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Artificial Intelligence & its Applications Master's Thesis

Development of a Smart RC Plane for Autonomous Human Detection in Desert Rescue Missions

Authors:

- Fahem Messilva
  messilva.fahem@cuillizi.dz
- Bouchama Abdellah
  abdellah.bouchama@cuillizi.dz

Advisors:

- Dr. Gasmi Rim
  gasmi.rim@cuillizi.dz

Examining Committee:

- (*President*) Dr. Ben Mechiche adberahhim
  Benmechiche.adberrahim@cuillizi.dz
- (*Examiner*) Mr.Riadh Matmat
  riadh.matmat@cuillizi.dz

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Abstract

This study presents an intelligent RC plane designed for search and rescue in desert areas. Combining aerial mobility with onboard AI, it autonomously scans vast, hard-to-reach regions to locate missing persons.

Equipped with GPS, IMU sensors, and a camera managed by a Raspberry Pi 5, the plane uses deep learning to detect humans in real-time. Detected data is compressed and wirelessly transmitted to a ground station via a long-range nRF24L01 module.

The ground station, based on an ESP8266 and computer interface, receives live telemetry and allows mission monitoring and manual control through a graphical interface.

This project illustrates the integration of computer vision, embedded AI, and low-cost aerial robotics for humanitarian use, with promising results for improving rescue efforts in remote areas like the Algerian Sahara.

Key words: RC plane, search and rescue, computer vision, embedded AI, desert detection, ground control station, autonomous system..

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- Countless brainstorming sessions full of ideas and creativity
- Late-night preparations and last-minute stress
- Teamwork, doubts, and breakthroughs
- Competitions, club activities, and university events
- Technical challenges that pushed us beyond our limits
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With all our gratitude, admiration, and affection,

Messilva & Abdellah

Thank you for everything. Truly.

Dedication

To little Selva, To the girl who kept going. Through storms, doubts, and silent battles you stood with grace. You turned pain into power, and dreams into light. I'm proud of the Girl you've become. This is not the end , just the beginning of something even more beautiful.

To my parents, my eternal shelter and my strength. ***Mom,*** your boundless love held my heart through every storm. ***Dad,*** your calm strength was my silent compass. As your only daughter, I carried our shared dreams. Your love, strength, and faith shaped every step. This success is ours , thank you, from the depths of my heart.

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0.1 General Introduction

In the era of the Fourth Industrial Revolution, smart technologies have moved beyond mere assistance to become essential tools for solving complex problems. Their integration into critical fields such as civil security, environmental monitoring, and emergency response marks a decisive shift in our ability to tackle extreme challenges. Among the most hostile environments, desert regions such as the Algerian Sahara present serious obstacles due to their vastness and extreme climatic conditions.

Every year, dozens of people go missing in these areas as a result of sandstorms, mechanical failures, or simple disorientation. Search and Rescue (SAR) operations face numerous difficulties: inaccessible terrain, lack of network coverage, extreme temperatures, and the absence of suitable technological resources. Traditional methods, though commendable, quickly show their limitations under such conditions.

In response to this situation, our thesis proposes an innovative approach: the development of an autonomous embedded system based on artificial intelligence, integrated into a radio-controlled glider (RC plane). This system merges computer vision, real-time image processing, embedded intelligent sensors, and long-range wireless communication to:

- Automatically detect people lost in the desert using aerial images

- Transmit their location and visuals to a ground control station

- Allow manual or semi-automated piloting depending on mission needs.

This work is structured around four interrelated chapters:

- Chapter 1 : introduces the context, presents the problem statement, reviews the current state of SAR operations in Algeria, and highlights the limitations of conventional methods.

Chapter 2 : explores related research work and includes a comparative analysis of several drone-based human detection systems.

Chapter 3 : presents the theoretical and technological background, including the AI models used (YOLO, Faster R-CNN), computer vision concepts, and image processing techniques.

Chapter 4 : describes the complete hardware and software implementation: selection of electronic components, embedded architecture, physical layout, radio communication setup, and multi threaded Python scripts.

