1. <u>Introduction and Background</u>

In the dynamic world of agriculture, the convergence of Mixed Reality (MR) and Virtual Reality (VR) technologies presents an exciting opportunity. Our project, "Harnessing MR and VR for Agriculture," explores these immersive technologies in farming.

Our goal is to integrate MR and VR into traditional agriculture, offering practical insights to tackle real-world challenges. We aim to boost efficiency, data-driven decision-making, and sustainability. This introduction provides an overview of our project's objectives, methodologies, and some very useful applications.

This project is specially designed to use VR headsets and drones for the betterment of agriculture. As discussed by ***(Rejeb et al., 2022)*** about the great effectiveness of drones in agriculture, we believe that drones hold true potential for this area of research. The usability of virtual reality in agriculture ***(Wang, 2021)*** proves the effectiveness of VR in the field of agriculture. VR Headsets with real-time video feed from fields provides a great Mixed Reality experience which makes it more immersive to maintain the quality of crops, maintain and manage livestock, detect irrigated and non-irrgated area, and many more applications in agriculture. Deep learning and computer vision also play a core role in the entire orchestra of research and development. Using deep learning models trained using state-of-the-art techniques to achieve the application of this project as explored by ***(Ravoor, 2020)*** to detect 5 different types of animals (elephant, zebra, giraffe, lion, and cheetah) and humans from images with very high accuracy. We will be developing the same kind of model but it will be trained on different types of data (on videos/images captured with upside-down views over fields with animals).

In consonance with these scholarly findings, our project aspires to bridge the gap between theory and practical implementation. In particular, we intend to leverage VR headsets, augmented by real-time video feeds from agricultural fields, to provide a holistic Mixed Reality (MR) experience. During the whole process of building this entire project, we will also be focusing on identifying a good journal to publish our paper, or at least our initial manuscript/draft should be ready and in submission at our finalized journal.

2. Problem Description and Objective

To create an integrated system that combines drone control and virtual reality headset interaction using Python and specialized libraries, enabling the project to expand itself for real-time coordination for applications such as missing animal detection, irrigation monitoring, surveying boundaries, Spraying and seeding needs, Soil and water samples in fields.

This project aims to develop a system that allows users to control a drone using a VR headset, facilitating tasks like missing animal detection in fields. By integrating Python, specialized libraries, and advanced operating techniques, we aim to ensure real-time communication between the VR headset and the drone, enhancing efficiency and user experience in various applications.

3. Tools and Techniques

Equipment:

Oculus Quest 2 HMD (provided by the supervisor)
Drone (Not confirmed yet/ can buy if needed)

DJI Tello EDU:

- Range: 100m
- Flight Time: 13min
- Speed: 8m/s
- Price: $150 + ($13 Tax)
- Programmable: Python
- Link to Buy: https://shemaps.com/product/tello-microdrone-edu-single/
- No Gimbal Support
- No advanced controls (limited coordinates access)
- Camera View not changeable

DJI Mini 2:

- Range: 15.7km
- Flight Time: 31min
- Speed: 12-15 m/s (based on air resistance)

- Price: 110K (used)
- Programmable: Python (But 3rd party integrations)
- Link to Buy: OLX https://www.olx.com.pk/item/dji-mavic-mini-2-fly-more-combo-kit-good-condition-iid-1076082586
- Gimbal Support
- Advanced Controlling System
- Camera View changeable
- Takeoff weight: < 249g

DJI Mavic Air Fly:

- Range: 10km
- Flight Time: 21min
- Speed: 29-38 m/s (based on air resistance)
- Price: 125K (used)
- Programmable: Python (But 3rd party integrations)
- Link to Buy: OLX https://www.olx.com.pk/item/dji-mavic-mini-2-fly-more-combo-kit-good-condition-iid-1076082586
- Gimbal Support
- Gyroscope Support
- Advanced Controlling System
- Camera View changeable
- Takeoff weight: < 430g
  (better option than DJI Mini 2 because of the Gyroscope support, providing more accurate and smooth movement with VR Headsets https://www.linkedin.com/feed/update/urn:li:activity:7101432621796081664?utm_source=share&utm_medium=member_desktop see this video for gyroscope advantage)

Hardware-Based Approach:

(DJI Mini 2 does not support thermal cameras as an attachment because it's a consumer-level drone with simple imaging and videography support. We can either opt for expensive drones (such as DJI Matrice Series) which can support heavy takeoff load and also provide gimbal support for extra attachment. Thermal cameras with good quality sensing are quite expensive ranging between $5000 to $10000). Plus, integration of heat cameras with drones is very limited and there's no official support to stream heat-sensing camera video to another device. With all of these constraints and limitations, we will not be using heat-sensing cameras as our main detection hardware instead, we will be developing a new and improved AI–based approach to provide a similar kind of result.

