

A.H.A.B.
(Autonomous Hot Air Balloon)

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Abstract

Autonomous mobile robots have many different shapes and forms, many of which have yet to be discovered. With our diverse environment there comes necessity for machines that can traverse the most challenging scenarios and still perform the functions and behaviors they were designed to accomplish. One way to explore a great deal of our Earth is through the concept of flight. Using the air as a highway, we can climb the highest mountains and travel across the raging seas unscathed. It is with this notion that A.H.A.B. was designed. To be able to travel over any terrain using sensors and a microprocessor to navigate the way is an amazing feat, and historically a talent that man has only recently acquired. The purpose of this report is to take you on the journey that has led to the implementation of A.H.A.B.

Executive Summary

It has been described as a “hot air balloon for travel by mice” which is an entirely possible concept, if mice didn’t have such a bad habit of chewing on things. Only it is much more than that.

From the outside, the “load” or basket is menacing with its black, sleek propellers whirring at different speeds. Each clear side has one of these monsters attached by means of a plexiglas shelf, quaint in its individual design yet overwhelmingly efficient. Beneath each shelf lie the eyes of A.H.A.B. consisting of one small purple light bulb and an ominous looking black box. In the center of each box a small black semicircle can be seen searching the environment for a faint signal of IR.

Breaking the excessive symmetry of the plexiglas platform, there is a lone pushbutton sensor on the bottom right-hand side of one wall. The small black rectangle is overshadowed by the strange white accessory that points straight down, wrapped in a tiny silver spring.

The entire load is connected at each corner to a strand of white nylon rope, which leads up to the bottom of the massive yellow balloon. With a diameter equal to that of two full-grown men, the golden beast dwarfs the tiny plexiglas box, casting its shadow several feet in each direction around the load. With the grace of a giant it hovers above the box, swaying with each gust of wind as the hot air inside swirls with trepidation.

With wires and hardware visible through plexiglas walls, this microcosm of electric intelligence demands attention from any onlooker as it rises with majestic freedom. This robot, this balloon, this A.H.A.B.

Introduction

Autonomous are fast becoming a major part of today's society in all shapes and sizes. Man continues to strive to design machines which not only perform menial jobs, but can also accomplish the most intelligent tasks.

Many autonomous robots have been designed and implemented in the past using various walking and rolling techniques. The goal I set at the beginning of the semester was to build a flying robot in the form of a hot air balloon. The robot was to have many of the same behaviors and characteristics as its predecessors.

I will discuss in this report the many different aspects of my design including the integrated system, platform, actuation, sensors, behaviors, and experimental layout. These discussions will include descriptions as well as steps which have been taken to successfully implement each aspect of my design.

Integrated System

The system I have used to design my robot is the Motorola 68HC11 EVBU board with the ME11 attachment provided by the Intelligent Machine Design Laboratory.

For the 68HC11, major peripheral functions are provided on-chip. An eight-channel analog-to-digital converter is included with eight bits of resolution. An asynchronous serial communications interface and a separate synchronous serial peripheral interface are included. The main 16-bit, free-running timer system has three

input-capture lines, five output-compare lines, and a real-time interrupt function. An 8-bit pulse accumulator subsystem can count external events or measure external periods.

Many other features are encountered by the addition of the ME11 attachment. With this combination, we have a complete microcontroller system with 32 Kbytes of memory. In addition we are able to access an eight-bit digital output which can drive, at 40 Khz, all IR sensors, LED's, and other equivalent loads. The ME11 also provides for the use of four digital input and four digital output enables which permits the system to use a single-line enable for eight devices.

Mobile Platform

The platform which I have designed is a basic 7x7 inch cube constructed of clear plexiglas, with the top side left open for burner extension. All four sides of the cube are attached using a plexiglas fusing adhesive. At the top of each corner there is a nylon rope which attaches to the balloon.

The balloon itself is constructed of yellow rip-stop nylon material. It has been scaled down from the design of a real-life hot air balloon, which was provided by World Balloon of Albuquerque, New Mexico. The design uses 16 equally constructed "gores", which when sewn together form an elongated sphere.

Actuation

To establish horizontal movement I have attached fans to all four sides of the box, pushing the balloon in the opposite direction of the side that a particular fan is located on. Each fan has been custom built, using a small motor provided by the Intelligent Machine Design Laboratory and a black plastic airplane propeller. The propeller is attached to the motor using a small cylindrical sleeve, which reduces the amount of space and creates a tight fit.

Vertical movement is controlled by a Benzomatic propane burner which heats up the air inside the balloon, causing it to rise. When the burner is turned off, the air inside the balloon cools and the balloon begins its descent.

