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Development of Drone-Based Human Rescue Strategies Using Virtual Reality

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Abstract

Despite the enormity of the tragedy, many cases can be saved in record time after accessing them and direct intervention. However, rescue teams may find intervention impossible or dangerous, mainly when major explosions or fires occur. After a disaster, commercial drones can be used to detect and search for survivors. They are controlled by iOS-installed Head Mounted Display (HMD) and virtual reality applications. This enables them to reach disaster areas, detect the presence of injured people, and pinpoint their locations. In this research, Artificial intelligence technologies, as represented by (Open CV Documentation) using PYTHON Code, are combined with Drone engineering capabilities to present robust virtual reality applications. The results demonstrated high accuracy in detecting the injured in the disaster area, complete immersion of the observer in the safe zone by default, and controlling the drone through HMD.

Keywords: An unmanned aerial vehicle, Skin detection, Head-Mounted Display, PYTHON, Open CV.

تطوير استراتيجيات الإنقاذ البشري القائمة على الطائرات بدون طيار باستخدام الواقع الافتراضي

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الخلاصة

على الرغم من فداحة المأساة إلا أنه يمكن إنقاذ العديد من الحالات في وقت قياسي بعد الوصول إليها والتدخل المباشر. أحيانا ، قد تجد فرق الإنقاذ هذا التدخل مستحيلًا أو خطيرًا ، خاصة عند حدوث كوارث مثل الانفجارات الكبرى أو الحرائق. بعد وقوع كارثة ، يمكن استخدام الطائرات التجارية بدون طيار للكشف عن الناجين والبحث عنهم. يتم التحكم فيها عن طريق شاشة مثبتة على الرأس (HMD) بنظام iOS وتطبيقات الواقع الافتراضي. وهذا يمكنهم من الوصول إلى مناطق الكوارث واكتشاف وجود مصابين وتحديد مواقعهم. في هذا البحث تم استخدام الذكاء الاصطناعي والمتمثل باستخدام Open CV مع لغة بايثون مع تكنولوجيا الطائرات المسيرة لتمثيل واقع خيالي دقيق لانقاذ الجرحى اثناء الكوارث. أظهرت النتائج دقة عالية في الكشف عن المصابين في منطقة الكارثة ، وكذلك الانغماس الكامل للمراقب في المنطقة الآمنة في التجوال بشكل افتراضي والتحكم في الطائرة بدون طيار من خلال HMD.

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1. Introduction

Day by day, the disaster magnitude of this planet is increasing indefinitely. These disasters vary according to circumstances, including natural or epidemic disasters and accidental disasters, the most dangerous of which are wars and explosions [1][2]. It is not limited to a specific region or country in this big world, and human is their first victim. Every year people lose thousands of loved ones who died or went missing due to these disasters. Third-world countries, especially (Iraq) have suffered from disaster tragedies caused by devastating wars and explosions that spanned many decades and claimed thousands of lives.

On the other hand, people lose their lives after the disaster due to the delay in saving them or loss under the rubble and disaster-stricken areas subjected to a specific disaster. Many institutions, research centers, and others are interested in developing technical capabilities to search for the wounded and survivors when disaster strikes and rush to rescue them in the shortest possible time. Therefore, rescuing the injured during natural or man-made disasters requires preserving the personnel assigned to the rescue from injury [3]. In order to provide a safe environment to perform work speedily and with high professionalism, away from exposure to injury or loss, in terms of lives or equipment and devices used in the rescue. This requires remote simulation of the disaster area, determination of the extent of the damage, quick search for surf rescue of their lives, and Mandell as the recovery of bodies. Commercial drones equipped with cameras are of great interest to amateurs and professionals in photography, exploration, and entertainment. Over time, the challenge has increased among aircraft manufacturers by providing advanced technologies and applications that provide an accurate high-resolution view through the image captured or video clip recorded via the drone and other uses that provide enjoyment to the general public. In addition to the entry of drones into the military, commercial, and air navigation systems [4]. This technology must be directed at developing the field of saving lives and locating the injured during disasters and crises [5]. It is not without challenges. The directly exposed to disasters may be dead or injured under the rubble of the building. It is necessary to develop the capabilities of the remotely piloted drone by integrating its available applications with other technologies [6][7] and passing it with intelligent software systems using artificial intelligence techniques. Commercial aircraft can identify the injured and provide quick answers to rescue teams to locate them conveniently to evacuate and save lives. Innovations in camera technology have significantly impacted the growing use of drones with thermal imaging cameras have provided emergency response teams with an ideal solution for identifying victims that are difficult to identify with the naked eye. However, the response time should be as fast as possible to rescue people, and using Real-Time Messaging Protocol (RTMP) [8] slowed the system. Therefore, the study aims to achieve high accuracy in detecting injured people in disaster areas and complete immersion of the observer in the safe zone when roaming by default using drone control applications, also creating this proposed system with less cost using an available component. In this research, artificial intelligence technologies, as represented by (Open CV Documentation) using PYTHON Code, are combined with Drone engineering capabilities to present robust virtual reality applications.
The rest of the paper is organized as follows. Related work is presented in Section 2. Section 3 explains the proposed method, and the conclusion is illustrated in Section 4.

