WHITE – DONKEY: Unmanned Aerial Vehicle for searching missing people.

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***Abstract*—Searching for a missing person is not an easy task to accomplish,so over the years search methods have been developed, the problem is that the methods currently available have certain limitations and these limitations are reflected in time location. Time location in a person search is a very important factor that rescuers cannot afford to waste because the missing person is exposed to great dangers. In people search the vision system of the human being plays a very important role. The human visual system has the ability to detect and identify objects such as trees, walls, people among others besides to estimate the distance to them, this gives the human being the possibility of moving in their environment. With the development of artificial intelligence primarily to computer vision it is possible to model the human visual perception and generate computer software needed to simulate these capabilities. Using computer vision is expected to search for any missing person designing and implementing algorithms in order to an Unmanned Aerial Vehicle perform this task, also thanks to the speed of this is expected to reduce the time location. By using of a Unmanned Aerial Vehicle is not intended to replace the human being in the difficult task of searching and rescuing people but rather is intended to serve as a support tool in performing this difficult task.**

***Keywords*—Computer Vision, Unmanned Aerial Vehicle, Search And Rescue System, Human Visual System, and Quadricopter**

I. Introduction

The search and rescue brigades aim to make relief actions immediately and adequate personnel who need the form, in the presence of an emergency. Brigade search and rescue identify and analyze the risk in their workplace also set functions for each of the members of the brigade in an emergency, search operations are always made by hunt groups of two or more brigadiers with the right equipment.

This Search And Rescue (SAR) system consists of individual elements that must work together to provide a global service[1]. The primary components are:

- A rescue coordination center to organize SAR services
- Communication within Regions Search and Rescue (RSR / SRR) and the outer SAR service.
- One or more sub-centers coordinators.
- SAR media including search and rescue units (USR / RSU) staffed with qualified personnel and specialized equipment.
- Designate a coordinator at the crash site (CLS / SMC).
- The staff mentioned above must be bilingual to better develop their activities.

Another common way to seek a missing people is employment of Search dogs, Figure 1. These kind of dogs have been the best search tools for SAR teams (search and rescue) because all dogs have highly developed senses of smell and hearing but not just any dog is useful for this activity because the dog has to be agile, fast and resist difficulties of the work done. Bloodhound breed is preferred for this activity. The search and rescue dogs are classified into two main groups, tracking dogs and air scent dogs, according to the task they was assigned.

Figure 1: Search dogs.

In addition to the search dogs today has made use of UAVs for performing search and rescue. These vehicles have the quality to cover large areas in a short time and vertical take off and landing , so they can be kept at a fixed point in the air.

II. Vertical Takeoff and Landing Vehicles

A quadricopter is an air vehicle propelled by four rotors, capable of taking off and landing vertically[2]. The quadricopters significantly reduced their size and weight, since the French aviation pioneer Etienne Oehmichen proved that it was possible the construction of theoretical helicopter with making Quadricopter Oehmichen No.2 in 1922, Figure 2. In the same year the American George Bothezat built a cuadrirrotor device but without lifting more than 5 meters above the ground, the interest in these systems was suspended for a while.

It was not until mid-twentieth century when interest in the quadricopters reemerged with projects financed by the United

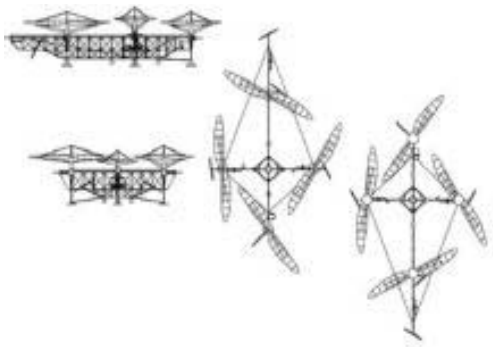


Figure 2: Quadricopter Oehmichen No.2 (1922).

