The Robot Builder

Volume Eleven Number Six June 1999

Notices

- Introductory Mobile Robotics Class - 10:00AM - 12:00PM
- Business Meeting - 12:30 - 1:00
- General Meeting - 1:00 - 3:00

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Inside this Issue

Inside the Gameboy Camera "Eyeball"

by Arthur Ed LeBouthillier

Introduction

Nintendo, the company that makes such entertainment machines as the Nintendo 64, also makes the Gameboy, a small handheld entertainment system which accepts a wide array of different game cartridges. It has proven to be very popular over the last several years. To accompany the Gameboy, Nintendo released the Gameboy Camera, which is a small eye-ball sized camera mounted on top of a game cartridge with an optional printer. When plugged into the Gameboy, the camera takes medium-resolution pictures of 128 X 123 pixels and supports a wide variety of graphic processing capability with the ROM chip included in the camera cartridge.

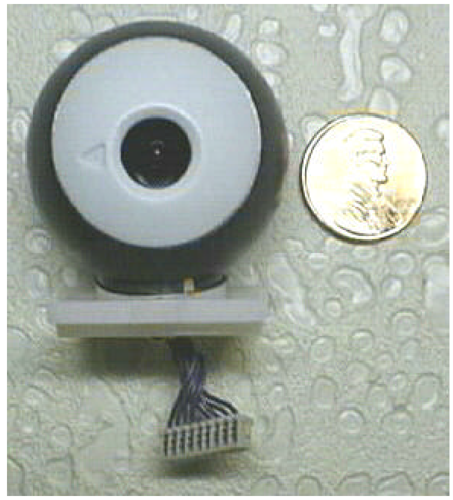

Figure 1 - Gameboy "eyeball" camera

The Gameboy Camera is based on the Mitsubishi M64282FP Artificial Retina, a single-chip CMOS imager chip with built-in image processing. Mitsubishi calls the chip an artificial retina because of the ability to perform such image processing functions as edge enhancement just like it is believed that the human retina does. Included in the chip are the pixel array, the processing functions and the logic control functions. Because of its design, it can be interfaced to a microprocessor which has an analog-to-digital converter without any additional active components. The only additional parts that may be required are biasing resistors to ensure that the analog video output is within a suitable range for the A/D converter.

This chip has lots of potential for robotics hobbyists who would like to add vision to their robots because it is readily available by removing the camera from the Gameboy Camera cartridge (available for about $50.00 at toy stores) and because it is easily interfaced to most popular microcontrollers which have built-in analog-to-digital converters.

The Mitsubishi Artificial Retina Chip

At the heart of the Gameboy camera is Mitsubishi's Artificial Retina Chip. It is a 16-pin clear-plastic IC and operates from a single 5-volt power supply. The chip provides seven image-processing functions including the positive image, the negative image, a couple of 1-D filtering modes and two 2-D filtering modes for edge enhancement and edge extraction.

Figure 2 shows the block diagram of the chip. The chip is controlled with a few 5-volt level logic signals and outputs an analog voltage on pin 14, Vout. The main clock signal is XCK which Mitsubishi specifies as being a maximum of 500 KHz although they don't specify any minimum. With a 500 KHz clock, the chip outputs about 30 frames per

(see Eyeball on page 5)

The Battling Bots are Coming and they're hungry

R. Colin Johnson
EE Times May 17, 1999

Lausanne, Switzerland - A "live" action battle of the bots will be fought here in September as the culmination of a competition now under way in cyberspace among programmers and their automatons.

Robot competitions abound in engineering circles. But in the Artificial Life Creators Contest that kicked off last month under the sponsorship of Cyberbotics S. A. (Penthalaz, Switzerland), programmers will create code that will be used both for jousting in cyberspace and for driving real Khepera robots - 50mm diameter sensor platforms - in competition. The live action showdown is scheduled to take place at the European Conference of Artificial Life here September 13-17.

Using Cyberbotics' Webots simulation software, competitors are battling it out now for the dominance of cyberspace. The current segment of the competition is scheduled to run continuously from April 15 to June 30, in preparation for the September's face off. Webots is available for a variety of platforms and can be downloaded free from www.cyberbotics.com/contest.html#DOWNLOAD.

