	150 Kg	150 Km	Fixed wing
Tactical	600 Kg	150 km	Fixed wing
MALE	1000 Kg	200 Km	Fixed wing
HALE	1000 Kg	250 Km	Fixed wing
Heavy	2000Kg	1000 Km	Fixed wing
Super Heavy	2500 Kg	1500 Km	Fixed wing

Table 3: Commercial Drones Available in Global Market [37, 38]

Model	Flight Mode	Flight Time	Speed	Weight (Kg)	Camera
Autel X-Star Premium	GPS · ATTI · IOC	Up to 25 minutes	35 mph	1.6	12 mp Single shot
Blade BLH7480A	Bind-N-fly	5-10		95 gm	EFC-721

DJI Phantom1			22.36	1.2	4K
DJI phantom 3 professional	GPS/GLONASS	23	35.7	1.28	1/2.3" CMOS
DJI Phantom4		28	44.7	1.38	1/2.3" CMOS
DJI Inspire 2	GPS	27	13.42	3.44	Visible, multispectral
DJI Inspire Pro	GPS	15	11.18	3.5	Visible, multispectral
DJI Matrice 200/210/210 RTK	GPS (P and S mode)	27	51.4	3.80	Zenmuse series cameras
KAIDENG K70C	Headless mode	10	---	0.57	2.0MP
Parrot ANAFI	GPS, GLONASS	25	34	0.32	½.4'' CMOS
PARROT BEBOP 2 POWER	GPS, GLONASS	30	---	0.525	14-megapixel CMOS
JXD 509G	headless mode, automatic landing	10	---	1.2	2MP FPV
Quanum Nova	GPS	15	---	0.875	Go-pro
SYMA X8HG	Headless mode	7 min	---	~1.5 kg	8-megapixel FPV
Yuneec Tornado H920	Waypoints, Orbit Me	24	24.85	4.9	4/3 Live CMOS 16MP
TYPHOON K	GPS	25	4.5	1.7	12 MP
TYPHOON H+	GPS	28	9	1.645	20-MP CMOS
WALKERA SCOUT X4	GPS	20	35	2.27	720p HD video
VOYAGER 3	GPS/GLONASS	25	---	3.650	1080p 60FPS
KAIDENG K70C	Headless Mode,	10	---	0.579	2-megapixel

4. Hardware Design and Challenges

The designing of the Unmanned aerial system includes the unmanned aerial vehicle and other subsystems which includes communication link between UAV and user, ground control station and accessories like gimbal, payload. The design of UAV itself integrates the parts evolving from vehicle frame to complete ready to fly the aerial vehicle. Selection of components like airframe, Controller, motor, propellers and the power supply is the crucial task and needs in-depth knowledge and full-fledged mathematical calculations to design a UAV for a specified mission. Figure 4 describes the subsystems and modules for the design of UAS.

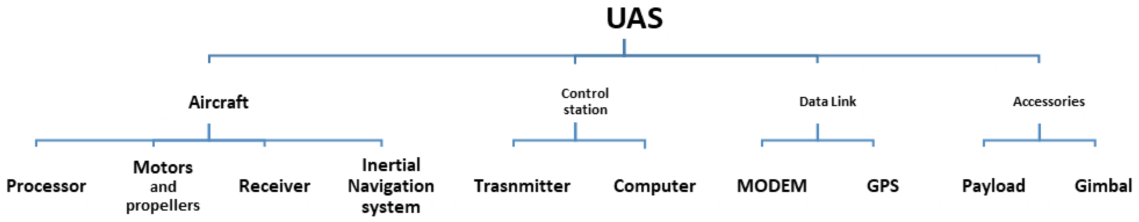

Figure 4: Unmanned Aerial System Subsystems

4.1 Aircraft design

The design challenges of an aircraft rely on the type of application which specifies the coverage area, maximum altitude, speed, climb rate, flight time or endurance, and stability [39]. All the specifications are prone to vary contingent on applications and the environmental effects. Higher altitude specifies a large coverage area and improves survivability although maximum altitude is limited by the aviation regulations. Climb rate also increases the survivability. Flight time is strictly dependent on the type of operation and aerodynamic design of aircraft.

