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IMPLICATIONS OF ARTIFICIAL INTELLIGENCE DRIVEN DRONE SYSTEMS FOR RECOGNITION OF ENVIRONMENTAL HAZARDS

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ABSTRACT

Artificial intelligence driven drone systems offer promising solutions for early detection and response to environmental hazards like wildfires and oil leaks. However, their widespread adoption raises significant ethical and environmental implications, including privacy infringements, algorithmic bias, data security, noise pollution, and greenhouse gas emissions. This study addresses these issues through literature reviews, surveys of affected populations, and prototype testing of AI models for disaster identification, in order to mitigate ethical issues. A specific metric was developed to rate drone components and identify the most sustainable options, minimizing the environmental impact. By promoting these solutions, this research aims to ensure the sustainable and responsible integration of artificial intelligence systems in environmental monitoring, protecting ecosystems and communities effectively.

1. INTRODUCTION

Modern technologies allow us to achieve things we never imagined would be real. One of them is artificial intelligence systems, currently experiencing the peak of their hype. They enable us, humans, to leverage them for our own benefit, using them everywhere including private houses, offices, applications, websites, cars, and recently, drones. They help us with everything, starting from writing emails and essays, and ending with driving cars and delivery of items. However, specifically, this paper will discuss implementations of artificial intelligence in drone systems for recognition of environmental hazards and the implications of this approach.

Such drones are divided into two main groups. The first group is used after a disaster to provide high-resolution images, and real-time visual and audio access, assisting in mapping the extent of destruction, identifying safe routes for ground teams, monitoring flood levels, locating missing individuals and aiding in rescue operations. These drones are typically deployed after fires, earthquakes, hurricanes, tsunamis, similar events. The second group is used to locate disasters, identify them as soon as they occur, and inform the admin panel, which can then verify and call the nearest emergency services, such as in detecting wildfires and oil leaks.

Examples of the usage of the first group of drones, also known as unmanned aerial vehicles (UAVs), are numerous: the Nepal earthquakes in 2015, Hurricane Harvey in 2017, the California wildfires in 2018, the floods in Indian states from 2018 to 2022, wildfires in Türkiye in 2020 and many more. In all of these catastrophes, without the opportunities drones provide it would have been much more difficult to rescue people and manage the situation. The efficiency of drones comes from their compact size, enabling them to navigate through small holes and areas filled with smoke and fire, while capturing real-time data. Importantly, their relatively low cost makes drones a preferred choice for most organizations and agencies over human-led missions.

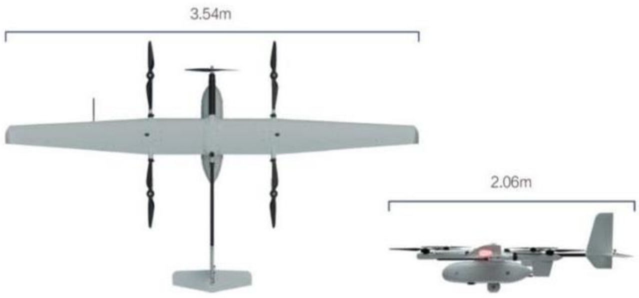

Fig. 1. Dimensions of the CW-15D drone

In comparison, the usage of drones from the second group is not as widespread. One example is the CW-15D drone flying over forests in high risk areas of Sichuan province, China. As can be seen in Fig. 1, although the drones might appear large, they are actually considered relatively small, with a wingspan of 3.54 meters and a length of 2.06 meters. They are equipped with visible and infrared cameras, capturing videos from low and medium altitudes and monitoring the key forest areas. However, the biggest drawback of this scheme is that the videos and photos are analyzed and processed by humans, sitting in their offices, behind monitors. While decisions made by humans are typically accurate, there are inherent limitations. One person can only monitor a limited number of drones, making it very expensive and challenging to implement such systems in bigger areas, as well as slowing down the process. And that is where artificial intelligence comes in. Instead of paying hundreds of thousands dollars to humans to monitor the areas, and still be limited to a certain number, it is more rational to create a specific program with a built in artificial intelligence and implement it into the drone's system, allowing it to recognize natural disasters autonomously and quite accurately.