States Navy, which sought the *Flying Jeep* as a means of air transport for troops in war zones, Figure3.

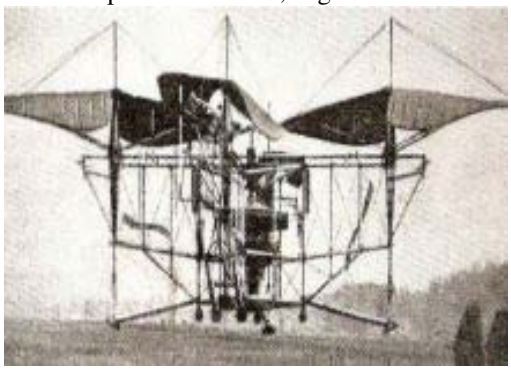


Figure 3: Flying Jeep, United States Navy.

Curtiss-Wright VZ-7 showed good maneuverability and ease of handling. The company Curtiss Wright delivered two of them in mid-1958 for testing. The aircraft performance was satisfactory, rose to 60 meters above ground level and moved to 51 km/h, but did not meet the standards of the navy and was returned to the manufacturer in 1960. That same year, Curtiss-Wright delivered another prototype X-19 aircraft. It flew for the first time in November 1963 and in August 1965 it collapsed, prompting the cancellation of the project. In 1956, another of these developments is the flight of the Convertawings quadricopter Model A, the control mechanism is much simpler compared to its predecessors, based on a differential device that balances the changes in the driving force of each rotor.

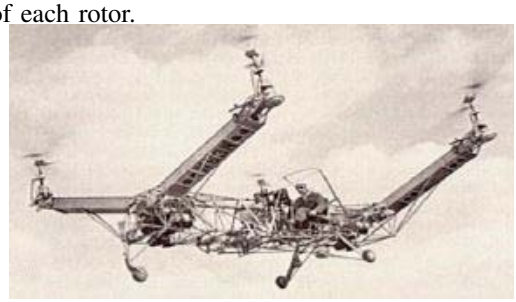


Figure 4: Convertawings quadricopter Model A.

The term UAV (Unmanned Aerial Vehicle) is common in the 90s to describe robotic aircraft and replaced the term Remotely Piloted aerial Vehicle (RPV). The interest in UAVs systems woke because a pilot aboard the aircraft is not required, allowing the use of smaller aircraft, with lower power requirements. These systems can perform dangerous missions in hostile environments or under adverse weather conditions without compromising the physical integrity of the pilot[3]. Nowadays, Searching and Rescue CENTUM company dedicated to developing engineering projects and specialty technology products, developed an unmanned vehicle with a search system in emergency situations. On the other hand, ACRE Surveying Solutions Company which is one of the main Spanish companies of topography services, leader in rental and sale of measuring instruments offers a service called thermography with UAVs for people search and rescue. Companies North Guardian UAV Services Canada and North Chile Guardian UAV Services offer real-time video and high-resolution aerial images. The UAVs are a great alternative to expensive flights with airplanes or helicopters for surveillance and rescue, they provide images for aerial photography, exploration, disaster and many other uses. Meanwhile in Mexico SkyBotica use a group of UAVs to serve in the searching work and air rescue of missing people, as well as damage assessment and mapping of natural disasters, which makes Morelos in the first bank to use the technology for this purpose. Equipping a UAV with a vision system facilitates the search and rescue of missing people and thanks to computer vision is possible to create computer algorithms that automatically carry out this task with great precision.

III. Theoretical Framework

A. Human Visual System

The eye receives light stimuli from the environment. Light passes through the cornea and reaches the pupil, the pupil contracts or expands depending on the intensity of light, if this is intense pupil contracts (miosis), if the light is dim, the pupil dilates (mydriasis), Figure 5. The Iris constriction is involuntary and is controlled automatically by the parasympathetic nervous system, the expansion is also involuntary, but depends on the sympathetic nervous system[4]. The retina contains cells called rods and cones, these sensory cells react differently to light colors and shape. The cones are concentrated in the center of the retina, while the rods are more abundant in the periphery thereof. Each cone is individually connected to the visual center of the brain, which in practice allow to distinguish two points of light separated by just a millimeter at a distance of 10 meters. Each human eye has 7 million cones and 125 million rods.