This project is part of both a technological and humanitarian effort. It demonstrates that through artificial intelligence, automation, and component miniaturization, it is now possible to design lightweight, efficient, and affordable tools that can significantly improve rescue operations even in the most remote and inhospitable regions

Chapter 1

State of the Art – AI-Based Human Detection in Desert Areas via RC Planes

1.1 Introduction

Natural environments in Algeria forests, beaches, and deserts cover a large part of the territory and are vital to the country's development. However, these areas are also the scene of numerous accidents and disappearances, often caused by extreme conditions, lack of monitoring, or delayed emergency response.
Forests are especially vulnerable due to frequent fires, difficult access, and poor communication infrastructure. In July 2023, fires in the northeast caused 34 deaths and significant material damage [1][2].
Beaches also witness many incidents. In the summer of 2023, over 55,000 interventions were conducted, including 36,786 rescues, but 7 drowning deaths were recorded [3][4].
In the desert, both natural and forced disappearances present major challenges. between 7,000 and 17,000 people faded during the 1990s [5]. Even today, extreme weather and lack of communication coverage make search operations difficult. A simulation in Tikoubaouine (March 2025) illustrated these obstacles [6].

1.2 Problematic

Despite the efforts of rescue teams, the current search methods used in Algeria's natural regions especially the southern deser remain limited in terms of speed, coverage, and precision. Harsh weather, vast and inaccessible terrain, and poor communication networks severely delay intervention efforts. Traditional aerial tools, such as helicopters and planes, are costly and unable to provide real-time human detection.
This raises a critical question: Can we enhance rescue operations by combining artificial intelligence with autonomous, lightweight aerial platforms capable of real-time person detection in extreme desert conditions?
This project seeks to address that challenge by designing a smart RC plane equipped with an onboard AI-based detection system. The objective is to create a responsive, low-cost solution that improves search accuracy and response time, ultimately saving lives.

1.3 Overview of Current Search and Rescue Methods in Algeria

In Algeria, search and rescue (SAR) operations are still largely carried out using traditional methods by various governmental bodies. The General Directorate of Civil Protection (DGPC) plays a central role in ground operations, particularly in remote and challenging regions like the Sahara, mountains, and forests. They organize regular field simulations, such as the major drill held in Tikoubaouine (Djanet) in March 2025, involving 18 teams from 17 provinces [7].
On the aerial side, the Algerian Air Force contributes with specialized aircraft equipped with navigation and guidance systems, along with military helicopters used in rescue scenarios [8].
Additionally, international cooperation reinforces national capabilities. Algeria works with partners such as the International Organization for Migration (IOM) to improve coordination and efficiency in desert-area SAR missions [9].

Figure 1.1: Aerial and Ground SAR Efforts in Algeria

1.4 Limitations of Traditional SAR Approaches in Algeria

Despite the efforts of the General Directorate of Civil Protection (DGPC), ground operations often face slow response times due to long travel distances and difficult terrain. The vastness of desert regions and the lack of sufficient resources make effective coverage a real challenge, especially during sandstorms or in dense forests.
Aerial support, though valuable, remains costly and limited in range. Aircraft require frequent refueling and are often hindered by poor visibility caused by weather conditions like sandstorms.
International collaborations, such as those with the IOM, help reinforce SAR missions, but dependence on external actors, limited operational scope, and administrative delays can reduce their impact. Moreover, these interventions often lack technological innovation, relying mainly on humanitarian aid rather than advanced tools like AI or autonomous drones.

1.5 Technological Gap and Innovation Potential

Given the limitations of traditional search and rescue (SAR) methods in Algeria particularly in remote desert areas the integration of new technologies has become essential. Delays in intervention, difficult terrain access, and the lack of communication infrastructure significantly reduce the effectiveness of rescue operations.
The rise of artificial intelligence and autonomous drones offers a promising alternative. With onboard object detection models, it is now possible to analyze images in real time and identify people even in complex environments. These technologies allow for wide area coverage while reducing operational costs and human risk.
This project therefore proposes an innovative solution based on an intelligent RC plane, capable of detecting, locating, and transmitting data via radio, with the ultimate goal of reducing search time and saving lives in hard-to-reach regions.

