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An Image Acquiring, Processing and Transfer System over Bluetooth for an Educational Robotic Platform

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***Abstract*— This paper describes a simple low-cost solution for image acquisition by means of a wireless wide-band communication. In order to provide the capability of transporting images in real time, the novelty resides in the image transfer system over Bluetooth that has been developed to allow machine vision.**

This work is a part of an ampler project; the development of an educational rover equipped with a robotic arm called VANTER, Spanish acronymous of «Non Crewed Autonomous Vehicle Specialized in Recognition». It is a prototype being developed by the authors of this work and it is aimed to work in automatized and guided mode.

The primary motivation for this work come up from the Department of Electronic Engineering, Computer Systems and Automatic at the University of Huelva (Spain). The main goal is to build a general purpose robotic platform in order to develop, practice and test remote control strategies, signal acquisition and machine vision for educational purposes.

The research group of this work has introduced several new developments to the prototype and the process has been divided in several phases of design, assembling and hardware programming.

Firstly it implies the implementation of a platform fitted up with traction DC motors and position sensors, a robotic handle arm with several free degrees, a master-slave microcontrollers' network based on the I2C bus, a point-to-point UHF communication for telecommands & telemetry data, and finally a virtual interface to control an image acquiring, processing and transfer system over Bluetooth.

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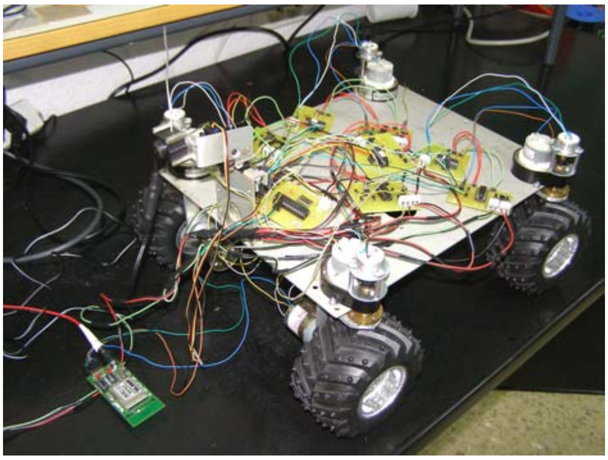

Fig. 1. Robotic platform devoted to test and research remote control strategies and machine vision of the mobile robot prototype called VANTER.

I. Introduction

MACHINE vision is an implementation of technologies and techniques for image acquiring and processing based on a camera, computer and mechanic systems. In the early 50 & 60 decades of the last century appeared the first vision systems thanks to the born of the computers. In the following years the main objective was improve the systems due to the space carrier [1], but until the 70 & 80 decades they were not introduced in laboratories or industries [2].

Mobile robots are able to do more today than ever before, thanks to recent technical advances and cost reductions [3]. They are often used in situations where low dimensions (such us gas pipes or mines) as much as dangerous environments (radioactivity, toxicity, etc) forbid the human presence.

The potential of robots to accomplish such tasks depends on how well they can locate and interact with objects in their environment [4, 5]. When a mobile robot moves in a low structured environment, it is necessary fit it up with perceptual capabilities. Machine vision and image processing are very broad areas of research, and there are an ever-growing number of creative and useful methods for retrieving information from images [6].

We have not located any citation about the use of vision software based on virtual instruments (VIs) like LabVIEW and Bluetooth applications, but there are slight references about some of these keywords. In example, a basic dynamic library for CCD-based cameras was firstly developed for VIs [7] and another works with Active-X objects just made an image acquisition but limited in functionality and control of its properties [8]. A client/server application was implemented for a distributed system applied to industrial environment where images captured from a camera were transferred over a TCP/IP network [9]. In the medicine area can also be found interesting developments applied to SPECT systems where an IP camera is used to send images on-the-fly through a TCP connection [10]. A remote data implementation using Bluetooth was developed to acquire data from a sinusoidal waveform [11]. In the framework of robots a Bluetooth communication was developed as a virtual web laboratory for engineering education [12] and finally, a remote image acquisition through Bluetooth was applied to the world's smallest and lightest micro-flying robot [13].