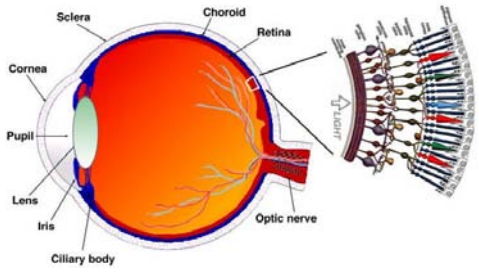


Figure 5: Physiology of Human Visual System.

Also, we want to define as Stereoscopic vision the physical and psychological faculty that human beings possess, which allows to view three-dimensional objects that are contemplated by binocular vision. On each of the retinas of both eyes, an image perspective of the same object is formed, which differ due to the different position of the views, producing the relief

effect. The distance between these two points of view, that is, the separation between the receptor organs of the human being, has an average value of 65 mm and is called interpupillary distance.

B. Digital cameras

Currently digital cameras are used to develop computer vision, because they have the properties of a digital information source: as signal to noise ratio constant and known, as well as an advanced technological infrastructure[5]. The cameras capture videos that translate into frames or pictures. A photograph serves to observe the environment and analyze it through a computer program. In a way that it can decide to perform movements to avoid obstacles, move objects, build maps, recognize objects, and others.

Figure 6: Digital Camera.

To learn how to work with images from a digital camera is necessary to know the technique used in digital photographs. This process is performed by a device called CCD (Charge-Coupled Device, device interconnected electric charges). The CCD is an integrated circuit that contains a number of capacitors coupled in a matrix form. These capacitors are light sensors of a certain frequency: the frequencies of red, green and blue which are the scheme named RGB. The CCD is composed of a matrix of a number of NxM light sensors that translate light energy into movement of electrons to cause an electric current energy.

The array of sensors is connected to a signal conditioner circuit and then to a integrated circuit that sample the signals sent by each light sensor of CCD from time to time T and then store the information in a temporary memory. Finally the memory information is sent to the software that will handle save, view or edit the captured image.

C. Computer vision

Computer vision is a branch of artificial intelligence that aims to mathematically model the processes of visual perception in living and generate computer programs that allow to simulate these visual capabilities, Figure 7.

The first attempt to solve the problems of computer vision was made by Seymour Paper in 1966. The computer vision is more complicated than most people might think. This is not the translation of lights, colors and nuances in pixels, is the translation of the pixels in abstract mathematical concepts.

Frank Rosenblatt in 1958 introduced their new algorithm, the perceptron, which is a form of a neural network[6]. Rosenblatt proved his Perceptron in the automatic classification of images. Although in research experiments, the algorithm seemed to be successful enough, it failed in field tests. Soon,

Figure 7: Visual Illusion.

and despite its natural beauty, the neural network were in disuse, although later research showed that this was largely unjustified.

After this early catastrophe, which stagnated scientific progress in artificial intelligence and computer vision, researchers focused mainly on solving image processing problem .The Image processing consist in pixel-level operations. Later in the 90s neural networks appeared again under the name of convolutional neural network. Despite its success, neural networks were still unable to perform the toughest tasks with three-dimensional objects in images without restrictions. Again, they were not favored by the community of computer vision. In the decade of the 90 and 00 was the true birth of modern computer vision. A sudden plethora of methods were proposed for dealing problems of computer vision generic stalwarts, such as object classification, object detection and segmentation, face recognition, etc. After the golden age, computer vision reached today, where it can finally begin to fulfill its prehistoric promises. Today, the modern version based on neural networks, deep learning, have the capability to classify the content of an image in a very precise way.