Figure 1.2: Bridging the Technological Gap in Algerian Search and Rescue

1.6 Research Objectives and Contributions :

This project aims to address the limitations of conventional search and rescue (SAR) methods by leveraging autonomous aerial technology and artificial intelligence. The main objectives of this work are as follows:
- Design and develop an embedded autonomous system based on a radio controlled (RC) glider adapted for flight in harsh desert conditions.
- Integrate an AI-based person detection model, capable of processing aerial images in real time to identify individuals in distress.
- Establish a long-range wireless communication link between the airborne system and a ground station to ensure continuous data exchange.
- Experiment and compare several object detection algorithms to evaluate their performance in terms of accuracy, speed, and suitability for embedded deployment.
- Deliver a replicable and low-cost protocol that can serve as a foundation for future SAR deployments in remote or hard-to-access desert regions.

By combining real-time detection, low-cost components, and wireless data transmission, this project contributes to the development of practical and scalable tools for enhancing rescue operations in Algeria and similar environments.

1.7 conclusion

In this chapter, we introduced the context and challenges of search and rescue operations in Algeria's natural areas, particularly in the desert. Despite current efforts, traditional methods remain slow, limited, and costly.
To address these issues, we propose a smart RC plane equipped with AI-based human detection to assist SAR missions. This innovative approach aims to improve response time and efficiency in remote regions.
The next chapter will explore the fundamentals of artificial intelligence and computer vision technologies used in our system.

Chapter 2

Literature Review

2.1 Introduction

The term artificial intelligence (AI) was officially introduced in 1956 during a conference at Dartmouth University, marking the beginning of research into simulating human intelligence through machines [10]. Since then, AI has expanded across numerous fields, including engineering, medicine, finance, and law, becoming a key research area in the 21st century [11].
Although AI is often seen as a modern innovation, its concept dates back to the 1950s, with early systems like The Logic Theorist (1955) [12]. Interestingly, AI-like ideas existed even earlier in myths such as the Golem, highlighting humanity's long-standing fascination with intelligent machines [12].t" from 1955. [12]

2.2 Artificial intelligence meaning

Artificial intelligence is the combination of two words artificial + intelligence. Where artificial means 'not real' or 'natural' and by intelligence means 'the ability to reason, to trigger new thoughts, to perceive and learn'. Artificial intelligence (AI) refers to the development of machines capable of simulating human reasoning and behavior. It combines computer science with disciplines like psychology and philosophy to build systems that can perceive, learn, plan, and solve problems similarly to humans [13]. An AI system is considered "intelligent" when it can adapt to its environment, respond to speech or stimuli, and make decisions. More broadly, AI aims to create programs that solve complex problems efficiently, often by mimicking human cognitive abilities.

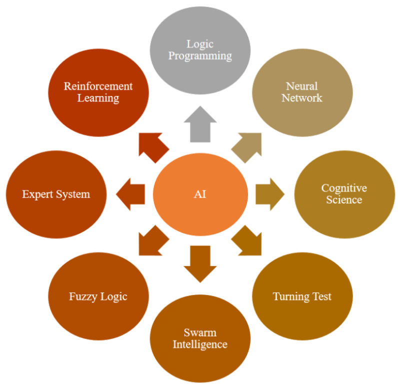

Figure 2.1: Factors included in AI

2.3 How AI Works: Step-by-Step Process :

Artificial Intelligence systems follow a structured development cycle to ensure efficiency and reliability:
- Collection & Preprocessing : Relevant data is gathered from various sources (images, text, etc.) and cleaned through normalization, error correction, and feature extraction to make it suitable for learning.[14]

- Data Splitting: The dataset is divided into training, validation, and test sets. This helps the model learn patterns, tune parameters, and evaluate generalization on unseen data.[14]

- Model Selection : An appropriate algorithm is chosen based on the task (e.g., classification or regression) and the dataset's complexity and size.[62]

- Model Training : The model learns from the training data by minimizing a loss function. Internal parameters are adjusted to improve predictions.[14]

Evaluation & Tuning : The model's performance is assessed using metrics like accuracy, precision, recall, and F1-score. Adjustments are made to improve performance.[14]

- Deployment : Once optimized, the model is deployed in a real-world environment to perform tasks on new data.[14]

- Monitoring & Maintenance : After deployment, the model is monitored continuously. If its accuracy drops due to data drift or changes, retraining or updates are applied to maintain reliability. [14]