Robot pairs compete to outlast each other by navigating a maze to find randomly distributed "food" dispensing stations. Cyberbotics has created a virtual version of the real maze that will be set up in Lausanne. Each robot starts the contest with the same amount of life force, which dissipates over time. the robot must search for food-dispensing stations to replenish its life force.

In competition, dueling robots are simultaneously set loose at random locations within the maze. The bots learn to recognize landmarks that lead to the food stations. The stations are green when full, and the robots "feed" by walking up to them. After feeding, a station turns red while it "recharges", a process that takes progressively longer each time it is carried out.

Eventually, one of the robots starves, and the survivor wins the round. the champion will be the robot with the highest number of wins at the close of the competition.

The winner of the online competition, in addition to cash awards, gets free admission to the September conference and a 10 pack license for the full version of Webots. The winner of the live competition will receive the grand prize: one of the Khepera robots that will fight it out at Lausanne.

The robot, developed at the Ecole Polytechnique Federale de Lausanne as a research and teaching tool and commercialized by K-Team (Preverenges, Switzerland), is a 50 mm diameter x 30mm high sensor platform with three wheels, two of which are powered by separate stepper motors. Its brain consists of a Motorola 68331 processor with 256 kbytes of RAM and 512 kbytes of ROM. Its standard sensor turret houses eight infrared proximity sensors, which can run untethered for about 30 minutes from on-board batteries.

Optional add-on turrets provide a gripper "hand" or other sensors. One sensor includes a micro-sized video camera, another a linear 64 pixel vision array and still another a general purpose I/O extension module for custom input. A radio communications beacon can also be mounted atop the Khepera for untethered remote operation.

For the contest, the Khepera will be equipped with a color version of the video turret, as well as the standard array of infrared sensors. In all, it will accept inputs from eight infrared sensors, equally spaced around its circumference, as well as from the forward facing 80x60 pixel color video camera.

Sony to Give Aibo Entertainment Robot Test Run

Yoshiko Hara
EE Times May 17, 1999

Tokyo - Using a cyberspace only sales effort, Sony Corporation will test market in June a home entertainment robot based on its proposed Open-R platform. With a price tag of $2,500 and a limited run of 5,000 units, all the robots are expected to be sold by month's end, many to competitors and software developers.

In making the announcement last week, Sony said it had set aside 3,000 of the first models for the Japanese market and 2,000 for the United States. A motion editor kit, which lets "power users" program original motions for the robot on a Windows PC, will be offered simultaneously. Delivery will begin in July.

"This is a kind of test marketing", said Tadatoshi Doi, a corporate vice president and president of the Sony Digital Creatures Laboratory. "We decided on a number that would allow us to have good control over our test marketing".

After analyzing the first model's reception, Sony plans to begin volume production. A second model, they suggested, could appear this year at the earliest, though Sony has not discloses the marketing plan for future models.

The robot is named Aibo, short for artificial intelligence robot. Aibo means partner in Japanese.

Aibo uses Memory Stick as a removable media and has two more joints than the prototype announced a year ago. Its total of 18 joints is powered by 18 motors to express emotion and ensure smooth movement.

The robot complies with the Open-R architecture that Sony proposed last June as the platform for entertainment robots. Aperios, the real time operation system, drives the Open-R bus, which has a 10 pin connector. Two of those pins are dedicated data transfer at 12 Mbits/second, one pin is for a 12 Mhz clock, three pins are for a 3.3V 1A power supply ;and four pins are for a 5V 2A driving power supply. In addition to a PC card, the architecture now supports MemoryStick.

"We want to grow the entertainment robot market [to the size] of one independent industry. The industry could grow larger than the PC industry", said Doi. "But Sony alone cannot grow the robot to an industry scale. So we decided about three years ago to make the platform open and to invite a large number of participants".

Noting that the CD format was completely open, Doi said that was the key factor in its quick launch. "We expect a quick take off for the robot by proposing an open Open-R". But Sony has not presented the Open-R architecture to other manufacturers, despite numerous inquiries after the prototype announcement, Doi said. Sony plans to license Open-R after it introduces a volume sale product and has completed the format.