Sensors

IR sensors have been attached to all four sides of the basket to detect obstacles while the balloon is in flight. All four sides are equipped with IR emitters which are constantly on, connected to the first two pins of the eight-bit output port on the ME11. When a sensor picks up traces of IR, it sends an analog signal to the 68HC11 board. This process lets the board know that an object has been encountered and the board in turn sends a signal to one of four motor drivers. This is the basic premise of object avoidance.

A single bump sensor has also been attached to the side of the platform, with the spring-loaded sensor extending below the bottom edge of the cube. The sensor is then pressed whenever the box is not in flight, and sends an analog signal to the EVBU board. This sensor is a very simple implementation yet very important for the behavior of the robot balloon.

Behaviors

First and foremost the most reliable behavior of A.H.A.B. is obstacle avoidance. As described above, IR sensors detect beams which have been reflected off of objects in front of them, and in turn activate the appropriate motor to keep the balloon from running into the object. This is accomplished by an infinite loop within the function *object_avoidance()*, as seen in the code at the end of this report.

Using the same sensors and emitters, there is also another behavior which resembles search-and-rescue. By turning the emitters off at a periodic rate, we are able to still search for IR, only if it is found while the emitters are off then the code is able to recognize that the signal is coming from an alternate source. This source resembles a lost ship or wrecked plane, which in a normal scenario may not be easily seen by the naked eye. With the recognition of the signal, the EVBU board then controls the motors in an effort to move towards the source. This is accomplished by another infinite loop which can be found within the function *beacon_detection()*, also included at the end of this report.

Experimental Layout and Results

There have been many small accomplishments along the way this semester on the road to a successful autonomous hot air balloon. Although there are too many to include them all, I will discuss a few of the major accomplishments.

The first task which required a multitude of experimentation was installing the motor driver circuits. These circuits consist of an optic oscillator, a TIP, and a few resistors. The actual circuit diagram is included at the end of this report.

Originally I had connected pin 2 of the optic oscillator(the signal line) to port A of the 68HC11 board. This was successful in operating the fan being tested and there is even a command in IC called *motor()*, which sends the appropriate signal through port A, pins 28 and 29. The problem however, was that I had four fans to operate and only two control lines to work with. The eight-bit output port on the ME11 became very important at this point, and I used the last four bits as signal lines for the four motor driver circuits. Testing was successful using the *poke(0x7000, 0x0_)* command, with the space representing the last four bits of this output port.

Still trying to accomplish object avoidance, the next objective was to create a way for the balloon to “see” its environment. Using digital IR sensors, I completed the “hack” as outlined by the Intelligent Machine Design Laboratory to be able to generate an analog signal. The sensors were then hooked to port E of the 68HC11 board, and could be read using the IC command *analog(#)*. IR emitters were simply hooked to the first two bits of the eight-bit output port on the ME11.

With all of these generating appropriate signals, the code which is attached at the end of this report was written, and object avoidance was finally accomplished theoretically. Experimentation actually consisted of objects moving towards the robot, instead of the robot moving towards the objects. This was due to a delay in the actual balloon itself, primarily due to a lack of funding.

This leads us to our final experiment. Testing of the actual flight capability of A.H.A.B. has been a definite learning experience, not to mention quite humbling. As of the time this report was written, testing has thus far been unsuccessful. This is because the burner which heats up the air inside the balloon itself is not strong enough to produce the temperature needed for flight. I have exhausted all possible solutions to this problem, even utilizing a paint stripper which resembles an industrial strength hair dryer and using three Benzomatic propane torches at the same time. The only thing that I believe will come close to heating the air inside the balloon to the needed temperature is a flame-thrower, and unfortunately I have no access to that caliber of burner, nor could I afford it.

Conclusion

It has been quite a journey these past four months, putting together knowledge from all previous engineering classes to accomplish this project. Being able to finally use some of the things that I have learned in the past four years has been an extraordinary experience, and I can guarantee that more projects are already planned for the near future. The whole experience is so dependent on trial-and-error, and with only one project I feel I can accomplish so much more now that I've learned from previous mistakes like trying to drill plexiglas, trying to heat 333.34 square feet of air with a blowtorch, and trying to make plastic fly.

I have created a perfectly functioning basket for a hot air balloon, using sensors to adapt to a changing environment and navigate towards a source of IR. However, the mechanics of the actual flight of the balloon did not work out the way I had originally hoped and for a project which has meant so much in the past four months it tends to be a little disappointing. The important thing however is the lessons that I have learned along the way and the promise that the future holds for artificial intelligence. If these failures didn't occur we wouldn't have any mistakes to learn from, and some of the most creative ideas would never have flourished. Some of the most outstanding ideas in robot design have come from hours of trying to figure out how to correct problems with initial designs. It is this concept that drives me to build again, to create another machine and continue the cycle which has now begun.