One of the modern computer vision approaches is the Viola-Jones algorithm [7]. This algorithm has a low cost in hardware, and consists of two main parts: cascade classifier, which ensures rapid discrimination and a trainer based on Adaboost classifiers. Viola Jones has a probability of 99.9% true positive and false positive probability of 3.33%, and in contrast to other algorithms used in methods of invariant characters,it process only the information present in a grayscale image. It does not use directly the image but instead uses a representation of the image called integral imaging. To determine whether a face is found in a image, the algorithm divides the integral image into subregions of different sizes and uses a series of classifiers (classifiers cascade), each with a set of visual features. In each classifier it determines whether the sub-region is a face or not. Using this algorithm saves considerable time because will not be processed subregions of the image that is not known with certainty that contain a face and only invest time in those subregions which may contain a face[8].

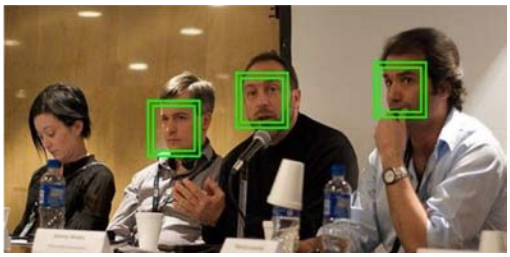


Figure 8: Algorithm Viola and Jones.

D. Principle of operation of Tetramotor

A four-engined is a six degrees of freedom system (x, y, z, pitch, roll and yaw), multivariable and tightly coupled. The main forces and moments acting on a four-engined are produced by their rotors, Figure 9. Two pairs of motors rotate in opposite directions to balance the total torque of the system[9].

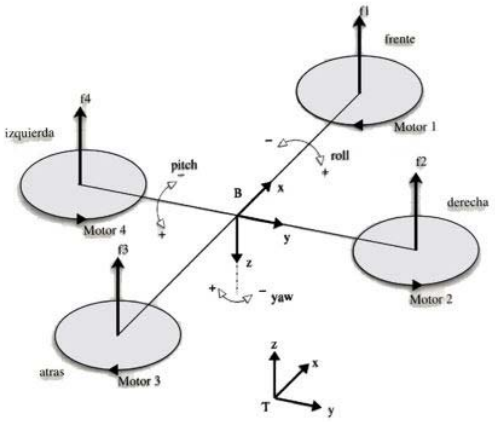


Figure 9: Principle of operation of Tetramotor.

Brushless motor:

A brushless electric motor (brushless) is an electric motor which does not use brushes to make the change of polarity in the rotor[10]. Brushless motors consist of a moving part which is the rotor, where the permanent magnets and a fixed part called the stator or casing. To make work a brushless motor is necessary to use an electronic speed control (ESC). An electronic speed control (electronic speed control or ESC) is an electronic circuit whose function is to vary the speed of an electric motor, direction and possibly to act as a dynamic brake. The ESC's are commonly used in motors electrically operated by radio control, with the variety most commonly used for brushless motors, providing a three-phase low voltage source electronically generated. An ESC may be a separate unit that plugs into the acceleration control channel in the receiver or may already be incorporated in this.

Transceiver:

A transceiver is a device that has a transmitter and a receiver that share parts of its own circuit. When the transmitter and receiver do not have common parts of the electronic circuit, it is known as transmisor-receiver. Since certain circuit elements are used for both transmission and reception, the comunicaton that provides the transceiver can only be half-duplex, which means that signals can be sent in both directions, but not simultaneously.

Microcontroller:

A microcontroller is a digital integrated circuit that can be used for very different purposes due to is programmable. It consists of a central processing unit (CPU), memories (ROM and RAM), input lines and output (peripherals), a microcontroller has the same basic function blocks of a computer. A microcontroller can be used for many applications, some of them are: management of sensors, controllers, games, calculators, sequencer lights, electronic locks, motors control. To use a microcontroller, its functions must be specified by software with programs which indicate the actions that the microcontroller must perform.