One of the first, successful AI-driven drones was launched during Carmel Forest fire in Israel, 2020, and the Dixie fires in California, 2022. The drones identified and located fire, and were used to map the fire's perimeter, identify hot spots, and assess the damage. This information helped CAL FIRE (California Department of Forestry and Fire Protection) and the Israeli fire service to come in time, make better decisions about where to deploy firefighters. Once again, the valuable resources, time, and most importantly, human lives were saved due to the existence of artificial intelligence. The rescue team already knew their route and quickly executed the operation, spending much less time in the fires and smoke than they would have if they had to search for people without a particular plan or path, saving both their own lives and the lives of people they were looking for. The efficient data processing by the artificial intelligence system in these cases was due to extensive training done beforehand, using huge databases and data sets, full of information and media regarding fires.

While having significant potential and as of current offering substantial benefits to society, this method also comes with its own set of implications. Despite numerous studies on the technical capabilities of artificial intelligence driven drones, there is limited research on the ethical and environmental implications of their deployment. Furthermore, existing metrics to evaluate drone components often fail to consider and overlook sustainability factors. Thus, this study addresses those gaps and issues. Among these concerns are privacy questions, wildlife disturbance, noise pollution and greenhouse gas emission. The study further extends to offer potential solutions and strategies to mitigate or at least minimize these concerns, ensuring that the integration of artificial intelligence into drones is responsible, ethical and sustainable.

2. RELATED WORK

Latest studies have shown that the rate of the growth of systems with artificial intelligence is increasing on a daily basis, as do the capabilities of such systems.

Recent research from MIT has introduced a significant advancement in the implementation of artificial intelligence for drone navigation through the use of liquid neural networks. These networks are designed to mimic the adaptability of biological brains, allowing drones to navigate and perform tasks in unfamiliar environments with greater precision and resilience. Unlike traditional neural networks, liquid neural networks can continuously alter their parameters over time, enabling them to handle unexpected or noisy data more effectively. This adaptability is crucial for drones that must operate in diverse and changing conditions, such as moving from a forest to an urban environment. The MIT team trained their liquid neural networks using data collected by human pilots, which allowed the drones to learn from expert navigation and then generalize these skills to new and drastically different environments. In tests, these drones outperformed other state-of-the-art navigation systems, successfully handling tasks like tracking moving targets and navigating through occluded and rotated objects in various settings. The researchers believe that this technology could significantly improve the efficiency and reliability of autonomous drones for applications such as search and rescue, environmental monitoring, and delivery services. The ability to adapt to new environments without additional training makes liquid neural networks a promising solution for the challenges faced by current AI-driven drone systems.

Another significant development is the usage of deep learning algorithms and edge computing to enhance real-time object detection capabilities in UAVs. This approach uses GPU-based edge computing platforms, systems and lightweight convolutional layers to optimize performance on resource-limited devices, making them highly effective for emergency rescue and precision agriculture applications. These extensive studies examined various real-time object detection networks across multiple domains, providing insights into the efficiency and accuracy of different detection architectures, such as anchor-based and transformer-based models. The papers have also explored the impact of variables like image size and confidence thresholds on the detection performance. A comprehensive survey focused on deep learning methods for object detection and tracking using UAV data addressed challenges such as scale diversity, small object detection, and direction diversity. Advanced techniques like multi-scale feature maps and deformable convolution kernels were highlighted for their ability to enhance detection capabilities in varied and complex environments. This review provided a detailed understanding of data processing and algorithmic strategies needed for effective UAV-based object detection. These studies underscore the progress in integrating AI with drone technology, improving the detection, monitoring of natural disasters. By leveraging deep learning and edge computing, these systems are becoming more efficient and reliable, paving the way for better disaster response and management.