The main components of aircraft subsystems are inertial measurement unit, motors, propellers and receiver, processor and an Airframe. The most common metallic materials to manufacture aircraft are alloys, aluminium and titanium, whereas nonmetallic materials include transparent and reinforced plastic [40]. Multicopter have the N brushless motors with N propellers. Electronic speed controller serves their purpose by varying the power supplied to motor commanded from throttle stick. They can fly in a particular direction and adjust their elevation, i.e. pitch (along X-axis, heading of quadcopter), roll (along Y-axis) and yaw (along Z-axis) by taking the inputs from Inertial Measurement Unit (IMU) consisting of three-axis accelerometer, gyroscope which provides 3-axis raw data and a GPS unit.

4.2 Ground Control System

The typical ground station consists of a wireless router along with a computer to capture, process and display of data. Typically a ground control station should fulfil requirements such as open system architecture, compatible with different platforms like airborne, ship and ground, execution of data in real time, ability to control multiple UAVs, payload control and communication with other ground control stations [41, 42]. Other safety and a security function that can be expected from the ground control station include the warnings and emergency action plan in case of any failure, power outage restoration.

4.3 Data Link

It set up a communication channel between the Aircraft sensors and ground control station (GCS).A wireless link IEEE 802.11, is used to make a communication between aircraft central data unit and ground control station, for this purpose routers equipped with omnidirectional antennas with high gain can be used to minimise path loss and make a signal to noise ratio higher. Now a day’s typical antennas work on 2.4GHz and minimum 12dBi gain. Additional wireless link based on orthogonal frequency division multiplexing (OFDM) is used for online video and images transmission to a ground station.

4.4 Accessories

With the advancement of drones, to carry out the applications such as photogrammetry, film shooting, mapping of a field, digital elevation models, monitoring and surveillance, UAV compatible cameras such as multispectral camera, thermal camera [43], hyper-spectral camera [44], digital camera [45] and film imaging units [46, 47] were used. Frequently, cameras weighing less than 12 lbs. are preferred for FPV applications, and a minimum of 12 megapixel camera is required for agriculture applications. Table 4 describes the developments in multispectral sensors for UAV.

Table 4: Common Multispectral Cameras for UAV

Model	Spectral Bands	Resolution	Weight(gm.)	Frame Rate
Tetracam ADC Lite	Green(520-600nm) Red (630-690nm) NIR(760-900nm)	2048X1536 pixel	200	----
Sentera NDVI and red edge sensor	Red, Red Edge and NIR	1.2Mp cmos	30	7 fps
Sentera	RGB ,NIR	CMOS 12.3 Mp (RGB)	80	30 fps
Phase One iXU 1000	RGB	100MP	1700	0.7
Ricoh GR2	RGB	16.2MP	221	4fps
Sentek GEMS	RGB, NIR	CMOS	170	1.4 (0.7 seconds between images)
Hasselblad	Visible			
H6D-50C		50 Mp, CMOS	2115	30 fps
H6D-100c		100 Mp, CMOS	2130	30 fps
GXRA16	Visible	16.2 Mp	550	3 fps
Mapir Survey 3	RG,NIR	12 MP(RGB)	76	---
GoPro Hero 4 Silver	Visible	12MP	81.6	15

Apart from multispectral cameras, thermal and Hyperspectral cameras are making the pace in remote sensing with drones. Drones equipped with thermal sensors are being used in mining, oil and gas industries. FLIR, telops commercial giants, have developed the thermal cameras compatible with drones. Hyperspectral sensors based remotes sensing records wavelengths with narrow spectral bands typically 5nm over the visible and NIR range. Hyperspectral images provide much more information with an ultra-high resolution where entire information is inherited in each pixel in contrast to multispectral sensors. Table 5 provides information about the developments in thermal and hyperspectral cameras for UAV.

Table 5: Representative Thermal and Hyperspectral Cameras

Manufacturer and Model	Spectral Range	Resolution	Weight	Frame Rate

FLIR Vue Pro	7.5-13.5 µm	1920 × 1080 pixel	---	30 Hz
FLIR Duo Pro R	7.5 – 13.5 µm	336 x 256pixel	---	7.5 Hz
Workswell WIRIS 640	7.5 – 13.5 µm	640 x 512 pixel	390 g	----
Zenmuse X7	7.5-13.5 µm	336×256 pixel	449 g	30 Hz
Pica NIR-200 Hyperspectral	0.9-1.7 µm	4.9 nm	2700	520 fps
Headwell Photonics	400-1000 nm	InGaAs	1025	----
Thermotenix sys.	800-1200 nm	Silicom ampohorous	105	----
Telops MSM2K	1.5-5.5 µm	320X256 pixel	---	90000 Hz
MS M100k	3 - 4.9 µm	640 × 512 pixel	---	120000 Hz
MS M350	1.5 - 5.4 µm	640 × 512 pixel	---	4980 Hz