IV. WHITE – DONKEY: Unmanned Aerial Vehicle

A. General Algorithm

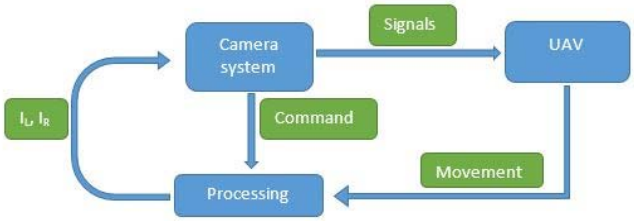


Figure 10: General Algorithm.

The proposal of this work comprehend 3 main stages, Figure 10:

1) Camera system, and Algorithm 1.
2) Processing, Algorithm 2.
3) Unmanned Aerial Vehicle, Algorithm 3.

Algorithm 1: Camera system

Input: Command, Movement
Output: I_L, I_R
1 Receive a command to take the picture.
2 Take capture of the environment that depends on the UAVs movement.
3 Delivery a left image and right image of the environment.

B. Description

After studding the different methods for object detection using techniques of computer vision and the principle of operation of the main elements that make up the UAV, is made the design and assembly of the vision system , the construction and UAV's configuration, the design of algorithms to perform image processing and design the algorithms for controlling the UAV.

Algorithm 2: Processing

Input: I_L, I_R
Output: Signals
1 Viola-Jons Algorithm is applied in I_L in order to detect people.
2 With the stereo pair images (I_L, I_R) the disparity map is calculated and stereoscopic vision is generated.
3 Telemetry is made Using stereoscopic vision in order to calculate the distance to the person from the cameras.
4 Four signals are generated from the telemetry.

Algorithm 3: Unmanned Aerial Vehicle

Input: 4 Signals
Output: Movement
1 Each received signal controls a different UAV‘s movement:
2 Pitch,
3 Roll,
4 Yaw, and
5 Rudder.

1) Capture stage: After checking the correct operation of the transmission between the camera and the receiver using Honestech VHS to DVD 3.0 SE software within MatLab software environment, certain properties of the video object are set according to our needs. Properties to set are as follows:

1) FramesPerTrigger.
2) ReturnedColorspace.
3) FrameGrabInterval.

Due to the video object always uses the same properties and for not performing the same procedure each time that cameras are used these settings are entered into a function called *configCam1* for the camera 1 and *configCam2* for camera 2 . Stereoscopic vision system is made using the new modeling and printing 3D technology in order to construct a base where the two cameras will be set, with a distance of 10cm between them, Figure 11.

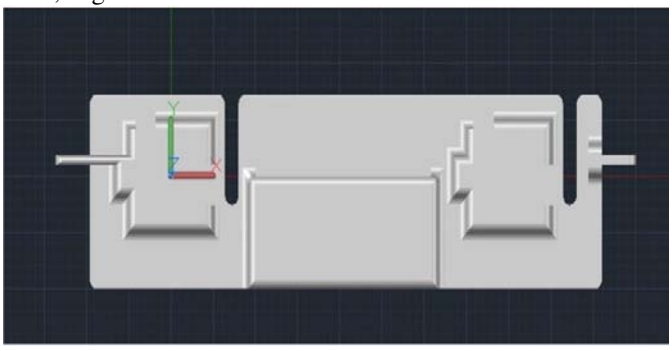


Figure 11: Stereoscopic vision system.

Now it is necesary to calibrate the cameras that make up the vision system, ie get the intrinsic and extrinsic parameters of both cameras and stereo system parameters, Figure 12. To calibrate the vision system the Zhang method is used[11], this method is already implemented in the MatLab software, so to use it simply is typed the *cameraCalibrator* command in the MatLab command window,once the calibration procedure is completed this tool returns an object with the parameters of the stereoscopic system.