2.4 Computer Vision

Computer vision is a subfield of artificial intelligence (AI) that enables machines to analyze and interpret visual data—such as images and videos using machine learning and neural networks [17]. If AI allows machines to "think," computer vision allows them to "see" and understand their environment. Although it mimics human vision, computer vision operates using cameras, algorithms, and data, enabling systems to detect objects, measure distances, and identify errors much faster than humans. A well-trained system can inspect thousands of items in a fraction of a second and flag even the smallest defects [17].
Its applications are growing rapidly across fields such as manufacturing, automotive, energy, and utilities, making it a powerful tool in modern automation [17].

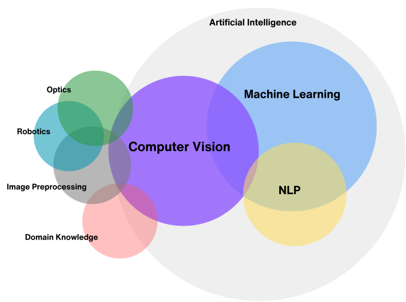

Figure 2.2: Computer Vision

2.5 Human Detection

Human detection is a key task in computer vision that involves locating people typically standing in images or video frames. It is widely used in applications like surveillance and driver assistance

systems, where it's often referred to as pedestrian detection [18].
The problem has been studied since the late 1990s, but remains complex due to variations in body shapes, poses, and partial occlusions. Techniques like Histogram of Oriented Gradients (HOG) and supervised learning have significantly enhanced detection accuracy by learning from large datasets of human images [18].

Figure 2.3: Human Detection

Detecting humans in images is vital for safety and surveillance. In complex environments like deserts or forests, traditional methods struggle. AI now plays a key role in improving detection under such difficult conditions.

1. Human detection on beaches:
Beaches are challenging for human detection due to light reflection, waves, and crowd variability. AI systems like Sightbit use computer vision on live video feeds to identify swimmers in danger and assist lifeguards in real time [19].

Figure 2.4: Human Detection in beaches

2. Human detection in forest environment :
Forests pose detection challenges due to dense vegetation and variable lighting. Drones with optical and thermal cameras improve results. Techniques like Airborne Optical Sectioning (AOS), combining multi-angle thermal views, help locate hidden individuals under tree cover [20].

Figure 2.5: Human detection in forest

3. human detection on roads :

In autonomous driving, detecting pedestrians is vital for safety. Modern systems use cameras, liars, and radars, paired with deep learning, to track and predict pedestrian movement in real time, reducing accident risks [21].

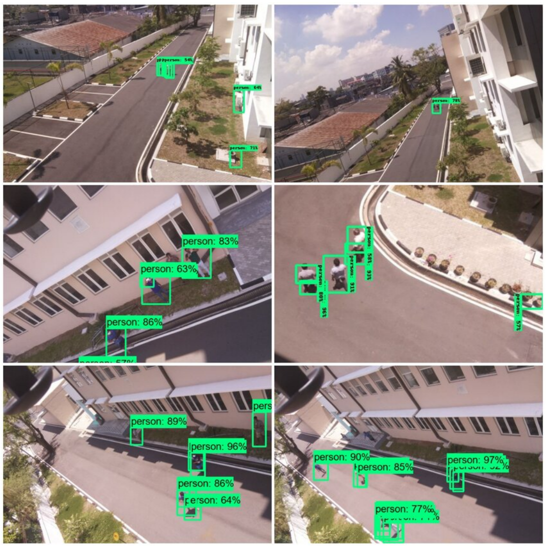

Figure 2.6: Human detection on roads

4. Human detection in desert environments :

The vast and uniform landscape of deserts, along with extreme weather, hinders human detection. Drones with thermal imaging overcome low visibility by spotting heat signatures, enhancing the speed and efficiency of rescue missions [22].
To strengthen the foundations of our research, we conducted a comparative review of existing studies addressing human detection in diverse natural environments such as forests, beaches, roads, and deserts. This literature review enabled us to identify and evaluate the most effective detection algorithms, while highlighting their specific strengths, limitations, and applicability to real-world search and rescue scenarios. The examples summarized in the table below served as key references to inform the development and evaluation of our own system.