II. Robotic Platform

A. Review Stage

From the beginning of the project, the development of the robotic prototype has been divided in different phases of design, assembling and hardware programming. These stages have successfully reached:

1) The mechanic design of a platform fitted up with DC motors for linear and angular movements, attached with optical encoders and potentiometers for positioning [14] (see figure 1). In that sense, the designs of the wheels have been adapted to obtain a more robust system and the electronic hardware have been migrated to printed circuit boards (see figure 3).
2) The mechanic design of a robotic handle arm with five free-degrees equipped with forceps able to pick up little solid samples from the ground [15].
3) A master-slave microcontrollers' network based on the I2C bus to control the robotic platform and the handle arm [16].
4) A virtual interface devoted to control remotely the hardware implementation by means of a point-to-point UHF communication. In this case, new enhanced functions have been implemented in the protocol between the remote visual interface and the microcontrollers' network that consider a new set of telecommands and telemetry packets.
5) A pad [17] integrated in the virtual interface has been implemented as a new way to control the rover's movements in real time. The virtual instruments open a reference and initialize the pad device to acquire data from the buttons and analog joysticks. When data are available, the application appends a picture that represents a polar graph with the degrees, axis coordinates and module values as shown in the figure 4. After assembling the data into packets, they are ready to be transferred to the rover side.

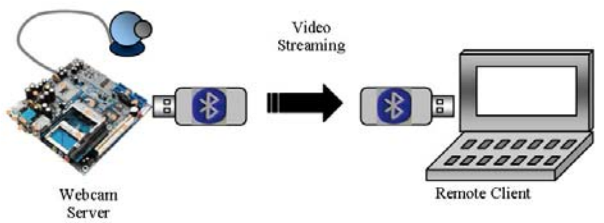

Fig. 2. The complete mobile robot/camera system consists on a webcam, a mini-ITX mainboard and two Bluetooth adapters for client and server machines.

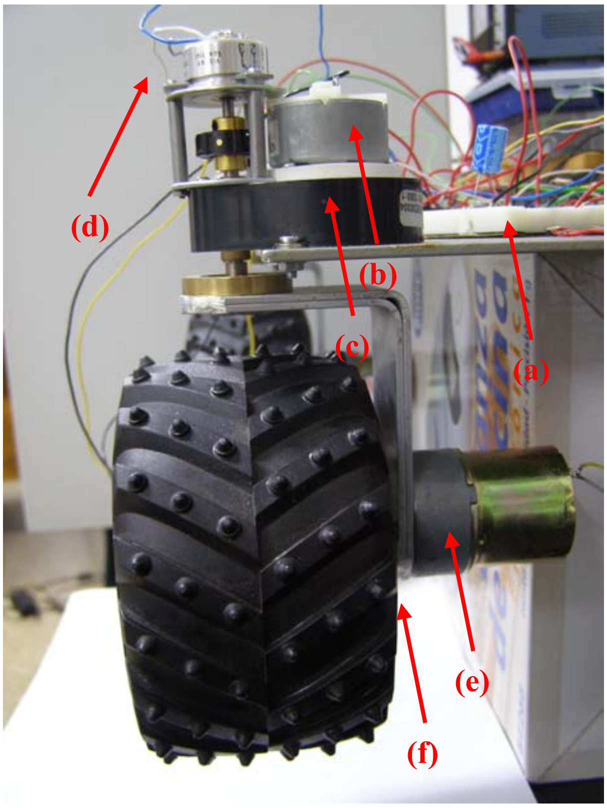

Fig. 3. This picture shows a wheel axis attached to the platform. It is controlled by each microcontroller (a) that provides signals to control the angular position (b). The DC motor is coupled with a reduction engage (c) which position is read by a potentiometer (d). The motor (e) turn at 120 r.p.m and the optic encoder (f) obtain the position.

B. Camera system

A simple low-cost solution for image acquisition using virtual instruments and USB cameras has been utilized in this project. The developed application provides the ability to make an image stream acquisition with NI-IMAQ for USB Cameras [18] and IMAQ Vision [19] for LabVIEW®.

A low resolution USB camera is mounted aboard the rover and it takes panoramic images around (see figure 2). To acquire and analyze shapes into the pictures, 320x240 pixels of resolution is enough for this purpose but other configurations can be selected. Besides, a higher transfer rate and throughput is obtained with a less size of file. The cameras may operate at various resolution and frame rates depending on the camera capabilities and its properties (automatic gain, contrast, saturation, bright, blink control, light & colour compensation, etc) can be set up using the camera manufacturer driver and Direct Show functions under Windows Operative System.

