THE AITHON BOARD: A CASE STUDY IN COMMERCIALIZATION OF A STUDENT PROJECT

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ABSTRACT

The Aithon board project started as a senior design project for engineering students at California Polytechnic State University, San Luis Obispo. The goal was to design and manufacture a robot controller board suitable for university use. One of the unexpected project outcomes was industry support to market and build the board. In this paper, we provide a technical overview of the board hardware and software, outline the strategies in marketing the board for external sponsorship, and describe educational outcomes achieved during the entire process.

INTRODUCTION

Designing the software and hardware for a robotics controller board can often be considered a suitable project for a 2-quarter senior design capstone experience. Often such a project successfully ends with the results being a prototype of the board design, a library of support software, and an accompanying report necessary to fulfill university requirements. Rarely does the project continue with external industry support for the manufacturing of the design. In this case study, the Aithon board was the result of a senior design project and has acquired industry funding in order to manufacture the board and bring it to market. This paper describes two main results of the Aithon project: the technical details of the board design and the subsequent process of seeking external funding for manufacturing.

BACKGROUND

In the engineering departments at Cal Poly, students are required to complete a 2-quarter senior project. The design project is viewed as an individual capstone experience to complete the undergraduate degree for engineering majors. This particular project started with the goal of extending upon previous locally designed robotics boards from the past [12] and creating a new design that could be utilized over the next several years.

The Aithon board project began as a senior project for an electrical engineering student in the Winter and Spring quarters of 2012. The initial goal for the senior project was to design a shield for the Arduino Mega [4] board that would be suitable for robot control projects. Upon specifying the requirements for the board, it was determined that all of the desired functionality would not fit on to an Arduino Mega shield. After the Arduino Mega shield implementation was deemed not practical, the project turned toward the development of a completely new robot controller board. The initial senior project was able to create a prototype design, but the design did not reach the point of fabrication.

In Fall 2013, another senior project student began working on the Aithon board implementation and was able to complete the design and software for the version discussed in this paper. A picture of the board is shown in Figure 1.

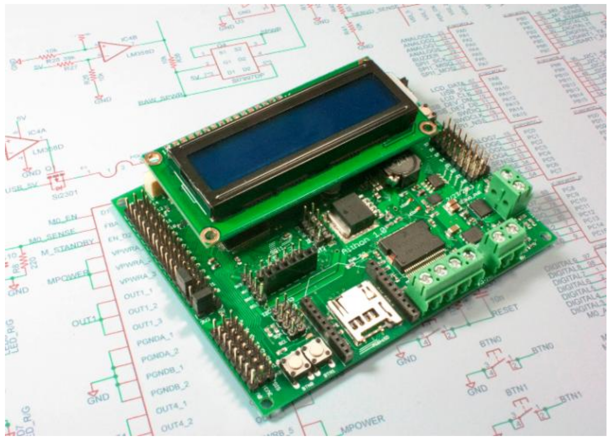

Figure 1 - Aithon board with LCD display

RELATED WORK

In the marketplace today, there are a number of embedded boards that can serve as robot controller boards. These boards include: Arduino Uno [3], Raspberry Pi [2], Beaglebone Black [2], and Maple [9]. This list provides some examples of recent successful open source embedded boards. Several of these boards are used as teaching tools in current computer science departments. The success of these boards has come about because of a combination of ease of use, open hardware and software designs, and relatively low cost. The Aithon board aims to continue in this trend.

In terms of software, some examples of real-time operating systems that can run on microcontrollers without a memory management unit include: FreeRTOS [6], NuttX [10], and ChibiOS [5]. ChibiOS was selected for this project. The software work for this project looks to integrate library features that are important to embedded design with a single board that is easy to use.

AITHON HARDWARE DESIGN

The Aithon board hardware was designed around a philosophy of maintaining a balance between integration and flexibility. Integration provides the advantages of having several features on a single board and the ability to provide software library support for that built-in functionality. On the other hand, power users tend to prefer more flexibility in a design as that allows more engineering versatility. In planning the features of the circuit board, the goal was to support medium sized robots where the motor current is approximately 5A continuous current draw at a voltage of 12V.

The board is built around a 32-bit ARM microcontroller running at 168MHz. Figure 2 shows a block diagram of the overall architecture of the Aithon board. The microcontroller is a 32-bit ARM Cortex-M4 with hardware floating point (STMicroelectronics STM32F407). The microcontroller itself provides the following features: 512KB flash memory, 192KB RAM, and up to 17 timers. While this chip does not put the board into a class that can run Linux with a memory management unit, the overall simplicity of the design does make it easy for students to start using the design without as much of a learning curve.