Figure 12: Calibration the vision system by means of the Zhang method[11].

2) Stage processing: Once the vision system is ready, to detect a person in an image the Viola-Jones algorithm is used which is already implemented in the MatLab R2015.

3) Person and face Detection algorithm:

1) Start.
2) Set the camera 1
3) Open and configure the computers serial port
4) Take a picture of the environment and storage it in the variable I
5) Define and configure the object detector using the *bodyDetector* constructor as input the variable I and name it *bboxBody*.
6) Define and configure the object detector using the *faceDetector* constructor as input image the variable I and name it *bboxes*.
7) If the content of *bboxes* or *bboxBody* is greater than zero draw a rectangle on the image using the size and coordinates of *bboxes* also draw a rectangle using the size and coordinates of *bboxBody*.
8) If there is no content in *bboxes* or *bboxBody* send a specific character from the computers serial port
9) End.

4) Algorithm to light a LED if a person is detected, it is performed in the MSP430G2553 microcontroller:

1) Start.
2) Set inputs ports.
3) Set outputs ports.
4) Configure the serial communication.
5) If the UCA0RXBUF register of the MSP430G2553 microcontroller receives a specific character turn a LED on.
6) If the UCA0RXBUF register of the MSP430G2553 microcontroller receives a specific character turn the led off.
7) End.

What follows now is to measure the distance to the detected person, is proposed the following algorithm .

1) Start
2) Load the cameras parameters, *camStereoParams*
3) Take a picture with the right camera , storage it in *frameRigth*
4) Take a picture with the left camera, storage it in *frameLeft*

5) Rectify the stereo images *frameLeft* and *frameRigth* using the object *camStereoParams* and storage the new images in *frameLeftRect* and *frameRightRect*
6) Convert *frameLeftRect* and *frameRightRect* to grayscale and storage them in *frameLeftGray* and *frameRigthGray*
7) Calculate the disparity map between *frameLeftGray* and *frameRigthGray*
8) Reconstruct the 3D scene
9) Detect person and face in the *frameRightGray* image .
10) If a face or a person is detected, send a specific character from the computer‘s serial port.
11) Find the centroid of the detected person.
12) Find the coordinates of the *centroids* in the 3D world.
13) Find the distance to the camera in meters.
14) If the distance is less than two meters send a specific character from the computer‘s serial port.
15) If the distance is greater than two meters send a specific character from the computer‘s serial port.
16) If a person is no detected send a specific character from the computers serial port.
17) End.

5) Control Interface: Due to the complexity of design, the time it takes to create an UAV from scratch and be able to control it from a computer, it was decided to use the *kk2.0* control board, Figure 13. This card is used in various aerial vehicles, such as:

1) Tricopter
2) Quadcopter +
3) Quadcopter X
4) Hexcopter +
5) Hexcopter X
6) Octocopter +
7) Octocopter X
8) Aero 1S Aileron
9) Aero 2S Aileron
10) Flying Wing
11) Singlecopter 2M 2S
12) Singlecopter 1M 4S

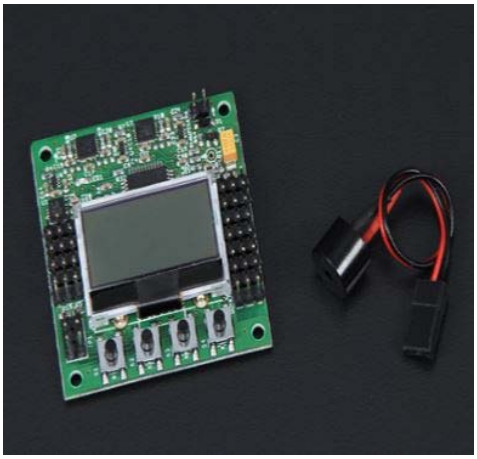


Figure 13: Control Interface.

