

Review Article

A Comprehensive Review of FPV Technology: Applications, Advantages, and Future Trends

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Abstract

FPV (First Person View) technology has revolutionized various fields, including unmanned aerial vehicles (UAVs), robotics, and renewable energy systems. This paper provides a detailed overview of FPV technology, focusing on its applications, advantages, and recent advancements. Initially developed for military and surveillance purposes, FPV technology has evolved to become more accessible and widely adopted in civilian sectors. The paper explores how FPV technology enhances user experience, improves efficiency, and offers environmental benefits. In recreational activities, FPV drones are widely used in drone racing and freestyle flying, providing an immersive and engaging experience. Professionally, FPV drones are employed for aerial photography, infrastructure inspection, and search and rescue operations, where the real-time video feed enables operators to make immediate decisions and adjustments, significantly improving task efficiency and safety. In robotics, FPV technology is used in teleoperated robots for industrial inspection and search and rescue missions, allowing operators to control devices with greater accuracy and confidence. In renewable energy systems, FPV technology is applied to floating photovoltaic (FPV) systems, which are solar panels installed on water bodies. These systems benefit from the cooling effect of water, improving performance and lifespan, and help conserve land for other uses, making them suitable for densely populated areas. Additionally, FPV systems reduce water evaporation, which is beneficial in water-scarce regions. Recent advancements in FPV technology include high-definition video, extended range, and integration with artificial intelligence (AI), which provide real-time analytics and decision-making support. Despite challenges such as regulatory constraints, technical issues, and ethical considerations, the future of FPV technology looks promising. Ongoing innovations and expanding applications in fields such as agriculture, environmental monitoring, and entertainment will further enhance the capabilities and utility of FPV systems. As the technology continues to evolve, it will play a crucial role in shaping the future of unmanned systems and renewable energy solutions.

Keywords

FPV, UAVs, Technology

1. Introduction

FPV¹ (First Person View) technology enables users to experience real-time visuals from remote devices via a live

video feed transmitted to displays or goggles. Originally developed for military and surveillance operations, FPV technology has expanded into recreational, professional, and innovative domains, including renewable energy systems. This

¹ First Person View

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paper provides a detailed exploration of FPV technology, encompassing its historical development, diverse applications, technical intricacies, and future potential. By addressing current challenges and opportunities, this study underscores the transformative impact of FPV technology across multiple sectors [1].



Figure 1. FPV.

2. History of FPV Technology

FPV technology originated in military and surveillance applications, where live video feeds from drones and unmanned devices were utilized for intelligence gathering and operations in hazardous or inaccessible environments. Early systems relied on analog transmission, offering limited resolution and range. However, advancements in digital video transmission and component miniaturization have significantly enhanced FPV capabilities. Modern FPV systems now provide high-definition video feeds, extended ranges, and improved reliability, making them accessible and widely adopted in civilian sectors such as recreational drone racing, industrial inspections, and renewable energy innovations.

1. **Early Developments:** The first FPV systems were

rudimentary and used analog video transmission. These systems were primarily employed in military operations and had limited range and resolution [2].

2. **Modern Advancements:** With the advent of digital video transmission and miniaturization of components, modern FPV systems offer high-definition video feeds with extended ranges and improved reliability. This has made FPV technology popular in hobbyist and commercial drone operations [3].

3. Applications of FPV Technology

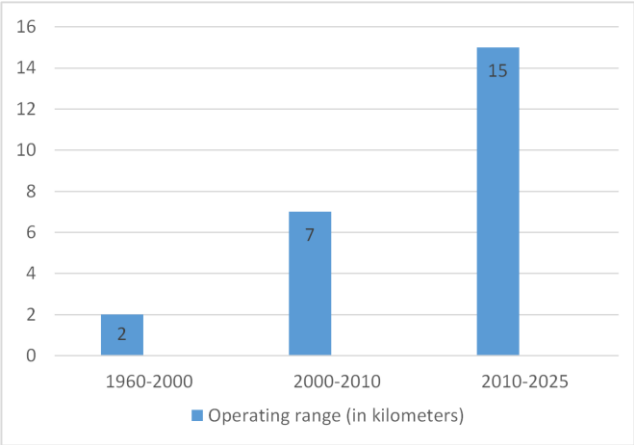


Figure 2. Evolution of FPV technology (range).