5. Data collection and analysis

The growing popularity with endless possibilities of drones drive us to figure out the methods to data collection and analysis to utilize them with leveraged potential. Since collection and processing of UAV data is a long process, involving data collection, pre-processing of images, classification of images for features extraction, calculation of mathematical equations based on reflectances such as Indices and then the creation of a suitable model for results visualisation and interpretation. This section of the paper describes each step and makes a comparison of software's dedicated for UAV data collection and processing.

Data collection step involves the flight planning, marking Ground control points (GCPs) for samples collected and the UAV flight itself. Correct Pre-processing with a needful accuracy of UAV data is the key step for the development of models because lack of pre-processing will distort the following processes and will generate the wrong outcomes. Pre-processing of UAV data includes the images selection, accurate georeferencing and ortho-rectification and mosaicking, (aligning images using Image control points, point cloud and GCPs). Classification of georeferenced UAV images includes the supervised and unsupervised techniques for planimetric features extraction like road, railway track, agriculture land, forest, land cover and water bodies. Maximum likelihood classification (MLC), random forest and Support vector machine (SVM) are the examples of relevant classifiers. Manual classification can be tried in case of unsatisfactory results. The next step is dependent on the case study, basically this type of processing is tried for Land use land cover classification, Agriculture biophysical parameters determination and soil study. Some of the popular Indices are Normalized difference vegetation Index (NDVI), Green-Red Vegetation Index (GRVI), Soil Adjusted Vegetation Index (SAVI) and Modified Chlorophyll Index (MCI). The last step is the creation of models for a specific case study.

5.1 UAV Data Processing Software

UAV software simplifies the flight planning, processing and analysis of UAV data to provide actionable intelligence to service providers and farmers so that inputs can be optimised and better decisions can be made with reduced cost. Besides agriculture, these software are often utilised in mining, construction, surveillance, rescue operation and recreational purpose also. A good UAV software at least must include the automation of UAV flight plans, augmented view, Geo-rectification of images and 2D/3D models generation. Table 6 creates a comparison chart of various UAV software with their pros and cons.

Table 6: UAV data processing software comparison

Software	Known for	Pros	Cons
Aero Points	AeroPoints provides accurate ground control points (GCP) for UAV survey.	Automatics Data Upload, fast and easy to setup	Lack in functions like NDVI maps, 3D models creation
Agisoft	Generation of 3D models and photogrammetric processing	Cost-effective all-in-one software suite with a full range of image sensors including NIR, RGB, thermal and multi-spectral.	Compare to Pix4d it is clunky and with less functionality. One license for one computer only.
Drone Deploy	Create accurate, high-resolution maps, reports, and 3D models, as well as real-time 2D Live Maps for immediate analysis.	more suited to agricultural applications and compatible with third-party UAV hardware and accessories	Surface detail for buildings is somewhat disappointing compared to the more specialised solutions from Agisoft and Pix4D.
Drone Logbook	Import your flight log to fill info automatically, view GPS trace and replay it in 3D.	Compliance & Custom Reporting, Mission Planning & Operations Calendar	Not capable to make Digital elevation and digital terrain models
DroneMapper Rapid	Orthomosaicking, DEM, Robust processing Algorithm	Freely available for download and testing on limited data set	Limited to processing of 150 images for a scene
DroneMapper Rapid Expert	Full photogrammetric functionality and allows input of up to 1000 geo-	Can be used upto 1000 georectified images and can	Does not have self-calibration facility