2. Related Work

Many studies and contributions have added the drone's capabilities in virtual reality applications and people's rescue operations during disasters and accidents. A research team contributed to developing a device to control the drone using Virtual Reality (VR) techniques using MEMS sensors and artificial intelligence techniques [9]. In another research contribution, drones are trained to provide medical response and protection to the injured during radiological and nuclear disasters time by integrating their capabilities with specific applications for mapping and sensing radiation levels inside nuclear plants that have been exposed to a specific accident and the spread of a high level of pollution inside them [10]. One of the things that are difficult to determine in aerial photographs that are captured using drones is the process of identifying humans within a particular image if it represents a proportion of 0.1 to 0.2 % of the image size and, accordingly, a convolutional neural network was trained to locate humans in a particular image. This contribution represents a significant challenge in locating humans and rescuing people from blurred vision or when a natural disaster occurs [11]. In conjunction with the outbreak of the Coronavirus (Covid-19), the drone was qualified to determine the human temperature by installing a specific sensor that can sense skin temperature and, through it, identify people infected with the virus and diagnose the disease condition [12]. The VR–drones, a technology that creates a virtual environment that simulates buildings by default, are activated by installing a screen in the head connected to a drone that roams inside the buildings or places to be detected [13]. This experience allows trainees to test their capabilities in driving drones and interact with the real world virtually. Researchers in [14] found a relationship between virtual reality and digital broadcasting using local Internet networks 4G and 5G. It is considered one of the technologies in employing digital virtual reality programs and games with live streaming; this approach can apply to capturing live video streams from a drone when sent to a natural disaster area. Deadly accidents are an eternal problem that humans work to address and find essential solutions to save people's lives at the time of occurrence or predict the occurrence, taking all measures to prevent its occurrence or reduce its losses. The authors [15] developed a disaster simulation in digital environments using drones and enhanced protection systems to allow rescuers to train on this technology and save people's lives during natural or synthetic disasters by creating digital maps and locating major disasters and the injured.

3. Proposed Method

This approach is an embedded system of several technical devices during which the drones are trained to identify the injured and the people who need a rescue operation during natural or man-made disasters. The special capabilities of virtual reality head-mounted display (VR-HMD) give the user wide vision with a high-quality video display [16]. This system simulates an environment for a specific disaster due to exposure to the causes mentioned above and trains a commercial drone with a high-resolution camera installed in its front to roam in this environment and receive a direct signal from it that is transmitted to a ground station. The observer controls the drone according to the principle of Fly Like Bird using virtual reality glasses (VR-HMD), which gives a three-dimensional view of the disaster environment inside it and reinforces his conclusions through direct analysis. Also, finding a mediator to receive the drone video signal in the real-time broadcast was by adopting hosting virtual servers or smart DJI controllers.

Figure 1 depicts the embedded system's mechanism for rescuing people and identifying the injured. This scientific contribution also protects observers and rescue teams while searching for the injured in disasters and provides quick response and urgent relief. Our integrated system comprises a control room in a secure location far from the disaster site. These devices are meant to complement one another. The system was generally divided into two components: installation and hardware. The second step is to run it through software applications, as shown in Figure 2.