3. METHODOLOGY

A script has been designed to build and train a convolutional neural network (CNN) using the Keras library for image classification tasks. The script begins by importing necessary libraries and defining constants such as image dimensions, directory paths for training and validation data, and the number of samples for each set. The build_model() function creates a sequential CNN model with convolutional, activation, pooling, flattening, and dense layers. It compiles the model using binary cross-entropy loss, and the RMSprop optimizer. The train_model () function prepares image data generators for both training and validation sets with specified augmentation techniques and rescaling. It then generates batches of augmented data and fits the model using the training data while validating it on the validation data. The main () function initializes the model, trains it, and saves the trained model to a file. In conclusion, the program automates the process of building, training, and saving a CNN model for image classification tasks. Then, another code sets up a web application using Flask, enabling uploading images and receiving predictions from the machine learning model that distinguishes between "Oil Spills" and "Wildfires". Key constants such as labels for the two classes, paths to sample images, the upload folder, allowed file extensions, and the model filename are defined at the beginning. The application includes functions to load the model and handle file uploads securely. The main route renders an HTML page where users can upload an image, which is then saved to the server if it is of an allowed type. Upon upload, the image is processed and fed into the model to generate a prediction, which is then displayed back to the user. The application configuration is set with necessary parameters, including secret keys and session management, and the Flask server is run with these settings. Successfully identified images are then stored in the system for further training and usage for comparison.

3.1 Methodology for ethical concerns

A quick survey effective for identifying the main concerns of the population regarding the AI driven drone system has been conducted among 100 people. The question set was designed in such a way that the responses would reflect both the issues people have encountered with AI-driven drone systems and the issues they would prefer to avoid in the future. The questions are following:

1. How familiar are you with the AI driven drones?
2. What ethical concerns might you have if AI-driven drones were used in your area?
3. How important is it to you that AI-driven drones operate with strong privacy protections?
4. To what extent are you concerned about the potential misuse of AI-driven drones for unauthorized surveillance?
5. How confident are you that current regulations adequately address the ethical implications of AI-driven drones?
6. How do you believe the ethical use of AI-driven drones can be improved?
7. Would you support the deployment of AI-driven drones if ethical concerns were adequately addressed?

This set of survey questions was chosen because they comprehensively address the ethical side of the implications, which is a critical aspect for understanding public concerns. These questions will help identify key areas such as privacy invasion, data security, bias in AI decision making. By gathering detailed feedback on these specific issues, this study points on the main ethical concerns and develops targeted solutions to address them. The artificial intelligence model created earlier will be adjusted based on the received feedback to mitigate the ethical concerns of the public.

3.2 Methodology for environmental concerns

To address the environmental concerns, the methodology involves a detailed and systematic approach focusing on noise pollution, carbon emissions, and wildlife disturbances. Numerous studies highlight the issues with drones being too noisy and emitting significant amounts of carbon, which can impact both human populations and wildlife. To eliminate, a comprehensive literature review will be undertaken to identify various drone components and designs that are quieter and environmentally friendly. Then, through experiment and analysis, a specific metric, Environmental Impact and Efficiency Metric (EIEM), which includes factors like noise pollution level, energy efficiency and carbon emissions, will be calculated and evaluated to compare the noise levels and carbon emissions of different drone models. The Environmental Impact and Efficiency Metric (EIEM) will be calculated using the following formula:

$$EIEM = (W_n \times (N_m \div N_t)) + (W_c \times (C_m \div C_t)) + (W_e \times (E_m \div E_t))$$