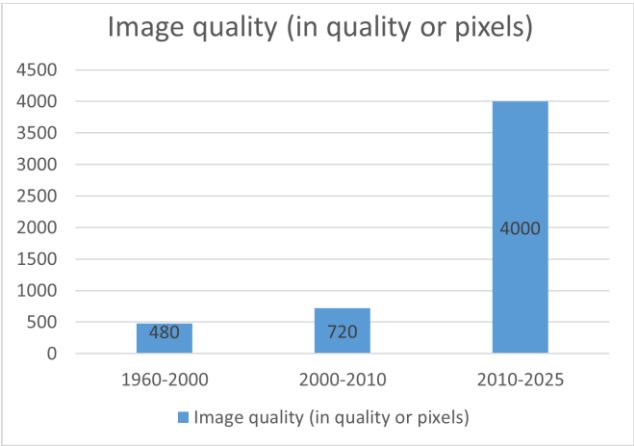


Figure 3. Evolution of FPV technology (Image quality).

Table 1. Comparison of FPV Applications in Different Fields.

FIELD	DESCRIPTION
UAVs (Drones)	Enhances recreational drone racing and freestyle flying with immersive first-person views. Improves professional tasks like aerial photography, infrastructure inspection, and search-and-rescue operations through real-time video feedback.

FIELD	DESCRIPTION
Robotics	Enables precise control of teleoperated robots in industrial inspections (e.g., pipelines, nuclear reactors). Supports search-and-rescue missions in disaster zones by providing critical visual data
Renewable Energy	Floating photovoltaic (FPV) systems benefit from water cooling to boost solar panel efficiency. Reduces land use conflicts and water evaporation in water-scarce regions.

Technical Formulas

1) Example 1: Signal Transmission Formula If discussing FPV video transmission, you might include a formula for signal strength or attenuation:

$$Pr = Pt + Gt + Gr - L$$

Where:
Pr: Received power.
Pt: Transmitted power.
Gt: Gain of the transmitting antenna.
Gr: Gain of the receiving antenna.
L: Path loss.

2) Example 2: Battery Life Estimation When discussing power management, you could introduce a formula to estimate battery life:

$$T = IC$$

Where:
T: Battery life (in hours).
C: Battery capacity (in mAh).
I: Current draw (in mA).

3.1. Unmanned Aerial Vehicles (UAVs)

FPV technology has revolutionized UAVs (drones) by providing pilots with a first-person perspective, significantly enhancing flight precision and user engagement. In recreational contexts, FPV drones are integral to drone racing and freestyle flying, offering immersive experiences through high-speed navigation and complex maneuvers. Professionally, FPV drones excel in aerial photography, infrastructure inspection, and search-and-rescue missions. Real-time video feeds enable operators to make immediate decisions, improving task efficiency and safety.

- 1. **Recreational Use:** FPV drones are widely used in drone racing and freestyle flying. The immersive experience of seeing through the drone's camera makes these activities highly engaging and enjoyable [3].
- 2. **Professional Use:** In professional settings, FPV drones are used for tasks such as aerial photography, inspection of infrastructure, and search and rescue operations. The real-time video feed allows operators to make immediate decisions and adjustments, improving the efficiency and effectiveness of these tasks [7].

3.2. Robotics

FPV technology has also found applications in robotics, particularly in teleoperated robots. These robots can be controlled remotely, and the FPV system provides the operator with a live view of the robot's environment.

- 1. **Industrial Inspection:** Teleoperated robots equipped with FPV technology are used to inspect hard-to-reach areas in industrial settings, such as pipelines and nuclear reactors. The live video feed helps operators identify issues and make necessary repairs without putting human lives at risk [4].
- 2. **Search and Rescue:** FPV-equipped robots are invaluable in search and rescue missions, especially in disaster zones. They can navigate through debris and provide critical visual information to rescuers, helping to locate survivors and assess the situation [7].

3.3. Renewable Energy Systems

FPV technology has been innovatively applied to floating photovoltaic (FPV) systems, wherein solar panels are installed on water bodies. These systems offer significant advantages, including increased efficiency due to the cooling effect of water, land conservation for alternative uses, and reduced water evaporation. Such benefits make FPV systems particularly suitable for densely populated regions or areas facing water scarcity.

- 1. **Increased Efficiency:** FPV systems benefit from the cooling effect of water, which can improve the performance and lifespan of solar panels [1].
- 2. **Land Use Optimization:** By installing solar panels on water bodies, FPV systems help conserve land for other uses, making them particularly suitable for densely populated areas or regions with limited land availability [6].
- 3. **Water Conservation:** FPV systems can reduce water evaporation by shading the water surface, which is beneficial in water-scarce regions [8].