Deep Learning and Computer Vision-Based Approach:

Another approach would be to use pre-trained computer vision deep learning models for object tracking and detection. Models like DeepSORT ***(Wojke et al., 2017, #)*** and YOLO ***(Redmon et al., 2016, 779-788)*** perform inference in almost real-time. Using these models, we can first test them in the fields and get the video stream from the drone's camera. We will divide the scenarios of testing into three parts, The first one is easy-level detection where we will be fine-tuning the models on publicly available animal datasets and we might add some synthetic data generated using Unity. The Second one is Medium-level detection, in which we will be collecting a dataset of farms and animals in the fields during testing and manually annotating them to enhance the performance of the model on the scenario that occurs not more frequently but still the probability of its occurrence is not low. The third one is Hard-level detection, at this level the proposed model should be able to detect animals with satisfactory to good accuracy but in order to make the model more robust to scenarios where the appearance of animals is not very clear the model should be able to detect animals from the current camera view further processing is necessary.

Programming Language:

Python is the most widely used programming language in the research field. Also, it provides a large number of libraries that can be used to automate processes of almost any kind. With this type of functionality provided by Python, devising a methodology and overall process of the control system is very much streamlined and convenient.

Drone Movement:

Tello Drone:

In order to control the drone, we will be using Python with a control system library provided by the Tello EDU. DJI and Ryze in collaboration developed a library specifically for Tello drones. It provides a complete interface to control the drone using Python code. It also gives functionalities of Advanced AI algorithms like object recognition, tracking and 3D reconstruction, and computer vision with deep learning technologies.

DJI Mini 2 & DJI Mavic Air Fly:

DJI doesn't provide open-source libraries or any library to communicate with their drones (proprietary framework). Although there are some SDKs ***(DJI, n.d.)*** provided by the DJI for the development of Mobile Applications. Because we are mainly focusing on building this project for AI and research we will be using Python for all the coding. For this, another open-source project is available which allows us to use Python to communicate with an Android application which is serving as a wrapper app for communication between DJI Drones and Python code. The name of the app is Rosetta Drone 2 ***(Terje, n.d.)***. It uses the UDP communication protocol for transmitting data between Android phones and Python code. For the Python side, we will be using DroneKit because it supports the MavLink protocol which will be communicating with the Rosetta Drone 2 by utilizing UDP.