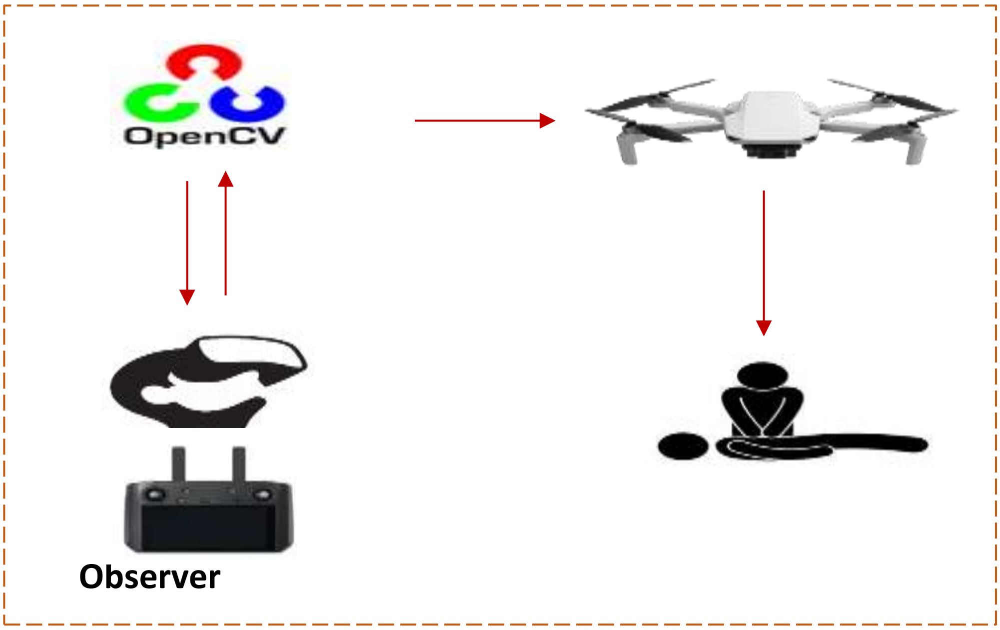

Figure 1: Overview of our system's technical mechanism

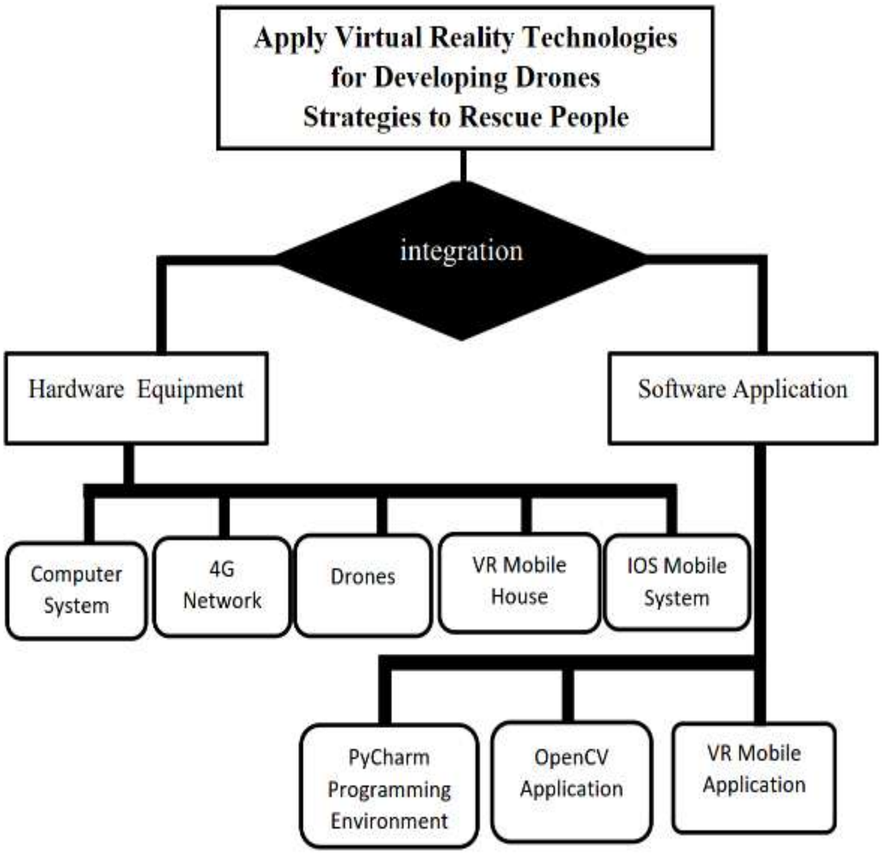

Figure 2: Complete embedded system equipment to rescue people

3.1 Real-time video capture

The high-resolution video captured by drone has a significant role in providing ideal results, especially in live broadcasts [17]. The process of analyzing the video transmitted by drones through the use of OpenCV algorithms requires high-quality video to obtain accurate results. Rapid progress in the development of high imaging capabilities of drones has made them a reliable source for many applications of artificial intelligence today. In addition to the high resolution provided by drones lenses in capturing video, where the sensor's accuracy for capturing a frame per video reaches 12 megapixels or more, the gimbal technology makes it stable during flight and non-shakable. It enables to capture Full HD or 4K video [18]. Our practical research used a DJI Mavic mini2 drone with a high-resolution camera to support HD video streaming. Other models of drones can be used in different capacities, as shown in Table 1.

Table 1: Different types of drones resolution

Drone	Resolution
Parrot Anafi	5344×4016
Typhoon H Plus	5472×3648
Mavic Air	4056×3040
Mavic Mini2	3840 ×2160
Mavic Pro Zoom	4000×3000
Mavic Pro2	5472×3648
Mavic Pro Platinum 3 DJI Mavic 3	4096x2160
Phantom 4 Pro v2	5472×3648

To ensure a clear result and accurate implementation of the algorithm, live broadcasting of the video captured by the drone to the algorithm implementation environment using the OpenCV libraries must have high speed without delay. Through practical experience, RTMP received the drone video signal from a standard DJI controller with a 4G or 5G internet signal, as shown in Figure 3.