Table 2.1: Comparative Summary of Selected Research Works on Human Detection by UAV

Title	Year	Algorithm Used	Key Results	Limitations
Human Detection from Drone using YOLOv5 for Search and Rescue Operation [23]	2023	YOLOv5 (n6–x6)	Trained on 5,210 annotated aerial images. Best model achieved high accuracy and real-time detection speed.	Data limited to dummies, no testing with extreme conditions.
Saving Lives from Above: Person Detection in Disaster Response using Deep Neural Networks [24]	2022	YOLOv3 with Darknet-53	mAP = 0.60; 1 km^2 covered in 2.3 min; increased robustness via 3 training phases	Low mAP for small resolutions, higher processing time. Small dataset, not tested in live drone deployment
Human Detection and Action Recognition for SAR using YOLOv3 [25]	2021	YOLOv3	94.9% accuracy for human and action detection; real-time speed (0.40 ms/image); supports 8 posture classes.	Limited to predefined actions, no thermal sensors , Does not address low-light or occlusion conditions
A Human Detection Method Based on YOLOv5 and Transfer Learning Using Thermal Images [27]	2023	YOLOv5 + Transfer Learning (RGB + TIR)	Effective for low-light UAV footage; tested on VisDrone 2021 RGBT dataset; optimized for Jetson Nano.	Only evaluated on thermal benchmark dataset; no integration with live UAV hardware; lacks field deployment.

2.6 conclusion

This chapter provided a foundational overview of the key technologies underlying our project, beginning with the definition and functioning of artificial intelligence. Through a step-by-step breakdown, we explored how AI models are built, trained, and deployed in real-world applications. The focus then shifted to computer vision a vital subfield of AI that enables machines to interpret visual data and its crucial application in human detection.
We examined the specific challenges of detecting humans in diverse environments such as beaches, forests, roads, and deserts, emphasizing how AI-powered systems can adapt to varying lighting, terrain, and visibility conditions. Each of these domains requires tailored approaches, highlighting the importance of selecting the right models and data types.

Finally, a comparative analysis of recent scientific research showcased the evolution and effectiveness of different human detection methods using drone imagery and deep learning. These insights not only justify the technical choices made in our project but also demonstrate the growing reliability and relevance of intelligent aerial systems in search and rescue missions.

Chapter 3

Conclusion

In a context marked by the continued growth of environmental and humanitarian challenges, Algeria faces a recurring and worrying problem: the disappearance of people in hostile natural areas, particularly in the Saharan desert. Given the limitations of traditional search and rescue (SAR) methods, which are often slow, costly, and poorly suited to vast desert expanses, it has become imperative to explore innovative technological solutions.

This thesis was part of this dynamic by proposing a comprehensive approach, combining artificial intelligence, computer vision, embedded systems, and light aircraft, through the design and development of an autonomous RC plane capable of detecting missing persons in the desert. Our approach covered all aspects of the project, from theoretical reflection to technical implementation, including a comparative analysis of AI models adapted to human detection.

We demonstrated the feasibility of such a system through:

- the creation of a dataset of real and augmented images adapted to the Algerian desert context

- the training of several detection models (YOLOv5n, YOLOv8n, YOLOv11n, Faster R-CNN)

- the selection of the most suitable model based on the compromise between accuracy, speed, and onboard integration capacity

- the integration of multiple onboard sensors (GPS, gyroscope, barometer, camera, radio modules) controlled by a Raspberry Pi 5

- the implementation of a wireless communication system based on the nRF24L01 module

- the development of an interactive graphical interface allowing the user to view flight information in real time and pilot the aircraft remotely.

The experimental results obtained demonstrated the system's ability to effectively detect people in visually complex environments, with satisfactory accuracy and stable performance. This project thus represents a concrete step forward in the field of intelligent rescue technologies.

There are numerous development opportunities: improved radio range, the transition to lighter and faster algorithms for greater autonomy, the integration of autonomous GPS navigation, and the extension of detection to other contexts (mountains, forests, sea).

In conclusion, this work proves that it is possible, with limited but well-utilized resources, to design an intelligent, embedded, reliable, and economically viable system capable of saving lives. This is an example of the impact that artificial intelligence can have when used to support humankind.

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