FPGA Board Implementation of an Color Tracking Mobile Robot System

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Abstract. This paper presents an application of CMOS camera module with monochromatic-based real-time object tracking system implemented on an FPGA. The system architecture was implemented using VHDL and Digilent Nexys2 board. The tracking process of mobile robot system uses a color classification method. It is shown that CMOS camera module based real-time object tracking system on FPGA circuit presented can track a solid color object in a scene when it receives input of a digitized PAL/NTSC stream.

1. Introduction

This CMOS camera module is color detection and in the having purpose a color classification. A common requirement in the field of color sensing is that of color identification, or sorting of objects by color [1]. Typically this type of application is simpler than a general-purpose color measurement application, since all we are interested in is identifying which of a predefined list of categories a color belongs. The OV7670 is an RGB color sensor capable of making high-resolution color measurements using the three values obtained from its red, green, and blue sensors [2]. For this application we will use the OV7670 to perform what color classification, or the matching of an unknown caller to one of a set of known colors [3]. This technique can be used in applications such as color detection robot.

2. System Overview

The attached image sensors collect data from the surrounding world and send it to an FPGA board. The FPGA embedded processor will control the sensors and processes the measured values. In order to quantify a color, we need to use one of the several color specification systems that have been developed for this purpose. For our purpose, a convenient system to use is hue, saturation, luminance (HSL). Due to the fact that human color vision is achieved in part by three different types of cone cells in the retina, it follows that three values are necessary and sufficient to specify any color [4]. The now CMOS camera module outputs color information in terms of red, green, and blue (RGB) values. Fig. 1 shows the system structure. These three values...
can be thought of as coordinates of a point in three-dimensional space, giving rise to the concept of color space. Hue, saturation, luminance (HSL) is one such color coordinate system, or color space, and is convenient for use in this application for a pair of reasons [5]. Finally, the software implementation was performed using the VHDL language program.

3. Hardware Design and Modules

3.1 Hardware Overview

The Nexys2 board is a complete, ready-to-use circuit development platform based on a Xilinx Spartan 3E Nexys2 FPGA in Fig. 2. Its on-board high-speed USB2 port, 16Mbytes of RAM and ROM, and several I/O devices and ports make it an ideal platform for digital systems of all kinds, including embedded processor systems based on Xilinx’s MicroBlaze. The USB2 port provides board power and a programming interface, so the Nexys2 board can be used with a notebook computer to create a truly portable design station [6].

Fig. 2  Digilent Nexys2 board structure.

The Nexys2 board provides for two-row 6-pin Pmod connectors that together can accommodate up to 8 pins Pmods. The four 12-pin connectors each have 8 data signals, two GND pins, and two Vdd pins. The Pmod connectors are labeled JA (near the power jack), JB, JC, and JD (nearest the expansion connector). Pinouts for the Pmod connectors are provided in Fig. 3.

3.2 CMOS Camera Module

This camera module is a 0.3 Megapixel (640 × 480) CMOS Camera Module based on OV7670 image sensor from OmniVision [7]. The OV7670 provides full-frame, sub-sample or windowed 8-bit images in a wide range of formats, controlled through the
Serial Camera Control Bus (SCCB) interface. This product bears an image array capable of operating at up to 30 frames per second (fps). All required image processing functions, including exposure control, gamma, white balance, color saturation, hue control and more, are also programmable through the SCCB interface.

**Color classification by hue:** A common task in color sensing is to identify an unknown color as falling into one of these general categories. As previously mentioned, the three photo-sensing elements in the OV7670 provide such a set of three signals in the form of R, G, and B. The three elements have spectral responses weighted in the red, green, and blue portions of the spectrum, respectively. While useful in performing color comparisons, monitoring color consistency, or performing color matching using a lookup table, these values are not very useful from a human-readable standpoint, as hue is not readily apparent upon inspection of a set of arbitrary RGB values.

HUE is associated with the dominant wavelength of a color, and is described by standard color names such as red, yellow, green, cyan, blue, and magenta. Saturation describes the degree of colorfulness a color becomes less saturated as it becomes more gray or white. Luminance describes the brightness of a color as luminance decreases, a color of a given hue becomes darker or darker.

**CMOS camera module experiment:** The camera has to the used pins is general power, ground pin, RGB video output 8 bits pin, vertical sync output pin, HREF output pin, system clock and pixel clock pin and others pins. The RGB video output D0 through D7 pins from to connect JC0 through JC7 of the Nexys2 board. Fig. 2 shows the system structure. Also another control pin connects to JA2 through JA7 of the pod. But camera from two data we have used a serial port to connect an LCD display. The LCD display used to the make for the image analysis and a color detector in classification. Fig 4 show for the CMOS camera connected structure

![CMOS camera module connected to Nexys2 board PMOD](image)

**3.3 Touch Screen Display**
3.2 inch TFT LCD module integrated a Himax HX8347-A TFT LCD controller and DS7843 compatible touch screen controller as well as an SD card cage. It is suitable for embedded systems which require display high quality color image or video with interactive control and storage purpose. The module interfaces to microcontrollers via a 2x20 pin 2.54 dual row pin header interface, can easily be connected any microcontroller or FPGA and DSP. We have tested OV7670 module and 3.2 inch display module with a XC3S500 embedded microprocessor. We have 3.2 inch display module using FIFO pins. That is generally a power, ground, serial interface and control, hardware setting, dump driver interface pins.

4. Conclusion

This paper presents an application of CMOS camera module with monochromatic-based real-time object tracking system implemented on an FPGA. A camera module is connected to Nexys2 board with some simple processing of RGB values, OV7670 can be applied to reliably determine the color of LED and other colored sources by calculating the hue value, and then sorting according to hue. For just a few colors widely differing in hue, absolute hue sort ranges can be set at design time and used reliably. For organizations that must distinguish from several hues, or among similar hues, possible known values should be sampled (measured), and stored by the system. Then during test, the best match of an unknown sample can be seen among the known possible hues. The hue method only works well, however, for highly saturated color sources.

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