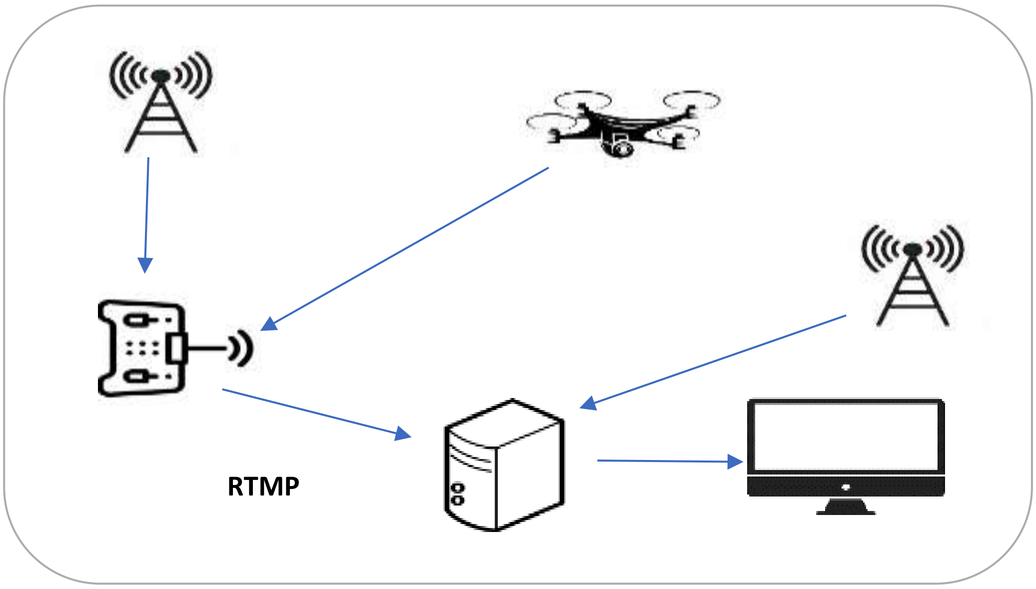

Figure 3: Drone video signal live broadcast to RTMP

The standard drone controller sends the video captured before to the server using RTMP, and the server delivers the video to the observer. RMTP is the standard posting protocol for live streaming and is supported by major software such as the Moving Picture Expert Group (MPEG) and Open Broadcaster Software (OBS). Through practical experience, there was a delay during the transmission process from the drone to the observer, and this was normal because sending the signal from the drone controller to the RTMP server takes about 8 to 10 seconds and depends mainly on the type of Internet service. That means it negatively affects more latency results of the proposed system [19]. Laboratory experiments have proven that using a DJI smart controller, Figure 4, instead of an RTMP server, provided a faster response time and low latency during the live broadcast from the drone located at the disaster region site when sending the signal to the observer in a safe region. In addition, the video signal sent to the 1080 high-definition resolution environment was compared to that received from an RTMP server, Figure 5. The damaged location was contacted via the local network (4G), which has a variable speed depending on the circumstances and coverage in the affected accident area. Using multiple local networks to strengthen and speed up the network was possible.