Where N_m is the noise level in decibels (dB), N_t is the maximum acceptable noise level in decibels (dB), C_m is the carbon emissions of the drone (in kg CO2 per hour of operation), C_t is the maximum acceptable carbon emissions (in kg CO2 per hour of operation), E_m is the energy efficiency of the drone (in watt-hours per km), E_t is the baseline energy efficiency for comparison (in watt-hours per km), W_n and W_c and W_e are the weights assigned to noise, carbon emissions, and energy efficiency, respectively, summing to 1. The weightings represent how important and crucial it is to reduce the particular measurement, with a lower magnitude of EIEM indicating a better result. Using this metric, a detailed table will be created that lists various drones along with their environmental impact scores. This table will serve as a comparative tool to identify the most suitable drones for our purposes. The data collected will assist in selecting the components and designs that produce the least noise and emissions, ensuring that the drone system is both quiet and sustainable.

4. EXPERIMENTS AND ANALYSIS

Initially, the developed artificial intelligence model was trained and tested for errors using a dataset, compiled from public repositories and simulated scenarios, of several hundred images, which included wildfires, oil leaks, both, or none. Out of 325 images processed, 318 were correctly determined, making the accuracy approximately 98% which means it is a quite precise model for our purpose. All of the 100 images were saved in the system for additional training, to further increase the accuracy and precision.

4.1 Analysis of the survey

The survey was conducted among nearly 100 people of diverse backgrounds and classes to ensure and maximize accuracy and minimize bias, as mentioned before. Roughly 55% and 31%

of the respondents stated that they are somewhat or very familiar with the concept of AI-based drone systems, respectively, making them a perfect fit for the purpose of the survey.

Fig. 2. Statistics of the answers

Analyzing the responses from Fig. 2, along with the answers to the main question, which state that 69% are concerned about privacy, 24.1% are concerned about bias in algorithms, 55.4% are concerned about data security and misuse, and 44.8% are concerned about potential misuse in surveillance, it's apparent that privacy is the primary concern. This includes worries about drones capturing and storing images of people's faces and bodies, as well as images of their houses and properties. To address this concern, the previously developed AI model needs to be adjusted so that it doesn't save photos containing people for further training.

4.2 Adjustment of the AI model

The program code has been adjusted. In the revised code, a critical addition is a new function called detect_human_faces(), passed with an argument image_path, leveraging pre-trained Haar cascades from OpenCV library. Haar cascades are a type of machine learning-based approach used for object detection in images. They work by analyzing patterns of intensity or color gradients in an image to identify specific objects or features. In the case of human face and body detection, Haar cascades are trained on a large dataset of positive and negative images to learn characteristic patterns associated with human faces and bodies. This function inspects an image to identify the presence of human faces or bodies. Within the main () function, following the model training and saving processes, an example application of the human face detection function has been integrated. Based on the outcome, the script makes a decision whether to proceed with saving the image for subsequent training iterations. If human faces or bodies are detected, the script bypasses the saving process to uphold privacy standards, and will be saved in case the program has not identified any presence of human beings in the image. This approach ensures the privacy and dignity of individuals depicted in the images, safeguarding their integrity and respecting their rights.

4.3 Creation of a list of drones to be tested

Before computing the value of EIEM, it's essential to identify a comprehensive list of potential drone models and high-risk of wildfires and oil leaks areas where the drones are expected to fly and monitor. Following a thorough review of all candidates, the following list of drones has been compiled:

1. DJI Matrice 300 RTK (M300)
2. Parrot Anafi USA

3. Skydio X2D
4. Sensefly eBee X with RTK/PPK
5. Draganflyer X4-P
6. Autel Robotics EVO II Dual
7. Altavian Nova F7200
8. Yuneec H520

And the following list of high-risk areas:

1. Amazon rainforest, Brazil
2. California, United States
3. Alberta Tar Stands, Canada
4. Siberian Taiga, Russia
5. Peruvian Amazon, Peru
6. Niger Delta, Nigeria
7. Australian Outback, Australia
8. Indonesian Rainforest, Indonesia

In selecting these drones, several factors were considered. Firstly, each drone offers unique advantages directly related to disaster response applications, such as long flight time, advanced imaging capabilities. Secondly, the drones were chosen based on their compatibility with AI integration, including the ability to carry the hardware and sensors, as well as support for third-party SDKs for custom AI development. Also, factors such as reliability, durability, and ease of deployment were taken into account to ensure optimal performance in challenging disaster environments. Whereas the high-risk areas are characterized by their susceptibility to wildfires and oil leaks, posing environmental and ecological threats that require monitoring and response measures as well as past experiences.