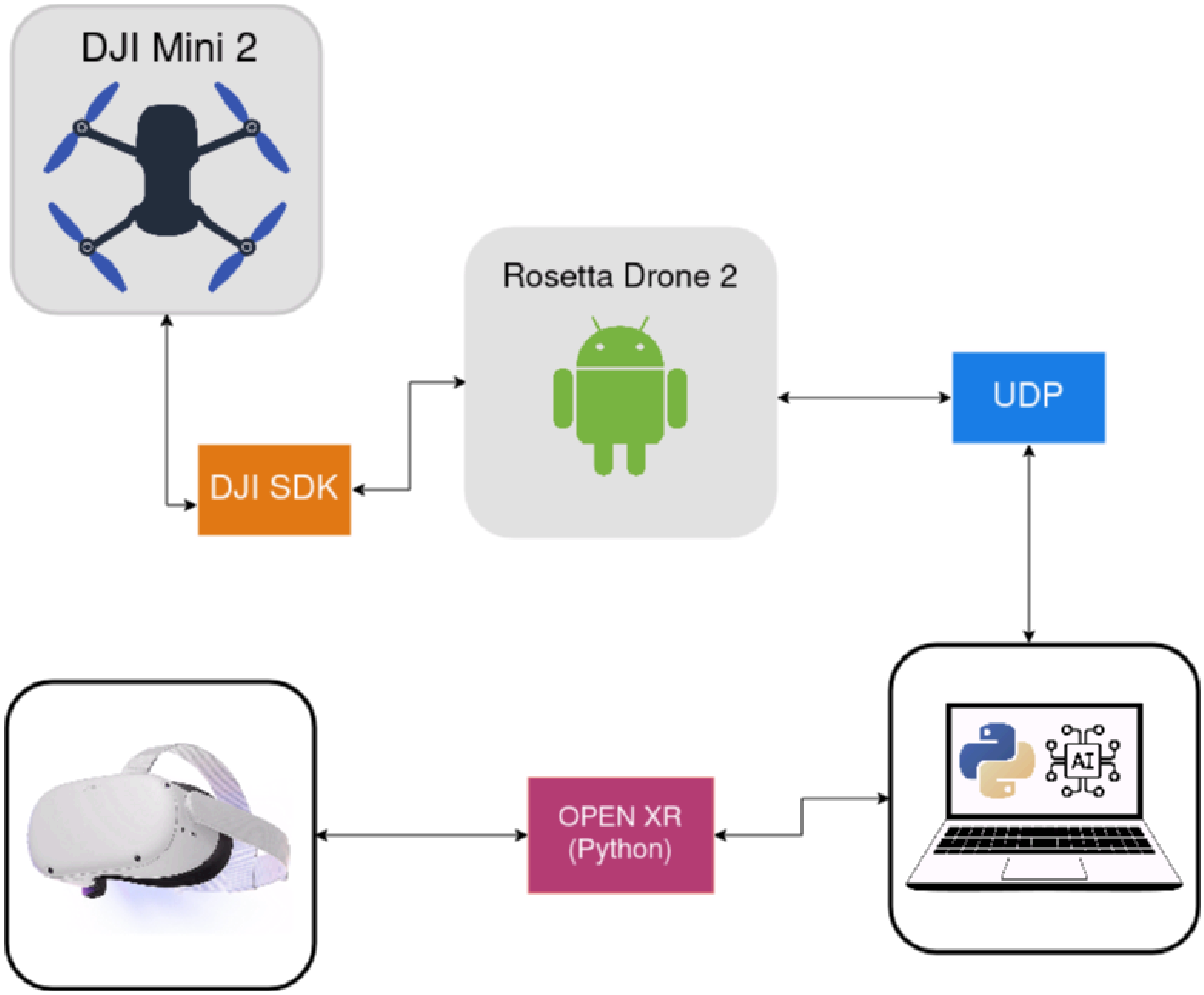
VR Headset Linking:

The **Vizard** Library ***(Worldviz, Inc., n.d.)*** was developed for the researcher to mainly focus on the development of research experiments done with VR headsets. It includes support for many VR headsets which includes the HTC VIVE, Oculus Quest 2, and many others. With this library, another interface called **OpenXR** can be used to connect the HMD to the script which is basically written using Python programming language. By using the OpenXR interface, we can access the input given by the user in the form of head movement, and then, this input can be used (from HMD) as input to the drone for flight control system coordinates.