Figure 4: DJI smart controller

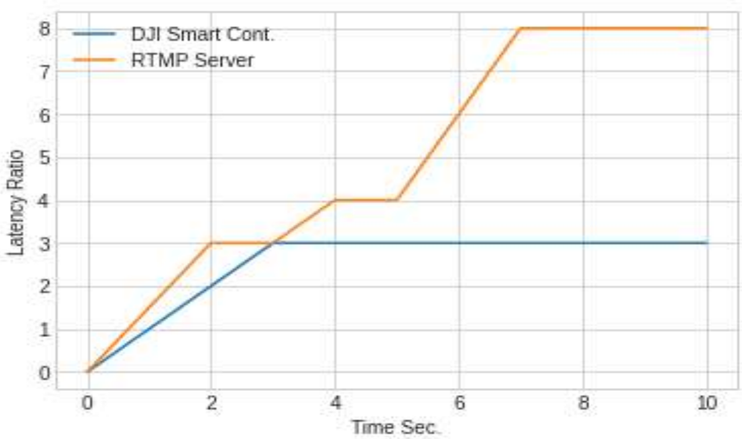

Figure 5: Latency ratio to time

3.2 Human detection in the disaster region

The video sent by the drone was analyzed using OpenCV techniques to identify injured people as a result of disaster operations, which was done using skin detection technology [20].

Skin detection means human skin color pixels and regions in an image or a video. In this paper, the mentioned algorithm was applied to detect humans in the scene captured by a drone. Skin detection applications were used for personality recognition and body tracking. Lighting and contrast were adequate on RGB pixels. The main steps of skin detection in the video captured from a drone were 1. download the input image or video and broadcast it to the programming environment; 2. convert the image to HSV color space; 3. generate the image histogram; 4. apply the classifier to determine the probability of a given pixel being skin-colored. The image must be converted from RGB to HSV in the second step. The HSV color model was a cylindrical representation of the standard RGB model [21].

HSV stands for values of Hue, Saturation, and Value. The detector used in the OpenCV library was from 0 to 255. The next step was finding the classifier function to determine a skin-colored pixel. The naive Bayes algorithm gives an accurate result and is easy to implement [22]. Besides, Naive Bayes classifiers often work much better in many difficult situations. Also, the advantage of the algorithm is that it does not require many training examples. By the Bayes theorem, taking into account the variable y and the dependent characteristic vector $(x1, \ldots, xn)$, the following relation were obtained in Equation (1), (2), (3) and as follows:

$$p(y|x_1, \ldots, x_n) = \frac{p(y)p(x_1,\ldots,x_n|y)}{p(x_1,\ldots,x_n)} \quad (1)$$

Eq. (1) can be simplified as in Eq. (2):

$$p(y|x_1, \ldots, x_n) = \frac{p(y)\prod_{i-1}^{n} p(x_i|y)}{p(x_1,\ldots,x_n)} \quad (2)$$

The classification rule can be obtained as in Eq. (3):

$$Y = argmax_y p(y) = \prod_{i=1}^{n} p(\,x_i|y) \quad (3)$$

Applying this rule to each video frames pixel captured by the drone, as shown in Fig. 6, the practical experience showed that the HD video captured by the drone had given advanced results in isolating the skin color from the rest of the scene details. Through the OpenCV code, a black mask was made on the rest of the body's details, during which the human skin was covered and visible. It was noticed that the features of the face were apparent, and the skin color could be distinguished from the rest of the details shown in the video sent by the drone.

Figure 6: Human skin detection

The main factors affecting human skin detection during drone use were the distance between the human target and drone lens [23] and the percentage of illumination directed at the target during a particular disaster [24]. The distance between the drone lens and the human target directly affects the captured video quality (spatial resolution is increased by reducing the distance and vice versa), then transmitted to the software environment to detect casualties in the disaster area. A test on a human target using a DJI Mavic mini 2 drone for three different distances was conducted, Figure 7, where the distances were respectively 8m, 6m, and 4m.