4.4 Calculating EIEM for each model

In order to calculate the Environmental Impact Evaluation Metric (EIEM), it's essential to establish both weighting factors and a maximum allowed threshold for each factor (noise level, carbon emissions level and energy efficiency). The value of W_e (weighting of energy efficiency) has been designated as 0.2, because of its lower importance compared to factors like carbon emissions and noise pollution. This decision is based on the idea that the direct impact of energy efficiency of the drones on the environment is comparatively lesser than that of other factors. The weighting of carbon emissions (W_c) has been established at 0.5, showing its greater significance in environmental assessments. This value comes from the wide-ranging consequences associated with substantial carbon emissions, including climate change and ecosystem degradation. In contrast, noise pollution, while still relevant, is perceived to have a comparatively lesser impact on the environment.

Following the weightings, threshold values have to be determined. The maximum noise, not causing significant noise pollution in the areas listed before is 65 dB, as it does not disturb the wildlife and allows proper drone work, assigning the value of $N_{threshold}$ to 65 dB. The carbon emissions threshold ($C_{threshold}$) is set to be 200 kg per hour and is aligned under international agreements such as the Paris Agreement on climate change as well as global efforts to mitigate greenhouse gas emissions and combat climate change. Lastly, $E_{threshold}$ (the energy efficiency threshold) is set to be 4 watt-hours per kilometer traveled. This decision comes from a practical and inclusive standard. accommodating a wide range of both fixed-wing and multi-rotor drones, ensuring effective usage without excluding widely-used models.

DJI Matrice 300 RTK (M300)

The model DKI Matrice 300 RTK shows excellent payload capacity for carrying AI hardware and sensors. Long flight time allows for extended missions during disaster response as well as advanced flight safety features, including obstacle avoidance and redundant systems. All of the parameters of the drone have been measured several times and the mean has been recorded for low uncertainty in the results. $N_{measured}$ is 70 dB (in 2 meters radius). $C_{measured}$ has been calculated by multiplying the power of the drone in kW and the average global carbon intensity of electricity (0.5 kg CO_2 per kWh). The energy consumption of DJI Matrice is 500 joules per second, which is the equivalent of 500 watts or 0.5 kilowatts. So the value for $C_{measured}$ is 0.25 kgCO2/h. However, that is the value per drone, but considering the dimensions of the high-risk areas, a minimum number of 500 drones will have to be deployed. So we multiply 0.25 by 500 and get 5. $E_{measured}$ (the energy efficiency) is calculated using the power of the drone, battery's voltage and distance possible to cover in 1 charge. For this specific model, the battery capacity is 5935 mAh at 44.4V (approx. 264 Wh per battery), flight time is up to 55 minutes (0.917 hours) and typical cruise speed is 15 m/s (54 km/h). Distance covered is 49.5 km (found by multiplying the flight time and speed). So energy efficiency is 264 Wh ÷ 49.5 km ≈ 5.33 Wh/km. By substituting all the values into the formula of EIEM, we get the value of 0.902.

Parrot Anafi USA

The Parrot Anafi USA offers several advantages, including its compact and lightweight design, making it highly portable and easy to deploy in various environments. With a maximum flight time of up to 32 minutes and a range of up to 4 kilometers, it provides endurance and range for mapping, surveillance, and inspection tasks. The drone's advanced imaging capabilities, including 32x zoom and thermal imaging, enable detailed and accurate data collection for various applications. The magnitude of EIEM for this model is 0.445.