The *kk2.0* control board has an IMU of 6 degrees of freedom that is quite sensitive, it is the MPU6050 which consists of a gyroscope and an accelerometer, this card is controlled with the HobbyKing *hk-T6A* receiver, the problem of this receptor lies in frequency because it is the same in which the cameras transmit, causing too much interference, making impossible to detect persons in a frame. The solution to this huge problem is to replace the receiver and the control circuit, so a new control circuit is used instead in order to deliver the same signals as the receiver delivers to the control board.

Chanel	Function	TH	TL
1	Aileron	1.54 mS	16.79 mS
2	Elevator	1.54 mS	16.79 mS
3	Throttle	1.02 mS	17.33 mS
4	Ruder	1.54 mS	16.79 mS
5	Aux	2 mS	16.32 mS

Table I: Measured values of each channel that the receiver delivers

From Figure 14, in Blue is the signal generated by the receiver and in yellow is the signal generated by the Microcontroller.

Figure 14: Signal generated by the receiver and the Microcontroller, blue and yellow, respectively.

Printed Circuit Board (PCB) design to generate the signals that control the UAV‘s movements, Figure 15.

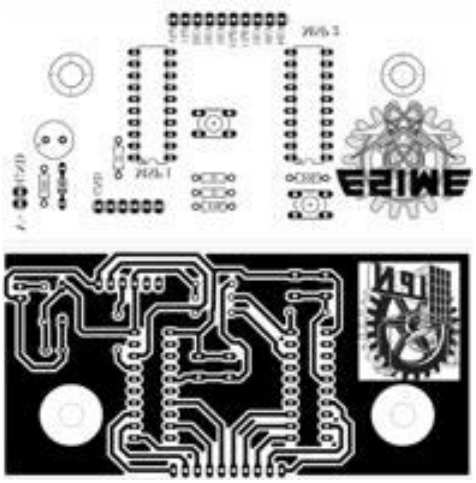


Figure 15: Printed Circuit Board of the UAV.

6) User interface: For the use of people search software be more user friendly, a Graphical User Interface (GUI) is designed with the *GUIDE* tool that the MatLab software provides. This *GUIDE* is composed of three main windows , the window 1 shows what records the right camera, the window 2 shows what records the left camera and in the window 3 the person detection process is shown, in this window the face of the detected person is shown, Figure 16.

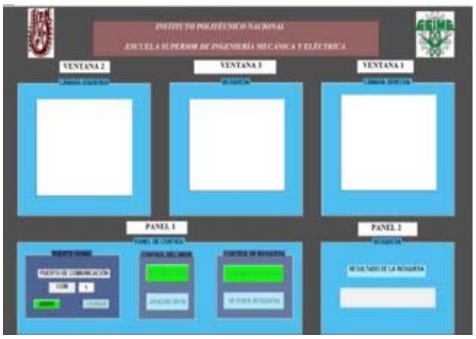
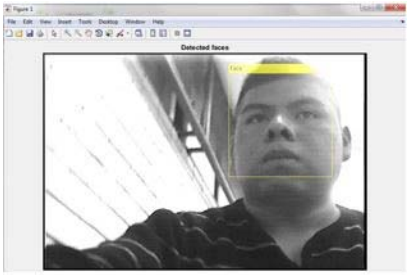
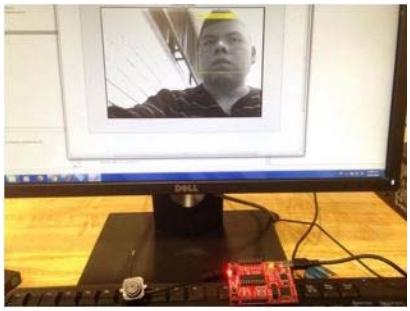


Figure 16: WHITE – DONKEY: User interface.