	tagged JPEG images of 12 Mpixel format or greater.	produce X8, X4 or X2 DEM	
Field Agent	Replacement of sentera's AgVault, allows you to scout your crops, capturing health and vegetation index data in near real time	IOS Mobile device enabled automated flight with unlimited NDVI images	Limited functionality for mobile free version, and 29$ per month for full functionality
Live NDVI	Video technology- livestream NDVI video at the field's edge	Provides NDVI video in real time while drone is still in air	Compatible only with Sentera Double 4K sensor
Pospac UAV	Direct georeferencing and post processing software	Maximum accuracy and efficiency with compatible drone	Compatible with APX-15 L-UAV
Pix4D	Plans UAV flight, Creates orthomosaics, point clouds and professional 3D models	Photo camera Self Calibration, automatic DTM generation	Topographic maps can be created only manually.
Photo Mod	Provides all photogrammetric products like DEM, dDSM, 2D and 3D- vectors, orthomosaics	high performance, simplified user-friendly interface and automation of photogrammetric operations	Does not have the camera self- calibration facility unlike pix4D
Sensefly eMotion	Drone flight planning and data management	Connects wirelessly to your drones, finger swipe flight planning and full 3D environment, Multiflight mission support	Very advanced software but no real time NDVI processing.
Sense fly Survey 360	Complete aerial mapping system	precise geodata , provides accurate point cloud and surface model outputs in lesser time	Does not provide fully 3D environment
Ugcs	3D mission planning environment , plan and fly mission without internet connection	enables supports for the majority of drones, creates routes from KML file, built in no-fly zones for major airports	No real time NDVI video, need of graphics card with DirectX 9 support

Virtual Surveyor	3D Visualization Photogrammetry, Virtual Surveying, flight planning and civil designing	Flood simulation capability, fast simulation and interoperable with Computer Aided Design environment, can process huge amount of data files	Virtual Surveyor is not responsible for reliability, accuracy and suitability of information.

6. Applications

Since Drones provide supremacy over conventional remote sensing technologies and their benefits lie in terms of less power consumption, less risk to human life, ease to data collection, hovering, and ultra-high spatial resolution forges them an excellent choice for surveying and mapping. Following pioneer, studies demonstrate the relevance and uniqueness of drones in the civil, logistics, agriculture and Defense sectors. Figure 5 depicts the potential applications of UAV in civil, environment and defence sectors.