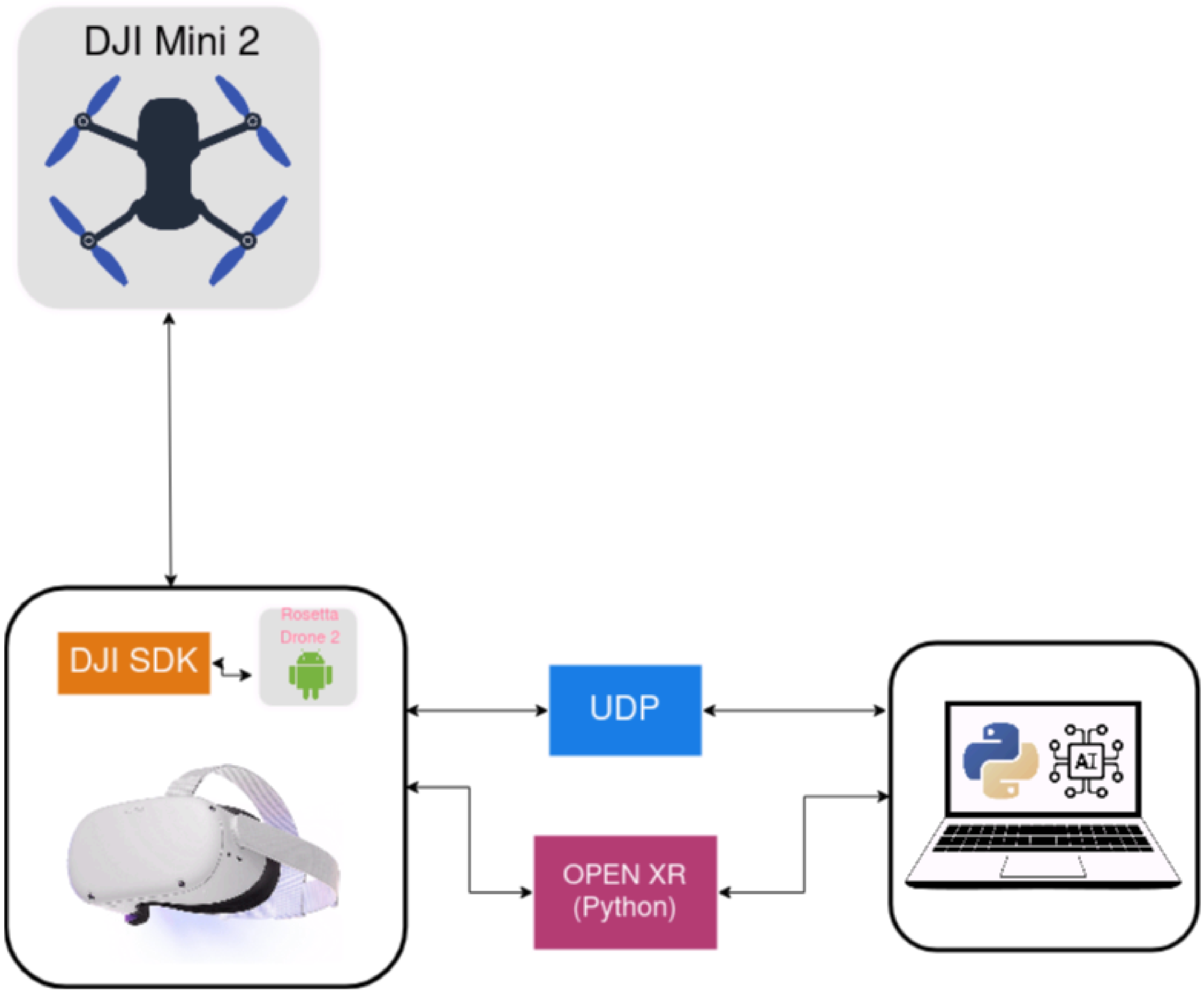
Other tools and libraries:

All of this can be achieved without advanced operating systems techniques but in order to reduce the latency and load from a single process, advanced operation systems techniques like Multithreading and multiprocessing will ensure that the load on a single/main thread/process does not become an obstacle to achieve the real-time based movement between drone and VR headset. This is one of the core objectives to achieve while doing all other things. Because if there’s any lag between VR headset movement and drone movement then it would not give a smooth experience. To perform object detection, missing animal detection, crop quality measurement, and display the output to the user in a VR headset, a lot of computational techniques need to be performed to ensure a smooth experience. Multithreading is mostly done with a built-in library provided by Python called threading**.**

Initial Project Flow



Improved Project Flow



4. Methodology

The proposed project aims to create an integrated system for drone control and virtual reality (VR) headset interaction using Python and specialized libraries. This methodology outlines the key steps and components involved in achieving this goal, while also defining the project's scope. At the end of the project, we will be submitting the initial draft of our research paper in a journal related to agriculture and virtual reality.

Project Scope:

This project will focus on the following aspects:

1. Drone Control:

   We will utilize the DJI Mini 2, which is programmable using DJI SDK and Python. The DroneKit library will be the primary tool for controlling the drone's movement, enabling functions such as flight coordination and waypoint navigation. DroneKit is a powerful Python library that allows developers to communicate with DJI drones, including the Mini 2, through a high-level API. With DroneKit, we can create custom flight plans, monitor the drone's telemetry data, and implement advanced flight control logic. This combination of the DJI SDK and DroneKit in Python provides us with the flexibility to develop applications for the DJI Mini 2, unlocking a wide range of possibilities for autonomous flight, aerial photography, and more.