C. Bluetooth System

The wireless modules used for this project were Bluetooth v2.0 class I USB adapters [20, 21] with enhanced data rate up to 2,1Mbps. The maximum transmission range is approximately 200 meters with a low power consumption of 100mW. The main features of these devices are that work in the 2,4Ghz license-free Industrial, Scientific and Medical (ISM) band. The Bluetooth specification allows authentication and encryption methods by default, besides it implement Forward Error Correction (FEC) and Automatic Repeat reQuest (ARQ) techniques.

When Bluetooth modules come together, they form a Personal Area Network (PAN) automatically, where each computer that contains a Bluetooth module is configured as either master or slave. Since each Bluetooth module has a unique device address, the master can initiate the establishment of a link with the slave, and the slave responds to the master.

The LabVIEW Bluetooth VIs [22] uses RFCOMM, which is a simple transfer protocol that emulates serial communication by means of the Winsock interface for Windows Operative Systems. The Bluetooth libraries can set

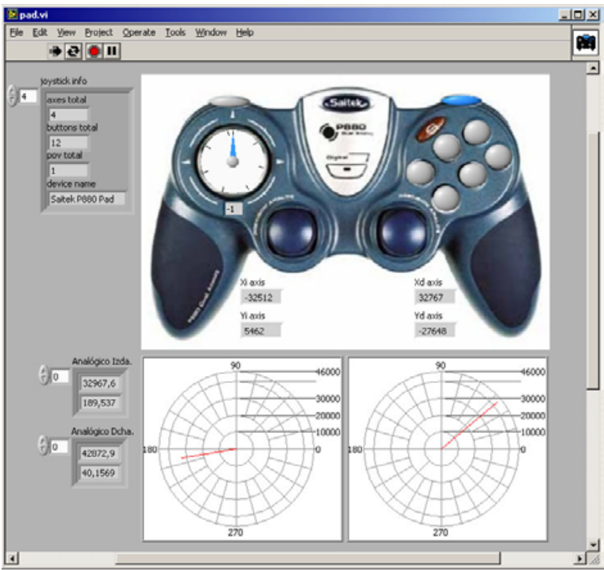

Fig. 4. An application to control the movements of the rover by means of a pad is shown in this picture. Data from buttons and analogue joysticks are available after assembling into packets.

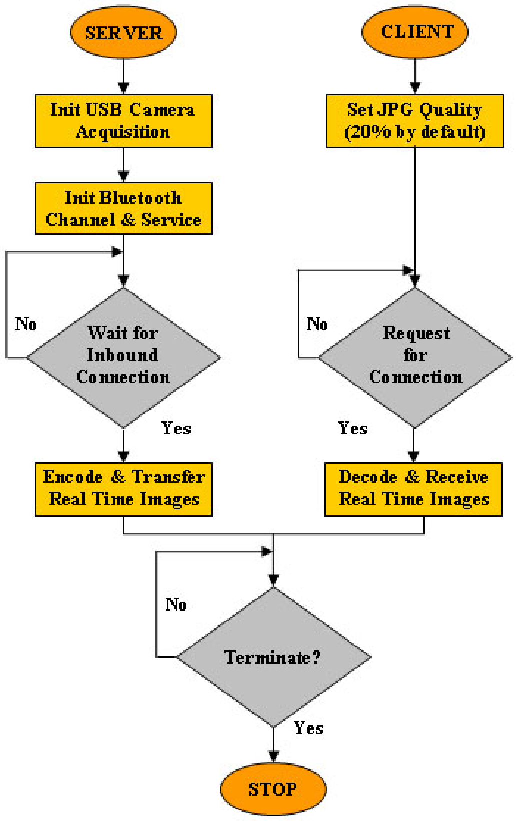

Fig. 5. The flowchart shows the Bluetooth communication link. Server and client sides start separately processes and accomplish the connection for transferring images.

the discoverable and connectable status of the local Bluetooth device. This utility provides a double security function; firstly it determinates whether to allow other Bluetooth elements to discover the device and second, it determines if the device allows other Bluetooth elements to pair it.

The Bluetooth server uses the Service Discovery Protocol (SDP) to broadcast the availability of the services that the server contains and listens for inbound connections. The client creates an outbound RFCOMM connection to the server and once the client and server connect to each other, they exchange data until the client or server terminates the connection.

D. Image Transfer System

The graphical application developed makes use of a client/server configuration equipped with two Bluetooth modules and a USB camera (see figure 5). The method uses a JPEG algorithm to convert the image stream captured from the camera [23] to an array of data and it transfers the string across the communication link. As the same way, the method can quickly uncompress the data in the remote client and convert the array to an image able to display. Server and client applications are separately explained in the following sections for further information.