Aibo packs a 64 bit MIPS RISC processor, 16 Mbit memory, 180,000 pixel CCD image sensor, microphone, speakers, and sensors of temperature, distance, acceleration, angular velocity and touch recognition.

Outside vendors supply the CPU, while two chips for signal processing and interface were home grown and dedicated by Sony to the robot.

A Simple Laser Range Finder

Tom Thornton

Background

One traditional method of range finding is based on triangulation. To use triangulation, you must know the baseline distance between the light source and the sensor, as well as the angles the sensor and source make with the baseline between them. Figure 1 shows one possible configuration for a triangulation range finder.

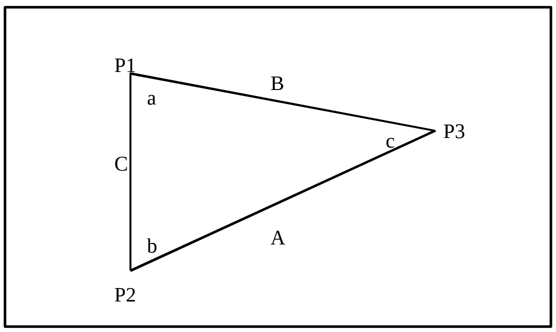

Figure 1 - Triangulation Configuration

Point P1 is the laser source, P2 the sensor, and C the baseline between them. P3 represents the target of interest. The length of the segment B (the range) can be found from measuring distance C between the source and the sensor, and the angles *a* and *b* that the source and detector make with the baseline, using the Law of Sines:

$$B = C \frac{\sin(b)}{\sin(c)} = C \frac{\sin(b)}{\sin(a+b)} \qquad (1)$$

This works well on geometry homework assignments, but turns out to be devilishly difficult in the real world because of the trouble involved in measuring the baseline and the angles *a* and *b* accurately and repeatably.

A Different Approach

In systems engineering it is often profitable to replace hardware with software. It turns out that this particular application is one of those instances.

Examination of Figure 2 and formula (5) reveals that there is a linear relationship between the distance to an object and the position of its projection on the image plane when illuminated by a spot (such as produced by a laser). We can use this observation to great advantage in simplifying the mechanics of a laser range finder.

Mount a CCD camera and a laser so that the beam from the laser passes through the optical axis of the camera (see Figure 2). I am using a Tyco kids camera that I got at Toys R Us for about $50. A better choice would be any of the Connectix Quick Cams because you wouldn't need a separate frame grabber. I got a pocket laser pointer at Harbor Freight for less than $10.

The placement of the laser with respect to the camera is completely irrelevant so long as their relationship is fixed. There is only one caveat, to detect small objects at various ranges, the laser and camera have to be relatively close together. I use a red plastic filter to minimize response to light other that the laser spot.

It is worth while to arrange things so that the laser beam crosses the optical axis approximately in the middle of the ranges of interest, i.e., if we want to measure distances from 2 to ten feet, the laser beam should cross the optical axis at about 6 feet from the image plane.

To calibrate the laser ranger, simply place a target at known distance x1 and measure the point u1 on the image plane. Then place a target at known distance x2 and measure u2 on the image plane.

Referring to Figure 2 we define the following:

$$d = x2 - x1 \qquad (2)$$

$$k = u2x2 - u1x1 \qquad (3)$$

$$N = (u1-u2)x1x2 \qquad (4)$$

(see Rangefinder on page 4)