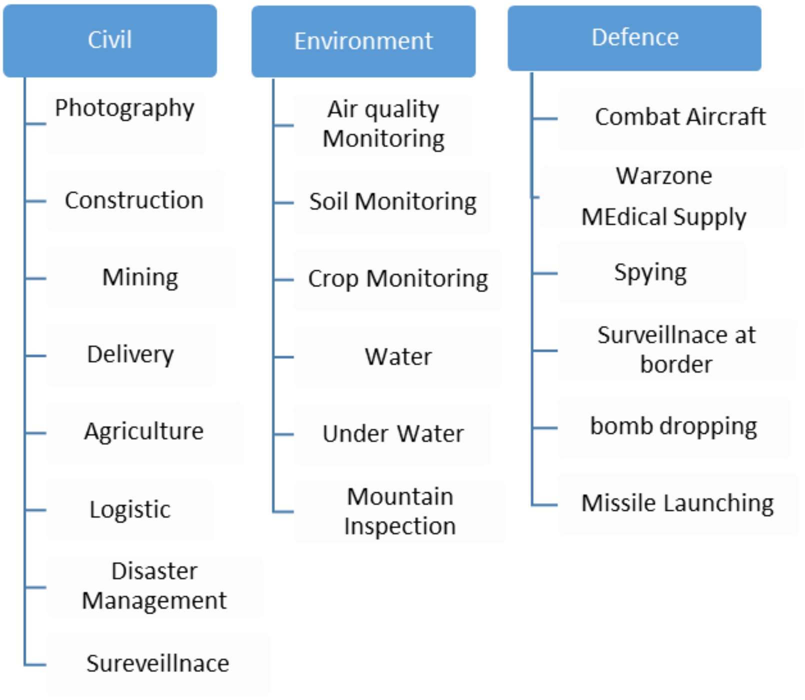

Figure 5: Potential Applications of Drones

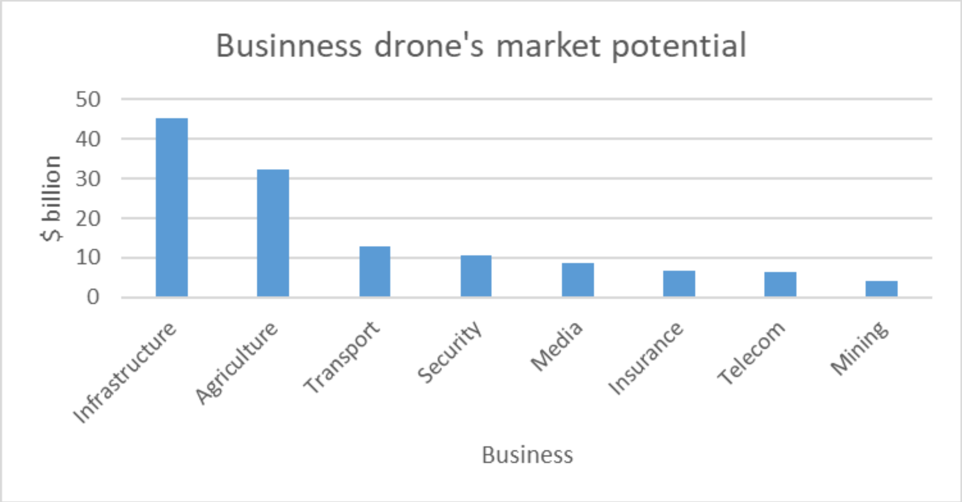

Figure 6: Market Potential of Drones

6.1 Drones in Agriculture

The sole aim of precision agriculture is to apply optimum amount of input at the right time and place to make better products. Common practices of precision farming are the data collection and variability mapping of agriculture lands, data analysis, making farming management decision based on results inferred from analysis and finally controlled application such as pesticide spraying and fertilisers. Agriculture has widely adopted the art of remote sensing using traditional satellite and aerial platforms. The capacity of a satellite to monitor map the vegetation is built upon the spatial, temporal and spectral resolution of sensors onboard such as MODIS, OLI, and AVHRR [48-52]. In 2013, the launch of Operational Land Imager (OLI) on-board Landsat 8 with a temporal resolution of 30m provided images with a spatial resolution of 30meters and 15 meters for panchromatic in 11 bands ranging from 435 nm to 12510 nm. [53, 54]. A considerable amount of research work has been carried out in the area of precision farming using satellite-based remote sensing, and the results are auspicious. Research work including wheat yield variation due to climate variation[55], mapping of irrigated areas using AVHRR time series analysis [56], estimation of crop yield[57-59], Crop water stress management [60, 61], forest cover classification and monitoring [62] has impacted Indian and global agriculture in terms of productivity analysis and farming management. However, this technique is somewhat limited to coarse resolution and cloud cover, Later on, UAS introduced the cheaper and low altitude alternative to providing high-resolution images.
[63] Used a Microdrone MD4-200 with a team ADC lite digital CMOS camera with image resolution of 1200x1024 pixels to estimate nitrogen and aboveground biomass of soybeans, alfalfa and corn crops. [64] captured the images of agriculture land using helicopter based unmanned aerial vehicle in a thermal band with 40nm resolution and 400-800nm spectral range with 20nm resolution using onboard Thermal and multispectral camera to target the biophysical parameters. [65] Used a drone along with multispectral and thermal sensors to delineate the spatial variability of water within a commercial rain-sustained vineyard.

6.2 Drones in Forestry, fisheries and wildlife protection

Drone bridges the gap of satellite imagery of less availability and cloud cover by performing Various tasks like measuring canopy height, tracking of forest wildlife's, support in forest management, forest fires detection and control, survey forests and mapping canopy gaps easily. [66] Targeted forest fire detection and monitoring using remotely controlled fixed wing UAV onboard thermal and hyperspectral sensors. Animal poaching and adverse climate conditions have a destructive impact on wildlife. UAV equipped with thermal sensors [67] along with satellite are being approached for monitoring, tagging and counting of animals which help to curb the poaching of animals and conserve the wildlife.

6.3 Drones in defence

The advent of UAV was started initially with the aim of transacting the war missions like intelligence, spying, reconnaissance vigilance and target detection; later they were introduced for civil and logistic applications [68]. USA, UK, Russia, India and Israel are the leading countries in the development and deployment of military drones. In 2017 the acceleration in the proliferation of military along with civilian drones was observed, and a maximum number of drone strikes by USA and UK were noted. Breakthrough research and remarkable advancements in the area of swarming drones, jet-powered and Microdrones. According to the Bureau of Investigative Journalism, the US launched more than two times more strikes in 2017 than the year 2016. Following the bar chart shows the data of US strikes on Somalia, Yemen and Afghanistan from the year 2014-2017[69].