E. Image Server

The application on the server side creates a list of available USB cameras found on the system that can be initialized. Once the list is given, the initialization session is accomplished and any USB camera listed can be selected by its corresponding index. The camera starts a continuous acquisition mode with the addition of a loop structure and the images can be continuously recorded and processed to display the camera output.

The method searches for all locally Bluetooth devices that are installed and it returns the Bluetooth address of the specific devices. The process creates a service for the Bluetooth server and it returns a Bluetooth channel that uses to listen for inbound client connections. The server waits for the client to accept the connection requested and once the connection is accepted, it is ready to send the images.

Before sending the images across the network, the application encodes the jpg image stream by setting the compression ratio, converts each image to an array and transfers each data by flattening the ASCII string.

The front panel window running while the image stream is sent is shown in figure 6.

F. Image Client

When the client application starts, it automatically requests a connection to the Bluetooth server, for so the unique Bluetooth server address and channel must be previously configured.

Once the connection with the server side is accomplished, the client selects the quality ratio of the images that wants to receive and it request the compression ratio to the server. After this, it is possible to read the data on the channel specified and cast the data into an ASCII representation unflattening it. The procedure acquires the amount of data to read and once the jpg image stream arrives, it is decoded and passed to the window to display.

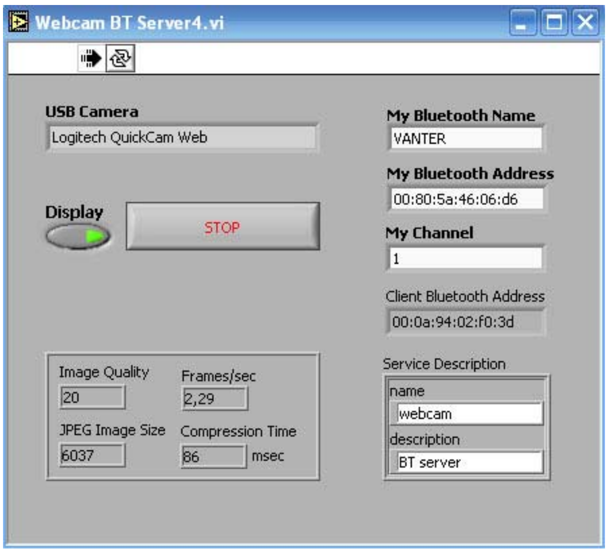

Fig. 6. Front panel of the virtual interface on the server machine. The camera listed grabs the images and send them over the Bluetooth channel with the compression desired.

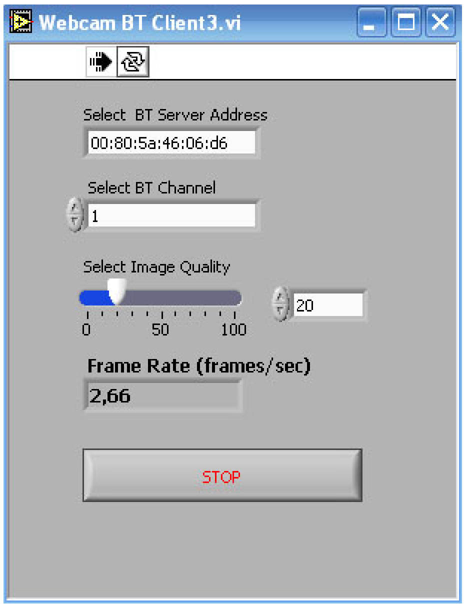

Fig. 7. Front panel of the virtual interface on the client machine. The video stream of images is requested with a specified compression rate.

The application sends a confirmation to the server to make sure that the server and client are in synchronization, so error checking in the loop will stop the program if a connection error occurs.

Either server or client that terminates the application sends the corresponding signal to the other side to abort the process. By means of a virtual stop button on the front panel (see figure 7), it is possible to close the Bluetooth network connection correctly.

III. ANALYSIS

The transfer speed across the Bluetooth link depends on the speed of the interfaces, the compression quality and the radiolink traffic. Compressing images takes processing power, and the faster you can compress the images the faster you can begin to send them across the wireless network.