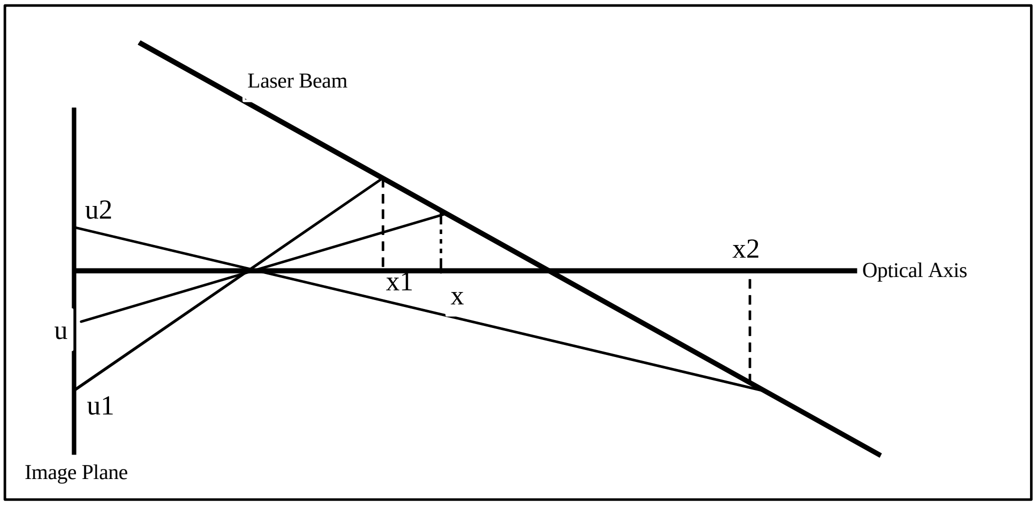

Figure 2 - Projection Lines

From the triangulation calculations shown previously in formula (1) and some algebraic manipulations it can be shown that for a target at arbitrary distance x:

$$x = \frac{N}{ud-k} \qquad (5)$$

where u is the position of the image of x on the image plane relative to the optical axis, and N, k, and d are defined as above.

To use the simple laser ranger, we locate the spot "u" on the image plane and calculate the range x directly from formula (5), simple and fast, even on a "low power" processor.

If our application needed real speed we could pre-compute a set of possible values for x in the range of interest, store those values in a look-up table and address the table by the value of u. The resolution would be limited by the amount of memory available for the table.

Summary

We have used software to overcome a nasty mechanical situation: that of repeatability of angular measurements; and in the process have produced a simple solution to range finding for small, and perhaps not-so-small, robots.

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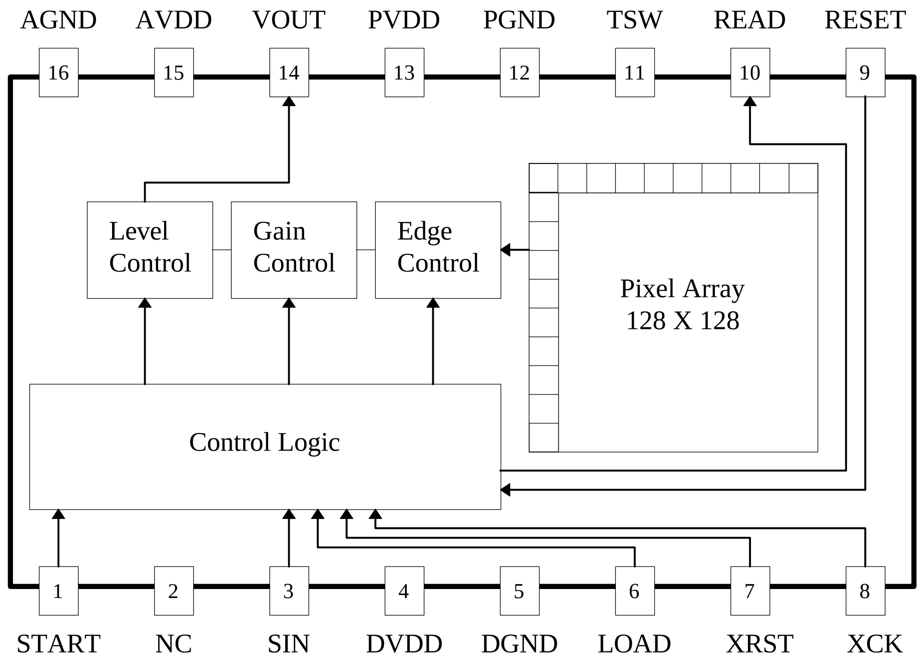

Figure 2 - Block Diagram and pinout of Mitsubishi M64282FP Artificial Retina Chip

second. However, Mitsubishi has said that the chip can be clocked at lower rates meaning that you can drive the clock at the rate of your microcontroller's analog-to-digital conversion. This is one of the neatest features of this chip; you can capture images with microcontrollers that might ordinarily be too slow to capture regular video. In some applications, you can probably minimize the memory you need by ignoring the pixels that you aren't interested in.