2. VR Headset Integration:

   The Oculus Quest 2 VR headset will serve as the interface for the user. We will employ the Vizard Library, with OpenXR integration, to connect the HMD to our Python script. This linkage will enable us to capture user head movement as input data for the drone's flight control system coordinates.

3. Multithreading and Multiprocessing:

   To ensure real-time coordination between the VR headset and the drone, we will implement advanced operating system techniques like multithreading and multiprocessing. Python's built-in 'threading' library will be employed to manage concurrent tasks, reducing latency and ensuring a smooth user experience.

4. Spatial Science Techniques:

   Spatial science techniques will be used to track objects of interest, such as missing animals. OpenStreetMap will be employed to display the detected object's location on a real map. The OpenCV library will estimate the object's speed, helping predict when it will leave the camera's view.

Project Approach:

The project will be divided into the following main sub-tasks:

1. Drone Control Script:

   Develop a Python script using the Tello Python library to control the drone. Implement functionalities such as autonomous flight, object detection, and tracking.

2. VR Headset Integration Script:

   Create a Python script using the Vizard Library and OpenXR to link the Oculus Quest 2 VR headset to the drone control system. Capture head movement as input for the drone's flight coordination.

3. Multi-Threading and Multiprocessing Implementation:

   Apply multi-threading and multiprocessing techniques to ensure real-time communication between the VR headset and the drone. Optimize performance to minimize latency.

4. Spatial Science Techniques Integration:

   Utilize spatial science techniques to track objects, like missing animals, and display their locations on OpenStreetMap. Estimate object speed using OpenCV.

5. System Integration and Testing:

   Integrate the drone control system, VR headset interaction, and spatial science components into a cohesive system. Thoroughly test the system to ensure smooth and responsive user experiences.

6. User Interface (UI) Development (if applicable):

   If required, create a user-friendly interface for controlling the system and visualizing data in the VR headset.

7. Documentation and Reporting:

   Maintain detailed project documentation, including code, algorithms, configurations, and results on GitHub. Prepare a comprehensive report summarizing the project's objectives, methods, and outcomes.

This technique lays out a detailed plan for creating a system that integrates drone technology with virtual reality, allowing for real-time control and data display. The project hopes to fulfill its goals more efficiently and effectively by focusing on these sub-tasks and applying the defined techniques and libraries.

5. Applications

Utilizing drones in agriculture, especially when combined with VR (Virtual Reality) headsets like the Oculus Quest 2 and computer vision (CV) and deep learning (DL) algorithms, can significantly enhance efficiency and precision in various agricultural tasks. Here's an explanation of the use cases:

1. Livestock Movement and Counting:

- Drones equipped with cameras can be used to monitor and manage livestock. ***(Najla Al-Thani, n.d.)***
- VR headsets can provide a first-person view for farmers to control the drone's movement.
- CV algorithms can help in counting and tracking livestock in real time, aiding in inventory management. ***(Mr. Gonzalo R. Canosa, n.d.)***
- Spatial science techniques can be used to keep track of missing animals. Once the animal is detected, OpenStreetMap can be utilized to draw the animal's location on the real map. By using the OpenCV library, the estimated speed of the animal can be calculated. Then this approximated value can be used to get an idea of how much time that animal would leave the current view of the camera. It can also help to overcome the problem of overcounting the same animals.

2. Irrigation Monitoring (Watered vs. Unwatered Area):

- Drones can capture high-resolution images of agricultural fields. ***(Alvino & Marino, n.d.)***

- CV algorithms can analyze these images to identify areas that need irrigation.

3. Surveying Boundaries:

- Drones equipped with GPS and cameras can quickly survey large areas.
- VR headsets can provide immersive control for precise navigation.
- CV algorithms can help in mapping field boundaries and detecting any encroachments or issues.

4. Spraying and Seeding Needs:

- Drones can be equipped with spraying or seeding equipment for precision application.
- VR headsets can enable operators to see exactly where to apply treatments.
- DL algorithms can analyze field data to determine the optimal distribution of seeds, fertilizers, or pesticides.