An analysis of the relation between the compression ratio and several features as the compression time, the jpg image size and the frame rate has been studied for this method. The video stream of jpg images taken for the analysis has low movement and quasi-static background. A total of 100 samples per quality compression in a survey from 0% to 100% have been collected and the results can be seen in the following charts (see figure 9). There are three different lines represented in the graphics: maximum value (blue), median value (pink) and linear or exponential regression (black).

The method uses a JPEG algorithm to compress the image to a binary string. The compression quality can be chosen between 0% (highly compressed and it looks very poor as shown in figure 8) and 100% (uncompressed and it looks exactly the same as the original). An optimum visual result can be obtained with a compression set up to 20% as shown in the figure mentioned.

One of the main aspects related to the processing power and the time to relay images over the Bluetooth channel is the size of the jpg file to transmit. As shown in the figure 9, these values vary between 2Kb-55Kb.

The JPEG algorithm achieves a compression time between 70-200 msec per image on the server machine. The figure 9 shows how the compression time grows highly when the compression quality is nearer to the original image (typically 90%).

The frame rate decreases inversely to the quality compression and the size of the file as shown in the third chart. It is important to note that the ratio varies between 11-1,5 frames per second.

As resume, we can check in figure 9 that a good quality image (from 90%) increases highly the size of the file. Its corresponding compression time is 130 msec with 16,5 Kb of medium size and 2,3 frames/sec.

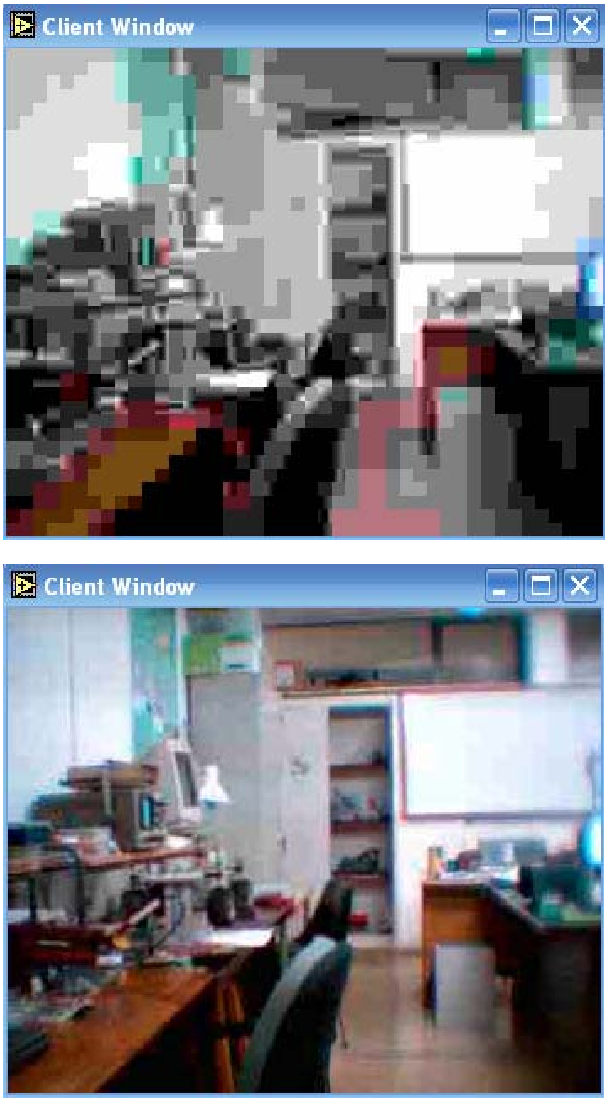

Fig. 8. The results after applying the quality compression to the images are shown in these two pictures. The upper image shows a quality ratio of 0% where a high pixilation can be noted. The second image shows a quality ratio set up to 20%.