Skydio X2D

The Skydio X2D boasts advanced autonomy and reliability features, making it adept at navigating complex environments with minimal human intervention. Its tough design ensures durability in adverse conditions, while flexibility allows customization for various mission requirements. However, its limited flight time and payload capacity, coupled with its pricing and regulatory considerations, may impact its suitability for certain applications.. The value of EIEM is calculated to be 0.673.

Sensefly eBee X with RTK/PPK

The Sensefly eBee X with RTK/PPK offers several advantages, including its fixed-wing design, which provides longer flight endurance and greater coverage area compared to multirotor drones. With a maximum flight time of up to 90 minutes and a range of up to 15 kilometers, it is well-suited for large-scale mapping, surveying, and agriculture applications. The value of EIEM is calculated to be 0.455.

Draganflyer X4-P

The Draganflyer X4-P offers several advantages, including a lightweight and portable design, which makes it easy to transport and deploy in various environments. However, its flight time is relatively short, limiting its use for extended missions. The value of EIEM is calculated to be 0.831.

Autel Robotics EVO II Dual

The Autel Robotics EVO II Dual combines several features, making it an excellent choice for various applications. It offers high-resolution imaging with an 8K camera and thermal imaging capabilities, providing valuable data for tasks such as search and rescue, inspection, and environmental monitoring. Additionally, while its thermal camera is useful, it may not match the resolution and sensitivity of specialized thermal drones. The value of EIEM is calculated to be 0.477.

Altavian Nova F7200

The Altavian Nova F7200 is a high-endurance drone designed for demanding applications, offering significant advantages in terms of range and payload capacity. Its long flight duration of up to 90 minutes and extensive range make it ideal for large-scale surveying, mapping, and monitoring missions. The drone's design allows it to carry high-resolution cameras and LiDAR sensors, providing versatile data collection capabilities. The value of EIEM is calculated to be 0.627.

Yuneec H520

The Yuneec H520 is a versatile drone known for its reliability and advanced features, making it suitable for a range of professional applications. One of its key advantages is the modular design, which allows users to easily swap out cameras and sensors. The H520 also offers impressive flight stability and precision thanks to its six-rotor design, even in challenging weather conditions. However, the Yuneec H520 has some limitations. Its flight time, while reasonable at around 28 minutes, is shorter compared to some other drones in its class, potentially requiring more frequent battery changes during long missions. The value of EIEM is calculated to be 0.570.

5. CONCLUSION AND FUTURE WORK

In conclusion, a comparison of the EIEM values for each drone is conducted to evaluate their environmental impact and efficiency.

Table 1. EIEM values of each drone

Drone name and model	EIEM value (3 s.f.)
DJI Matrice 300 RTK (M300)	0.902
Parrot Anafi USA	0.445

Skydio X2D	0.673
Sensefly eBee X with RTK/PPK	0.455
Draganflyer X4-P	0.831
Autel Robotics EVO II Dual	0.477
Altavian Nova F7200	0.627
Yuneec H520	0.570

From Table 1, it can be seen that the Parrot Anafi USA model is the most efficient and sustainable, having the lowest EIEM value. Closely following are the Sensefly eBee X and Autel Robotics EVO. Therefore, the following conclusion can be drawn: to mitigate environmental issues, drones with the smallest EIEM values should be utilized, making the Parrot Anafi USA an excellent choice. The EIEM factor considers both noise pollution and carbon emission levels, as well as energy efficiency. Then, to address ethical concerns, the AI model developed earlier in the study should be implemented, as it effectively addresses the most significant issues identified in the survey while maintaining high accuracy.

In future, it is planned to further develop the AI model so it can recognize other environmental hazards including but not limited to tsunamis, floods and hurricanes, as well as improve the algorithms for better accuracy.

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