5. Collecting Soil and Water Samples:

- Drones can access remote or hard-to-reach areas to collect samples.
- VR headsets can assist in navigating to specific sampling locations.
- CV can help identify suitable sampling points, while DL can analyze sample data for soil or water quality assessments.

The combination of drones, VR headsets, CV, and DL technologies offers several advantages in agriculture:

- **Efficiency:** Drones can cover large areas quickly, saving time and labor.
- **Precision:** CV and DL algorithms can provide detailed insights, helping farmers make data-driven decisions.
- **Safety:** VR headsets enable operators to control drones without needing to stare at a remote controller, improving situational awareness.

This integrated approach has the potential to revolutionize modern agriculture by optimizing resource use, reducing environmental impact, and increasing overall productivity.

6. Milestones

We will be dividing the tasks among all team members but during the phase of development, team members will be working interchangeably on the same activities or different tasks. Here is a tentative schedule of activities with their proposed tentative dates:

Activity	Tentative Date
FYP-I	
VR Libraries	Till 20-09-2023
VR Head Movement Data	21-09-2023 to 04-10-2023
Libraries for Drone	5-10-23 to 19-10-23
Drones selection	20-10-23 to 26-10-23
Controlling drones with Server	27-10-23 to 16-11-23
VR to Drone Communication	17-11-23 to 17-12-23
FYP-II	
Testing Drones and VR Communication	18- 12-23 to 31-12-23
Applications with Deep Learning and Computer Vision	01-01-24 to 01-03-24
Testing of Applications in Fields	02-03-24 to 23-04-24
Paper Submission (Early Draft in-submission)	24-04-24 (Depending upon the submission date of the selected journal

References

Alvino, A., & Marino, S. (n.d.). *Horticulturae | Free Full-Text | Remote Sensing for Irrigation of Horticultural Crops*. MDPI. Retrieved September 15, 2023, from https://www.mdpi.com/2311-7524/3/2/40

DJI. (n.d.). *DJI Developer Technologies*. DJI Developer. https://developer.dji.com/

Mr. Gonzalo R. Canosa. (n.d.). *A Real-Time Method to Detect and Track Moving Objects (DATMO) from Unmanned Aerial Vehicles (UAVs) Using a Single Camera*. MDPI. Retrieved September 15, 2023, from https://www.mdpi.com/2072-4292/4/4/1090

Najla Al-Thani. (n.d.). *(…)*. (…) - Wiktionary. Retrieved September 15, 2023, from https://ieeexplore.ieee.org/abstract/document/9140588/authors#authors

Ravoor, P. C. (2020, December 22). *(PDF) Deep Learning Methods for Animal Recognition and Tracking to Detect Intrusions*. ResearchGate. Retrieved September 15, 2023, from https://www.researchgate.net/publication/346600017_Deep_Learning_Methods_for_Animal_Recognition_and_Tracking_to_Detect_Intrusions

Redmon, Joseph and Divvala, Santosh and Girshick, Ross and Farhadi, & Ali. (2016, June). You Only Look Once: Unified, Real-Time Object Detection. *Proceedings of the IEEE Conference on Computer Vision and Pattern Recognition (CVPR)*, 779-788. https://www.cv-foundation.org/openaccess/content_cvpr_2016/html/Redmon_You_Only_Look_CVPR_2016_paper.html

Rejeb, A., Abdollahi, A., & Rejeb, K. (2022, May 18). *Drones in agriculture: A review and bibliometric analysis*. https://www.sciencedirect.com/science/article/pii/S0168169922003349

Terje. (n.d.). *Rosetta Drone*. GitHub. https://github.com/RosettaDrone/rosettadrone

Wang, Y. (2021, August 11). *The Influence of Virtual Reality Technology on the Cultivation of Agricultural Students*. Hindawi. Retrieved September 15, 2023, from https://www.hindawi.com/journals/misy/2021/7699106/

Wojke, N., Bewley, A., & Paulus, D. (2017). Simple online and realtime tracking with a deep association metric. *IEEE Xplore*, 3645-3649. 10.1109/ICIP.2017.8296962

Worldviz, Inc. (n.d.). World Viz. VIZARD FEATURES