References

1. Handout from EEL 5666 “IR Analog Hack”, Mekatronix, Gainesville, FL.
2. “Mobile Robots”, Joseph L. Jones and Anita M. Flynn, A K Peters, Ltd., 1993.
3. Assembly Instructions for the ME11 Expansion Board for the 68HC11 EVBU”,
Novasoft/Mekatronix.
4. World Balloon, Albuquerque, NM.
5. “HC11”, Motorola, Motorola Inc, 1991.

Source Code

```
/*Mark von Oven          */  
/*EEL 5666              */  
/*Spring 1998           */  
/*A.H.A.B.(Autonomous Hot Air Balloon)*/
```

```
/* GLOBALS */
```

```
/* Constants */
```

```
int TEST=90;
```

```
/* Sensory Registers */
```

```
int OB1, OB2, OB3, OB4;
```

```
int GROUNDED;
```

```
/* Flags */
```

```
int emitters=0;
```

```
void wait(int milli_seconds)
{
    long timer_a;

    timer_a=mseconds() + (long) milli_seconds;
    while(timer_a>mseconds()) {
        defer();
    }
}
```

```
void sensor_module()
{
    while(1) {
        OB1=analog(4);
        OB2=analog(5);
        OB3=analog(6);
        OB4=analog(7);
        GROUNDED=analog(0);
    }
}
```

```
void turn_emitters_on()
```

```
{
```

```
    poke(0x7000, 0xf0);
```

```
    emitters=1;
```

```
}
```

```
void obstacle_avoidance()
```

```
{
```

```
    while(1) {
```

```
        if (GROUNDED==0){
```

```
            if ((OB1<TEST)&&(OB2<TEST)&&(OB3<TEST)&&(OB4<TEST))
```

```
                poke(0x7000, 0xf0);
```

```
            else if ((OB1<TEST)&&(OB2<TEST)&&(OB3<TEST)&&(OB4>=TEST))
```

```
                poke(0x7000, 0xf8);
```

```
            else if ((OB1<TEST)&&(OB2<TEST)&&(OB3>=TEST)&&(OB4<TEST))
```

```
                poke(0x7000, 0xf4);
```

```
            else if ((OB1<TEST)&&(OB2<TEST)&&(OB3>=TEST)&&(OB4>=TEST))
```

```
                poke(0x7000, 0xfc);
```

```
            else if ((OB1<TEST)&&(OB2>=TEST)&&(OB3<TEST)&&(OB4<TEST))
```

```
                poke(0x7000, 0xf2);
```

```
else if ((OB1<TEST)&&(OB2>=TEST)&&(OB3>=TEST)&&(OB4<TEST))
    poke(0x7000, 0xf6);
else if ((OB1>=TEST)&&(OB2<TEST)&&(OB3<TEST)&&(OB4<TEST))
    poke(0x7000, 0xf1);
else if ((OB1>=TEST)&&(OB2<TEST)&&(OB3<TEST)&&(OB4>=TEST))
    poke(0x7000, 0xf9);
else if ((OB1>=TEST)&&(OB2>=TEST)&&(OB3<TEST)&&(OB4<TEST))
    poke(0x7000, 0xf3);
}
}
}
```

```
void beacon_detection()
{
    while(1) {
        if ((GROUNDED==0)&&(emitters==0))
            if ((R1<TEST)&&(R2<TEST)&&(R3<TEST)&&(R4<TEST))
                poke(0x7000, 0x00);
    }
}
```



```
else if ((R1<TEST)&&(R2<TEST)&&(R3<TEST)&&(R4>=TEST))
    poke(0x7000, 0x02);
else if ((R1<TEST)&&(R2<TEST)&&(R3>=TEST)&&(R4<TEST))
    poke(0x7000, 0x01);
else if ((R1<TEST)&&(R2<TEST)&&(R3>=TEST)&&(R4>=TEST))
    poke(0x7000, 0x03);
else if ((R1<TEST)&&(R2>=TEST)&&(R3<TEST)&&(R4<TEST))
    poke(0x7000, 0x08);
else if ((R1<TEST)&&(R2>=TEST)&&(R3>=TEST)&&(R4<TEST))
    poke(0x7000, 0x09);
else if ((R1>=TEST)&&(R2<TEST)&&(R3<TEST)&&(R4<TEST))
    poke(0x7000, 0x04);
else if ((R1>=TEST)&&(R2<TEST)&&(R3<TEST)&&(R4>=TEST))
    poke(0x7000, 0x06);
else if ((R1>=TEST)&&(R2>=TEST)&&(R3<TEST)&&(R4<TEST))
    poke(0x7000, 0x0c);
}
}
```

```
void main()
{
    turn_emitters_on();
    wait(50);
    start_process(sensor_module());
    start_process(obstacle_avoidance());
    start_process(beacon_detection());
}
```