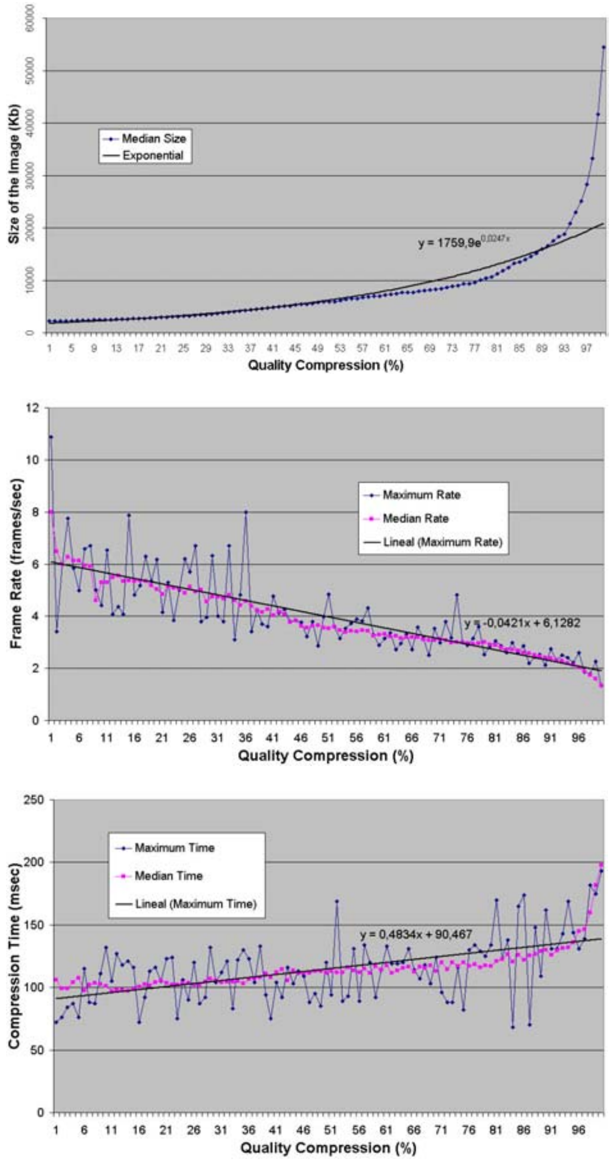

Fig. 9. The graphic charts show above the size of the jpg file, compression time and frame rate related to the quality compression selected by the client system.

IV. Educational Purposes And Discussion

During the development of the project VANTER, the rover is being noted as an excellent platform for training and testing remote control strategies, signal acquisition and processing techniques. This how-to supposes a scene where undergraduate engineering and Ph.D. students are working and improving their knowledge.

The reason is that all developments are made by the research group of the project: hardware (mechanic structures, joints, DC motors, sensors, electronic devices, etc), software (C language and virtual instruments) and the analysis tools (monitoring of packets, network activity and statistic data).

Finally, this work has utilized very low-cost solutions that can be used when time and cost provide tight constraints on a hardware and software design.

After reviewing the experience obtained and the analysis of the image transfer system over Bluetooth, there are several items to be improved. The way to acquire images using a low-cost USB camera has pros and cons [24]. First, the advantages that can be enumerated are:

1) This solution can be used by anyone using low-cost hardware along with LabVIEW software.
2) This solution is highly mobile, since USB cameras can be used nowadays on most computers and laptops.

By other hand, the disadvantages are:

1) There is typically lower resolution in CMOS cameras than in CCD cameras, although adequate for the present purposes.
2) The image acquisition via USB may be too slow for some applications. In fact, for the solution described in this work, it supposes a low frame rate as shown in the analysis section. Acquisition via USB is the main inconvenient for an optimum throughput. The image acquisition speed depends on the capabilities of the camera and the frame ratio is directly related with the camera vendor driver.

In that sense, any serious application in vision should be considered a wider view of hardware capabilities, especially for those applications requiring high resolution, high throughput and large data transfers which are enabled by image acquisition boards.

Thanks to the last results obtained, we are currently developing new enhanced functions related to this work and we expect to obtain early other camera features as zoom or motion controls (that are very useful for our purposes). Also, a function able to select so many cameras aboard the rover as needed provides a better interaction with its environment.

V. Conclusion

In this work we describe a low-cost solution for image acquisition via a wireless wide-band communication. In order to provide the capability of transporting images in real time, the novelty resides in the image transfer system across to a Bluetooth network.

This prototype is a step in the development way of a mobile robot equipped with a handle arm called VANTER, Spanish acronymous of «Non Crewed Autonomous Vehicle Specialized in Recognition». It is a prototype being developed by the authors of this work and it is aimed to work in automatized and guided mode.

VANTER is being developed with a double objective: (1) to serve as multi-platform for real testing of control strategies (remote or not) devoted to machine vision and signal processing, and (2) once be ready, it will be a robotic vehicle doted with open standard systems, with application in areas where dimensions as much as hard environments (radioactivity, toxicity, etc) prohibit the human presence.

Due to the motivation of this work, the project is targeted to educational purposes, where undergraduate engineering and Ph.D. students from University of Huelva (Spain) are training and improving their knowledge.

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