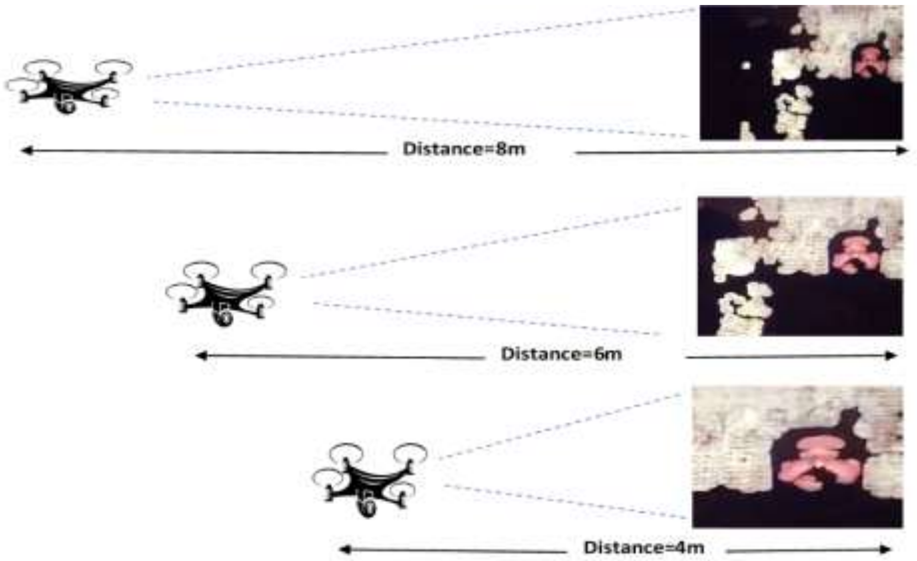

Figure 7: Distance changing between drone and target

The distances may be higher in the real environment to detect the infected using skin detection technology. However, low-flying can detect the injured more significantly, and small drones can fly at low altitudes, especially when their use is combined with virtual reality technology [25].

The peak-to-noise ratio was a metric for comparing image resolutions [26]. Table 2 shows the results value of frames drone captured at three distances. The results showed that the PSNR value increases as the drone approaches the target, and thus the resolutions resiliency of the frame increased with the availability of sufficient lighting; these results significantly affected our scientific contribution.

Table 2: Quantitative evaluation of distance to PSNR

Distance	Resolution	PSNR
4 m	753×579	44.35
6 m	1000×933	47.71
8 m	1000×1110	49.36

3.3 HMD VR connects to the drone

The full immersive head-mounted display (HMD) given in virtual reality applications was a solid contribution to our focus in the research [27]. Where the virtual reality (VR) provides the observer who receives the drone broadcast a comprehensive and virtual view of the disaster area and also enables him to control and direct the drone with a head movement as if it is wandering in that target area to reach the survivors or the specific targets [28]. It has become common to control drones using virtual reality applications. There are versions for those planes that are compatible with head-up glasses, which can be controlled and directed through the movement of the head. Virtual reality (VR) applications can be installed on mobile phones and are compatible with working with drones. It was encouraged to build this embedded system, use HMD to support the monitor, increase its capabilities to reach survivors or injured in the disaster area, and roam it virtually within this perimeter [29]. Laboratory and field experiments were conducted, Figure 8, where the drone was controlled by virtual reality HMD through the movement of the head, and the drone lens achieved a response to the commands of the head. A virtual disaster was simulated, and the live broadcast video stream was received from the drone, using the detection of the skin to rescue survivors or injured were identified. Figure 8 was extracted from a long video describing all the experiment details. In more detail, the laboratory results were obtained in a virtual environment outside the laboratory that accurately simulated this experiment.

Figure 8: People rescue simulation in the lab.

4. Conclusion

Scientific contribution and practical experience have proven that the growing capabilities of the drone and its technological progress have given a great incentive to use in embedded systems that provide service to people, especially the process of rescuing humans exposed to damage during the time a particular disaster. As represented by (Open CV Documentation) using PYTHON Code, artificial intelligence technologies were combined with drone engineering capabilities to present robust virtual reality applications.

It was recommended to develop work environments, especially university laboratories, and train students to integrate virtual reality applications with those used in controlling drones to solve many problems that may face society. In future work, deep learning in skin detection applications is recommended to present more accurate results and provide greater possibilities in analyzing the video signal received from drones. Through practical experience, it has been observed that conscious results depend primarily on the type of drone used and people with low incomes of its lens in capturing video or images. Therefore, it is advised to use the newer drone generations with a broad vision, are more accurate in video capture, and are more stable when flying at different altitudes.

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