4. Technical Aspects of FPV Technology

4.1. Components

An FPV system comprises several key components, each

playing a critical role in its functionality:

- 1) Camera: Captures high-resolution video feeds in real-time.
- 2) Transmitter: Sends the video signal from the camera to the receiver.
- 3) Receiver: Receives the video signal and transmits it to the display or goggles.
- 4) Display/Goggles: Provides the operator with an immersive view of the live video feed.

Additionally, modern FPV systems leverage advanced technologies such as digital video transmission, low-latency processing, and AI integration to enhance performance and user experience.

4.2. Video Transmission

FPV systems use various technologies for video transmission, including analog and digital methods.

1. **Analog Transmission:** Early FPV systems used analog video transmission, which was less expensive but offered lower resolution and was more susceptible to interference [3].
2. **Digital Transmission:** Modern FPV systems use digital video transmission, which provides higher resolution, better range, and greater reliability. Digital systems also offer features like low latency and high frame rates, enhancing the overall user experience [5].

4.3. Battery and Power Management

FPV systems require efficient battery and power management to ensure prolonged operation and optimal performance.

1. **Battery Types:** Commonly used batteries include Li-Po¹ and Li-ion² batteries, which offer high energy density and long life cycles.
2. **Power Consumption:** The power consumption of FPV systems is optimized to balance performance and flight time. Advanced systems use energy-efficient components and algorithms to maximize battery life [9].

5. Advantages of FPV Technology

5.1. Enhanced User Experience

FPV technology offers numerous advantages, including:

- 1) **Enhanced User Experience:** Immersive first-person perspectives improve engagement and precision in activities like drone racing and tele-operated robotics.
- 2) **Improved Efficiency:** Real-time visual feedback enhances task efficiency in aerial photography, infrastructure inspection, and search-and-rescue operations.
- 3) **Environmental Benefits:** FPV systems in renewable energy

applications contribute to land and water conservation, addressing critical resource management challenges.

The first-person perspective makes the operation more intuitive and enjoyable.

1. **Drone Racing:** FPV drones are the preferred choice for drone racing due to the enhanced speed and agility they offer. Pilots can navigate through complex courses with precision, thanks to the live video feed [3].
2. **Teleoperation:** In robotics, FPV technology allows operators to control devices with greater accuracy and confidence, as they can see exactly what the robot sees [14].

5.2. Environmental Benefits

FPV technology in renewable energy systems offers environmental benefits, particularly in floating photovoltaic (FPV) systems.

1. **Land Conservation:** By utilizing water bodies, FPV systems help preserve land for agricultural, residential, and other uses, which is crucial in densely populated areas [15].
2. **Water Conservation:** The shading effect of FPV systems reduces water evaporation, which is particularly beneficial in regions facing water scarcity [14].

5.3. Improved Efficiency

FPV technology improves the efficiency of various tasks by providing real-time visual feedback.

1. **Aerial Photography:** FPV drones enable photographers to capture high-quality images and videos from unique angles and perspectives, enhancing the creative possibilities [7].
2. **Infrastructure Inspection:** FPV-equipped drones can inspect bridges, power lines, and other infrastructure more efficiently than traditional methods, reducing the need for manual inspections and improving safety [7].

6. Recent Advancements

6.1. High-Definition Video

Recent advancements have significantly enhanced FPV technology:

- 1) **High-Definition Video:** Modern FPV systems now support HD and 4K resolutions, providing clear and detailed video feeds.
- 2) **Extended Range:** Innovations in transmitter and receiver technology enable long-distance operations, expanding applications in surveillance and inspection.
- 3) **AI Integration:** Artificial intelligence enhances real-time analytics and decision-making, particularly in

¹ Lithium Polymer

² Lithium-ion

search-and-rescue missions and wildlife monitoring.

- 4) **Example:** **DJI**, a leading drone manufacturer, has integrated HD FPV systems into their drones, allowing for high-quality live streaming and recording [7].

6.2. Extended Range

Improvements in transmitter and receiver technology have extended the range of FPV systems, making them suitable for long-distance operations.

Example: Some advanced FPV systems can transmit video signals over distances of several kilometers, enabling broader applications in surveillance and inspection [10].

6.3. Integration with AI

The integration of artificial intelligence (AI) with FPV technology has opened new possibilities. AI can process the live video feed to provide real-time analytics and decision-making support.

Example: AI-powered FPV drones can automatically detect and track objects, enhancing their capabilities in search and rescue missions and wildlife monitoring [7].