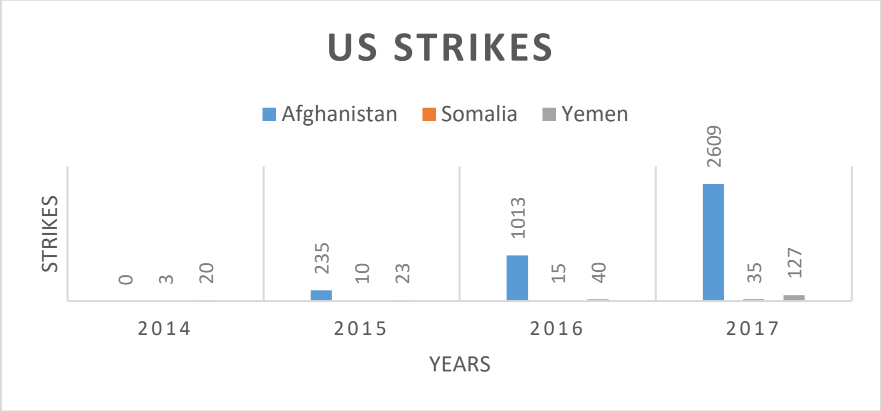

Figure 7 Number of drone strikes carried out by the USA

India recently has developed DRDO Lakshya, DRDO Aura, DRDO Rustom a Medium-Altitude Long-Endurance (MALE) system being used for target acquisition, releasing missiles, bomb dropping and combat missions [70].

6.4 Drones for civil applications

Drones are being fascinated in all commercial stratums from electricity companies to the railway industry. Electrical companies are preferring drones for inspection of high tension lines with ease of risky task of climbs and power outages[71, 72]. Railway companies have employed drones for monitoring and inspecting the track faults in constrained access areas. The Indian government is planning 3d mapping of thousands of kilometres long railway corridors and national highways. Amazon inspired from margarita pizza delivery with drones, tested the parcel delivery with drones although commercialisation of this project is awaited. Drones are helpful in performing search and locate operations of missing people during calamities condition. A trial to locate people in Donegal mountain range, Ireland and rescue operation of 200 people in flood zone by Chennai police, India exemplifies the potential and necessity of drones. Medical facility delivery using drones performed in many countries like the USA. Electricity generation through high elevation and high-speed drones is another exploratory area.

7. Challenges

7.1 Technological gaps

There is always a tradeoff between Payload capacity and flight time in drone technology. Conventionally, onboard lightweight lithium-ion batteries are used to supply power to UAV, but their power backup is not comparable with other batteries. With the increase in payload, endurance decreases and hence mission may not get its completion. Fixed wing drones are efficient in power usage, but they have the drawback of hovering and speed control. Flying a single drone may also encounter a flight failure due to some technological and climatic reasons, so there is always a need to provide backup. Upcoming swarm flight of drones can execute this task, where in case of failure of one drone, others complete the mission. This technology is dependent on Swarm motion of insects, ants and birds and makes use of artificial intelligence, yet in developing phase.

Drones are still limited by controlling through human operators, integration of Artificial Intelligence will allow a drone to make smart decisions and operate accordingly instead of human controllers. Possible gains and harms are yet to be explored in this direction[73, 74].

Drones also suffer from windy conditions and adverse climate changes. Spraying Drones are efficient to spray less area, but for mass spraying, they become less efficient, and the operation cost becomes high.

Another concern is too technical learning of garners to make use of drone-based precision farming and to make the drone-based system fully automatic from image acquisition to making complex statistical models and decision support system. A GPS mounted on drone connects with four satellites to detect the position, velocity and elevation accurately. Since GPS signals are very much prone to noise and interference, there is a finite possibility of losing contact. At that time it is recommended that instead of emergency landing, their location should be estimated. The inertial navigation system combined with GPS provide a solution for this situation. Efficient algorithms have to be designed and tested to estimate the position and elevation correctly.

Besides the drone hardware design challenges, the cameras used for precision agriculture applications also puts some limitations.

The multispectral images collection is very much prone to get affected by total irradiation along with sun angle and adverse weather conditions such as rain, heavy wind. Comparison of UAV data and satellite data puts two significant limitations that data has to be resampled to make equal spatial resolution images and secondly, if there is a cloud cover then it is almost impossible to compare the images since the information beneath the ground gets shadowed.