(a)



(b)

Figure 17: Face Detection, (a) Preview and (b) Algorithm integrated into the *LaunchPad*.

V. Results

A. Turn a LED on if a face is detected in a Image

Figure 17 shows when a face is detected in a image, a LED turns on, which is already integrated into the *LaunchPad* development tool.

B. Measure the distance to the person from the cameras.

Being ready the stereoscopic vision system this was placed focusing to a person(Figure 18), after that, the program implemented in the MatLab software is run and as a person was found in the left frame the distance to this was measured.

C. Connection to the Unmanned Aerial Vehicle

Connection and Disconnection the transmitter with the receiver on the UAV for controlling it from a computer. Figure 19 show (a) Armed or Connection Mode of the Unmanned Aerial Vehicle, (b) Safe or Disconnection Mode of the Unmanned Aerial Vehicle, and (c) Unmanned Aerial Vehicle connected and in operation.

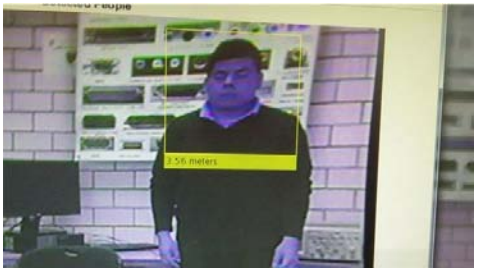


Figure 18: Measure the distance to the person from the cameras.

D. Matlab GUIDE

From Figure 20, the GUIDE in initial conditions, shows only in active state the serial port control and gives the option to introduce an ID corresponding to the port to be used. When the serial port is opened successfully, the button to power the UAV is enabled, which enables communication with this, besides the search start button is enabled too.

From Figure , in order to begin the searching the UAV begins to take off vertically and subsequently to turn on its own axis. In the central window of the GUIDE is shown graphically whether or not there is a person, besides the search panel indicates it verbatim.

Once the UAV found a person in the surroundings, it moves toward it, if the distance to the person is less than 2m the UAV stops for the security of the person found, otherwise the UAV is in progress, Figure 22. Showing the face of the detected person in the central window is made with the aim of the software operator decides whether the face of the person found matches any person reported as lost.

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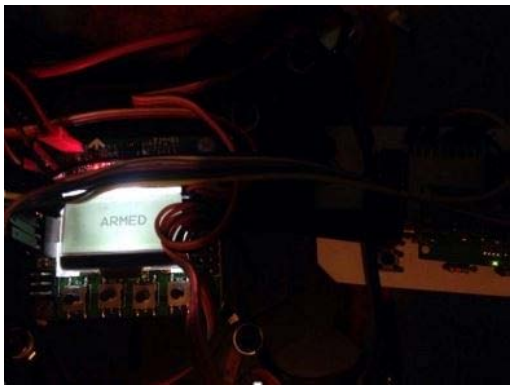

(a) Armed Mode

(b) Safe Mode

(c) UAV flying

Figure 19: Connection to the Unmanned Aerial Vehicle, (a) Armed or Connection Mode of the Unmanned Aerial Vehicle, (b) Safe or Disconnection Mode of the Unmanned Aerial Vehicle, and (c) Unmanned Aerial Vehicle connected and in operation.

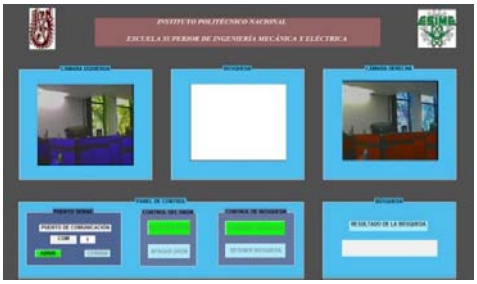

Figure 20: GUIDE in initial conditions.

Figure 21: GUIDE in initial conditions.

Figure 22: When the UVA found a person in the surroundings.

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