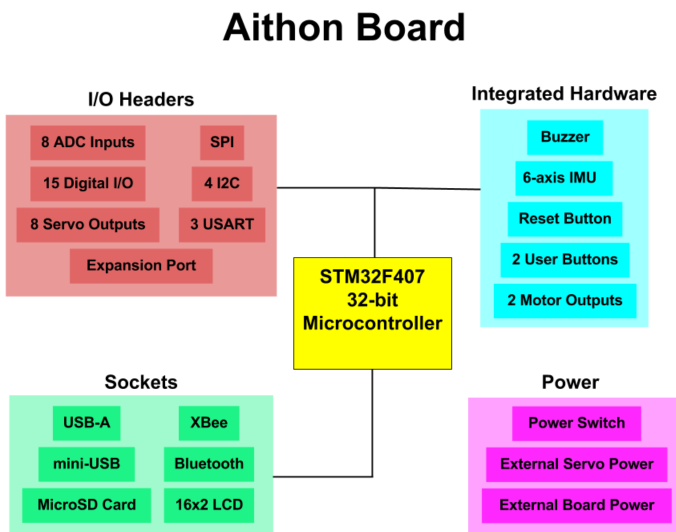

Figure 2 – Block diagram of Aithon board design

The board headers and sockets are selected in order to provide a wide array of flexibility. All digital I/O pins are 5V tolerant (running at 3.3V), meaning that they can accept 5V digital signals that some sensors output. There are 15 of these digital pins and that is not including the various bus headers that are on the circuit board. Analog inputs are useful for measuring sensor voltages that provide a range of input values and the Aithon board provides 8 analog inputs. In order to connect to RC servos, there are 8 connectors for standard 3-pin servo headers.

Flexibility is provided through the following standard interfaces: up to 3 USART, up to 4 I^2C, 1 SPI header, 1 SWD header, 1 12-bit DAC output, mini-USB (device) port, standard USB (host) port, XBee socket, Bluetooth header (accepts modules directly and provides wireless programming support), and a MicroSD card socket. There is also an expansion port for future expansion boards and shields.

Power circuitry is very important when designing a board for student use. There may be mistakes in wiring connections. The Aithon board can be powered with a 7-24V input and the board includes reverse polarity protection and a power switch. Additionally, the board provides support for external power to be supplied to the servos. There are two on-board regulators: a 10A 5V switching regulator and a 5A 3.3V regulator.

Integrated functionality is provided through the following features: 3-axis accelerometer, 3-axis gyroscope, temperature sensor, 2 channel H-bridge motor driver - 5A per motor, LCD port, on-board buzzer, 2 push-buttons, and 2 software controlled LEDs.

AITHON SOFTWARE

The goal for the software is to provide easy-to-use libraries which allow students to start creating projects quickly. A primary reason for the success of the Arduino platform is the fully developed software library available for download that enables students to install the software and start developing applications almost immediately. One of the goals with the Aithon software was to achieve a similar level of development ease.

The Aithon board uses ChibiOS [5], which is a fast, open source, and real-time operating system. ChibiOS can be programmed in either C or C++ and comes with several pre-built library functions which abstract low-level operating system details such as hardware device drivers. In addition to the libraries that ChibiOS provides, a full set of libraries has been written for each aspect of the Aithon board. The Aithon libraries are themselves open source and have complete documentation.

The board can be programmed through several interfaces. By default, programs can be uploaded to the board over USB or UART. The board can also be programmed wirelessly over Bluetooth or XBee.

SEEKING EXTERNAL FUNDING

Although the design of the board was an academic success, one of the major outcomes of the project was the ensuing search for funding to make the board available for other students to use. Once the design and testing of the board was well underway, the next challenge was to seek funding to have the board produced in quantity. The university robotics club was interested in acquiring approximately 100 boards in order to distribute them for use during club meetings, personal projects, and robotics competitions [7].

In order to fund the production of the boards, different avenues were researched to get the financial support needed. Instead of approaching companies to obtain sufficient financial support, it was determined that a crowdfunding approach [1,13] through Kickstarter [11] would be the most viable option at the time.

Kickstarter is a website that helps projects obtain external funding by allowing anyone from the general public to pledge some amount of money to a project, usually in exchange for a reward, if that project is successful. The rewards are typically the products themselves. Each project determines a financial goal and if the goal is reached by the end of the project campaign, then the project is considered successful and receives full funding from the pledges. If the project does not meet the funding goal, the project does not receive any funding.

When the Aithon board campaign on Kickstarter was launched, the financial goal was set to $18,000. That amount would cover the cost of manufacturing enough circuit boards to reward all campaign supporters as well as provide a sufficient number of extra boards for use on campus.

A Kickstarter campaign typically lasts 30 days and during the time the Aithon Kickstarter campaign was active, there were several opportunities to publicize the Aithon board. The city of San Luis Obispo had its first annual Mini Maker Faire and there was a booth available to show the capabilities of one of the Aithon boards and to distribute informational flyers about the board on Kickstarter. At the university campus, there were opportunities to present the design to industrial advisory boards that consisted of industry members interested in campus programs.

Several social media sites, such as Facebook, LinkedIn, Twitter, and Reddit were used to extend the reach and exposure of the board. Posts to relevant online discussion forums also proved effective as a means of garnering publicity. Partway through the Kickstarter campaign, several companies were contacted in order to obtain pledges toward the Kickstarter campaign. One of the companies contacted was STMicroelectronics, the semiconductor manufacturer of the microcontroller on the Aithon board.