There are eight 8-bit registers which control all aspects of the chips operations. Data for each of these registers is shifted in serially via the SIN (serial in) synchronized with the XCK (clock) and latched with the LOAD signal. The serial data consists of eleven bits of data, three bits for the address and eight bits for the data. The registers configure image capture with the chip. Two 8-bit registers combine to form a 16-bit register designating the exposure time in clock pulses. Other registers control the image gain, the kind of image processing performed, the output voltage offset, the dark threshold, the degree of edge enhancement, and a few other parameters.

The video output signal is a 2 volt peak-to-peak value which can be offset by 1 volt in the positive range, thus giving 0 to 2 volts output. The pixel voltages are output row by row at each clock pulse once the READ signal goes high. This is not the same as standard video. The only synchronization signal is the XCK signal which you generate; therefore, you control the rate at which the data is transferred.

Operation

After the registers are loaded, the START signal initiates continuous image capture. After the number of clock pulses specified for image exposure, the READ signal goes high and the analog values for the pixels appear on the VOUT pin, with each successive pixel voltage appearing in synchronization with each clock pulse. Since your processor generates the clock signals, it controls the rate of image capture and data transfer.

The Gameboy Camera "Eyeball"

Nintendo's Gameboy camera brings the pins of the Mitsubishi Artificial Retina chip to a 9-pin connector of odd metric size (visible at the bottom of figure 1). Table 1 shows the functions of these pins. The Gameboy Camera "Eyeball" is a ready-made unit for your use. It physically houses the chip, provides the optics and brings the signals to a connector. You will probably want to replace the connector with one which is more widely available.

(see Eyeball on page 6)

Pin Number	Signal Name	Function
1	DVDD, AVDD1, AVDD2	+5Volt supply
2	START	Initiate capture Input
3	SIN	Serial Data Input
4	LOAD	Data Latch Input
5	XRST, RESET	System Reset Input
6	XCK	System Clock Input
7	READ	Image Ready Output
8	Vout	Analog Video Output
9	DGND, AGND1, AGND2	Power and Signal Ground

Table 1 - Gameboy “eyeball” connector pin functions

The Gameboy Camera is easily disassembled, resulting in the pieces shown in figure 3. The main circuit board contains 128 K of battery-backed RAM, 1 Meg of ROM and what appears to be a complex programmable logic device (CPLD) to control all of the signals. Because the full function of the proprietary chip has not been identified, it is not known whether the camera might more easily be controlled through the card-edge connector than by talking directly to the artificial retina chip. However, since documentation is available for the retina chip, it seems easy enough to interface directly to it.

Summary
This has been a quick overview of the Gameboy Camera “eyeball” and the Mitsubishi M62482FP Artificial Retina chip. It shows that a cheap, readily-interfaceable camera suitable for hobby robotics is available from local toy stores. It offers great possibilities for robotics hobbyists because it provides a state-of-the-art CMOS imager with built-in image processing.

In the future, I will report on my experiences with using this chip.

Arthur Ed LeBouthillier

References and more information are available at a website that I am dedicating as a central source of information on this camera. The address is:

http://home.earthlink.net/~apendragn/gbcam

At this site will be found Mitsubishi’s original documentation and other information on using the camera.

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Arthur Ed LeBouthillier - editor

The Robotics Society of Southern California was founded in 1989 as a non-profit experimental robotics group. The goal was to establish a cooperative association among related industries, educational institutions, professionals and particularly robot enthusiasts. Membership in the society is open to all with an interest in this exciting field.

The primary goal of the society is to promote public awareness of the field of experimental robotics and encourage the development of personal and home based robots.

We meet the 2nd Saturday of each month at California State University at Fullerton in the electrical engineering building room EE321, from 12:30 until 3:00.

The RSSC publishes this monthly newsletter, The Robot Builder, that discusses various Society activities, robot construction projects, and other information of interest to its members.

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