Onboard thermal sensors can detect the water utilisation of plants based on radiated temperature. The temperature variations in plants are exiguous which makes it difficult to discriminate other factors which may affect plant water such as sun irradiation. So further research is required.

7.2 Safety, Privacy and Security Issues

Some life-threatening issues because of rapid use of drones uncovered the concerns and challenges towards safety and security. Airworthiness, malicious practices and interference to public property are the primary concerns of safety, which puts a significant question mark on use of drone since modern approaches to resolve these issues are not up to the mark and does not give guarantee for the safe use of a drone. Air traffic control needs to be installed and monitored to ensure the inference avoidance in the airspace.

Table 7: State of the art and Proposed solutions to UAV challenges [75, 76]

Challenges	**Concern**	**The present state of the art**	**Proposed Solution**
Technological challenges	Payload and Endurance	The tradeoff between payload and flight time	Design Standards Improvement

Safety and security	Malicious practices and interference to private and public freedom	Certification and guidelines but not explicitly mentioned (if yes they are in drafted form)	Allocation of the Unique identification number(UIN) License for owners and flyers
Aviation interference	Breaching commercial and restricted airspace	The user must keep the drone in Sight	Use of onboard GPS and Jammer
Liability	Public or private damage	No clear guidelines	Governing bodies should create laws and guidelines
Government rules and regulations	Confined regulatory frameworks, insufficiency of international standards	Heterogeneous, discordant regulations and conflict between regulations and technology	Creation of Air traffic control board for drones, Balancing regulations
Privacy	Exposure to public and private property	Legal actions are taken	Proper guidelines and regulations

7.3 Controlling bodies and Regulations

Since long, UAV has been used for military purpose but the bans, inadequate rules and shortcomings interrupted the universal acceptance of UAV. The advancement and accelerated use of UAV in commercial applications demands for regulation challenges in order to ensure the safe, secure and authenticated use. [77]. International Regulatory bodies like the International Civil Aviation Organization (ICAO) and European Aviation Safety Agency (EASA) invites states and organizations to frame policies and standards for civil aviation enterprise [78]. Several countries are making efforts in this direction and have proposed regulations [79], some of them are being discussed in the following section.

Australian Civil aviation safety authority revised the unmanned aircraft regulations in 2016 and included the new rules for remotely piloted aircraft. A pilot license and certificate is required for remote operation of UAV weighing greater than 2 kg. The certification covers many aspects including pilot information, maintenance, liability and safety aspects. Similarly, German air traffic act imposes rules and demands authorisation from aviation authority for an unmanned aerial vehicle weighing more than 5 kilograms and not being used for recreational purposes. Authorisation ensures the privacy, public safety and information protection. Unmanned aerial vehicles weighing more than 25 kilograms are restricted to take a fly beyond visual line of sight. France recently imposed two regulations for the use of civilian UAV. These regulations classified the UAV into three classes creational, experimental purpose and particular activities drone. Drone authorisation, altitude limits, weight and performance limits are mentioned in the regulations. France aviation laws also restrict the movement of the drone geographically such as in military peripheries, historic monuments, national parks and nature reserves. In India, Director General of Civil Aviation (DGCA), Department of Civil Aviation drafts and regulates the policies for remotely piloted aircraft. A Unique Identification Number along with UAV operator Permit is required to fly drones, with proper adherence of guidelines such as prohibition to restricted areas such as Eco-Sensitive areas, beyond 500m into the sea from the coastline and beyond 25 km from international border [80, 81]. Israel civil aviation authority regulates the laws regarding manufacturing, training and operations included the flight elevation, regulated and recognised routes and communication devices in Israel and enforced these rules to all instructors, operators and manufacturers. Violation of licensing rules imposes the same penalties as applicable to manned aircraft. The United States Federal Aviation Administration (FAA) integrated the unmanned aerial system in the National Airspace system with the conditions of not compromising with safety, security and capacity.

8. Conclusion

The future generation is dependent on drones; they will create a new market. Drones are being upgraded and adopted by almost all commercial markets including precision agriculture, logistics and infrastructures. Future technology focused on increasing endurance, payload, improvement in the interaction between human and UAV and making clear rules and regulations for the safe and secure operation of UAV. Besides this, Integration of Artificial intelligence with drone technology will enable the drone to take decisions and independence to human controllers.

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