Discussions began with STMicroelectronics and the decision was made to work with the company in order to move the product into the commercialization stage. Talks with ST continued and as the Kickstarter campaign was getting closer to the end with just under half of the funding that was needed pledged so far, the decision was made to successfully cancel the Kickstarter project. In the time that has passed since the ending of the Kickstarter campaign, development on the Aithon board has continued with ST in order to bring the board to market.

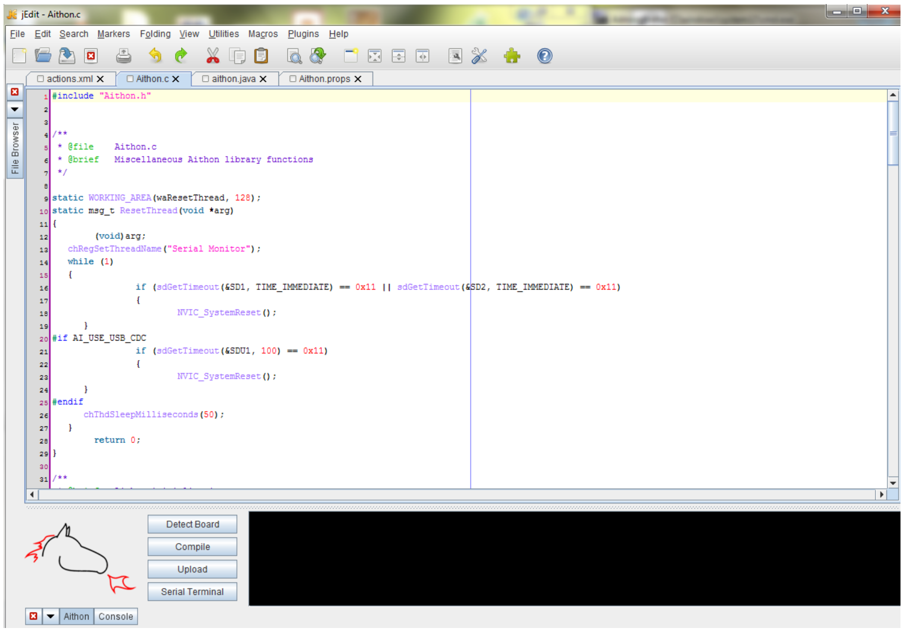

Figure 3 – A screenshot of the Aithon IDE (jEdit with custom Aithon plugin)

LESSONS LEARNED

There were several educational outcomes achieved with the Aithon project. In terms of the project itself, the software and hardware design required several hours of student time and effort. Each revision required approximately one month for the update process: board design modification, board fabrication, acquisition of components, board assembly, and testing. Software implementation required detailed consideration of operating system selection, library interfaces, and overall software architecture. Cost was under consideration throughout the design process.

In terms of pushing a product to the commercialization stage, there were several steps that required both a good amount of effort as well as maximization of unexpected opportunities. For the Kickstarter project, it was understood that a short video tended to be more effective. The percentage of viewers who viewed the entire 2 minute Aithon video was approximately 53%. Additionally, announcement posts to relevant online discussion forums were a good method to obtain rapid feedback in regards to the software and hardware design. Although the use of social media during a crowdfunding campaign can provide the necessary coverage to get a project off the ground, the publicity does not come without effort. Maintaining personal contact with supporters required constant attention. Fortunately, larger publicity was achieved through the university Facebook page.

In working with an industrial partner in order to bring a product to market, there is a balance that needs to be achieved between the requirements of an industry schedule and those of an academic schedule. Use of an online issue tracking system has allowed the Aithon project to maintain a working balance between those two needs.

The experience obtained by the students involved in the project has been very beneficial and broadly based. Students have been involved with hardware engineering, software engineering, video development, marketing, cost analysis, design for manufacturing, and customer analysis.

FUTURE WORK

Work is in progress on building a plugin for an IDE called jEdit [8]. jEdit is a lightweight cross-platform text editor for programming. Figure 3 shows a screenshot of the current implementation of the Aithon plugin in jEdit. The capabilities of the plugin include the ability to automatically detect a board, compile a program with the libraries, upload a user program, and communicate with the Aithon board through a serial terminal. The Aithon libraries created for ChibiOS will continue to be updated to further improve functionality and readability.

Finally, the Aithon board has been designed to interface with expansion boards supporting various features. Work has yet to be done on designing expansion boards.

CONCLUSION

The Aithon board started a senior design project intended to create a circuit board and supporting software that would support the needs of designing medium sized robots in a university environment. The design provides the flexibility for advanced users to design without being constrained while giving new users the ability to start with pre-built libraries.

After the design was completed, a search for external funding was undertaken to support the manufacture of a larger quantity of boards. This process started with the launch of a crowdfunding project through Kickstarter. Eventually, a semiconductor manufacturer was alerted of the board design and is providing support to bring the project to market.

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