7. Challenges and Limitations

While FPV technology offers significant benefits, it also encounters several challenges:

- 1) **Regulatory Constraints:** Strict regulations on altitude, distance, and privacy limit FPV drone operations, particularly in urban areas.
- 2) **Technical Issues:** Latency, interference, and battery life remain critical concerns affecting system performance.
- 3) **Ethical Considerations:** Privacy risks and potential misuse for unauthorized surveillance necessitate careful ethical management.

7.1. Regulatory Constraints

Many countries have strict regulations regarding the use of FPV drones, particularly in urban areas. These regulations often limit the altitude and distance at which FPV drones can operate.

Example: In Iran, the use of FPV drones is regulated to ensure public safety and privacy [16].

7.2. Technical Issues

Technical issues such as latency, interference, and battery life can affect the performance of FPV systems.

1. **Latency:** Delay in the video feed can make precise control difficult, especially in fast-paced activities like drone racing.
2. **Interference:** Analog FPV systems are more prone to interference from other electronic devices, which can disrupt the video feed.
3. **Battery Life:** The power consumption of FPV systems can be high, limiting the operational time of drones and robots.

7.3. Ethical Considerations

The use of FPV technology raises ethical concerns, particularly in terms of privacy and surveillance.

1. **Privacy:** FPV drones can capture video feeds of private properties and individuals, raising concerns about unauthorized surveillance.
2. **Surveillance:** The potential misuse of FPV technology for surveillance purposes needs to be carefully managed to avoid infringing on civil liberties.

8. Future Perspectives

8.1. Technological Innovations

The future of FPV technology holds immense promise, with anticipated advancements in:

Video Quality: Development of low-light and thermal imaging capabilities for security and emergency response applications.

Regulatory Frameworks: Standardization of international regulations to balance safety, privacy, and innovation.

Broader Applications: Expansion into precision agriculture, environmental monitoring, and immersive entertainment through VR/AR integration.

Additionally, the integration of AI and machine learning will further expand the capabilities of FPV systems.

Table 2. Evolution of FPV Technology.

ERA	KEY FUTURE
1960-2000	Analog systems with low resolution, short range, and high latency
2000-2010	Transition to digital transmission, improved resolution, and reduced latency
2010-Present	HD/4K video, AI integration, and extended range for commercial and industrial use

Example: Research is underway to develop FPV systems that can operate in low-light conditions and provide thermal imaging, opening new applications in security and emergency response [13].

8.2. Regulatory Frameworks

As the use of FPV technology becomes more widespread, regulatory frameworks will need to adapt to ensure safety and privacy. Collaboration between governments, industry stakeholders, and researchers will be essential in developing balanced regulations.

Example: International organizations are working on standardizing regulations for FPV drones to facilitate their use while minimizing risks [10].

8.3. Broader Applications

FPV technology is expected to find broader applications in fields such as agriculture, environmental monitoring, and entertainment.

- Agriculture:** FPV-equipped drones can be used for precision agriculture, monitoring crop health, and applying pesticides more effectively [11].
- Environmental Monitoring:** FPV drones can assist in monitoring wildlife, tracking environmental changes, and assessing the impact of human activities on natural ecosystems [17].
- Entertainment:** FPV technology is increasingly being used in virtual reality (VR) and augmented reality (AR) applications, providing immersive experiences in gaming and simulations [12].

9. Conclusion

FPV technology has profoundly impacted diverse sectors, including recreational activities, professional applications, and renewable energy systems. By enhancing user experience, improving task efficiency, and offering environmental benefits, FPV systems continue to drive innovation. Despite regulatory and technical challenges, ongoing advancements ensure that FPV technology will play a pivotal role in shaping the future of unmanned systems and sustainable energy solutions. Its ability to provide a first-person perspective enhances user experience, improves task efficiency, and offers environmental benefits. Despite challenges such as regulatory constraints and technical issues, the future of FPV technology looks promising, with ongoing innovations and expanding applications. As the technology continues to evolve, it will play a crucial role in shaping the future of unmanned systems and renewable energy solutions.

Abbreviations

FPV	First Person View
UAVs	Unmanned Aerial Vehicles
AI	Artificial Intelligence
Li-Po	Lithium Polymer
Li-ion	Lithium-ion
FPVS	Floating Photovoltaic Systems

Author Contributions

Mojtaba Nasehi is the sole author. The author read and approved the final manuscript.

Conflicts of Interest

The authors declare no conflicts of interest.

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