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Microsoft Kinect Sensor Evaluation

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Abstract

My summer project evaluates the Kinect game sensor input/ output and its suitability to perform as part of a human interface for a spacecraft application. The primary objective is to evaluate, understand, and communicate the Kinect system's ability to sense and track fine (human) position and motion. The project will analyze the performance characteristics and capabilities of this game system hardware and its applicability for gross and fine motion tracking. The software development kit for the Kinect was also investigated and some experimentation has begun to understand its development environment. To better understand the software development of the Kinect game sensor, research in hacking communities has brought a better understanding of the potential for a wide range of personal computer (PC) application development. The project also entails the disassembly of the Kinect game sensor. This analysis would involve disassembling a sensor, photographing it, and identifying components and describing its operation.

I. Introduction

The Microsoft Kinect game sensor is a revolutionary device that is changing the way electronic consumers interact with their Xbox 360 console and PCs. This piece of gaming technology has an abundance of capabilities that enables it to track human position, gestures, and recognize speech for voice commands. Because the software development kit was not available at the time of the Kinect's release in November, 2010, independent developers all over the world have hacked USB interface to allow repurposing of sensor capabilities, controls and 3D environmental mapping, resultin in many amazing interactive PC applications. The Microsoft Kinect is processed by Primesense's PS1080 System-on-a-chip SoC, processor. The Kinect is equipped with an infrared I.R. transmitter, a color image complementary metal oxide semiconductor CMOS camera, and a depth image CMOS camera. This trio of tracking technology allows the Kinect to track up to four people.

II. Early Stages of Evaluation

NASA Johnson Space Center's Human Interface Branch, EV3, is interested in the Kinect because of its capabilities in tracking human position, hand gestures, speech recognition, and the application of these capabilities to human interface in future spacecraft. EV3 sees this sensor as a very promising new hands-free human interface technology. This portion of the summer project introduced me to the technology behind the Kinect game sensor and to perform research in the technology as well as the software development kit.

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Figure 1. shows the real-time display generated from the depth image CMOS. A large amount of the processing was done by Microsoft. Interfaces including the Kinect's Application Programming Interface API, were all done by Microsoft as well. The calculations concerning what the Kinect detects as human and how it reports computations to the computer is all done by Primesense's system. The PS1080 SoC includes a USB 2.0 which allows all data to pass to the host. Primesense will also be licensing its PS1080 SoC technology to non-gaming devices that will be available at local retailers this year (2011).

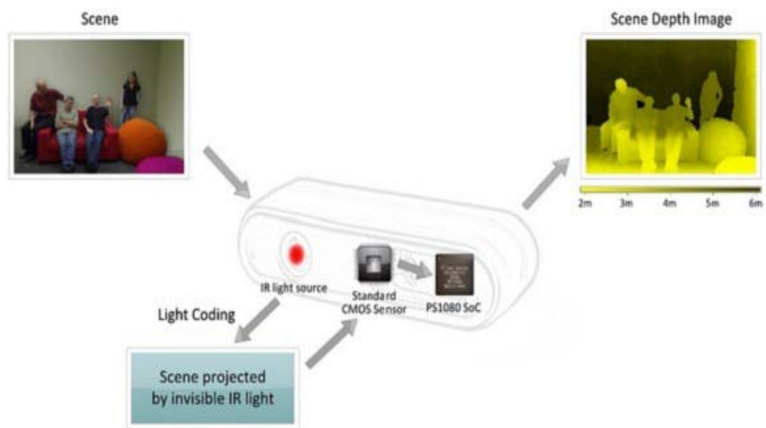

Figure 1. Primesense Depth Image CMOS. The I.R. invisible light is emitted and tracked by the depth image CMOS. The PS1080 SoC then generates a depth image.

III. Kinect for Windows Software Development Kit (Beta Version)

The Kinect software development kit beta, SDK beta, became available to download in mid June, 2011. The SDK runs on the Visual Basic development environment by Microsoft. The programming language used for practice and implementation for this project was C++. The SDK is a toolkit for application developers. It accesses the Kinect device connected to computers running on Windows 7 operating system. The Kinect SDK includes drivers, APIs for sensor video streaming and human motion tracking, installation documents, and resource materials. It offers capabilities to developers to build applications with C++, C# or Visual Basic by using Visual Studio 2010.

The Kinect for Windows SDK beta includes: 1. *Raw Sensor Streams* to access raw data from the depth and color camera sensors, and also the microphone array. 2. *Skeletal Tracking* to track one or two people moving within the range of the Kinect's tracking capabilities. 3. *Advanced Audio Capabilities* to allow developers access to the sophisticated noise suppression and echo cancellation, beam forming microphones to identify the current sound source and integration with Windows 7 speech recognition API. 4. *Sample Code Documentation* which includes more than 100 pages of technical information. 5. Easy Installation which is a complete installation of 100 megabytes. Developers can install the SDK in minutes with a Kinect device unit. The kinect SDK also includes a sample game called "Shape Game Demo" which is a simple application that includes the application's source code.

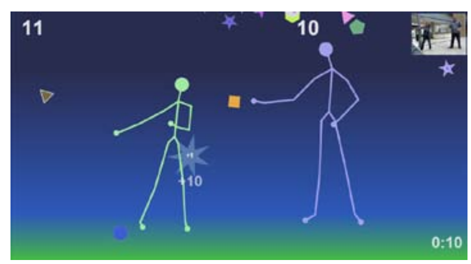

Figure 2. Shape Game Demo. The Kinect SDK beta includes this as a sample application.

IV. Kinect Sensor Teardown

Disassembling the Kinect sensor was a fairly easy process. The teardown of the Kinect sensor is nothing new to technology enthusiasts. Many websites offer suggestions, pointers and even offer the disassembling process for you. The dismantling process took a total of ten phases, each with additional dismantling processes for the minor things. The duration for the Kinect disassembling process took a week's time while at the same time photographing the process and documenting the findings. The main resource for the disassembling process was a website by 'ifixit'. This website serves as a free repair manual that anybody with technical knowledge can edit. The ifixit website offers repair manuals for just about every piece of technology from tablets to smart phones. At the time of the Kinect disassembling process, ifixit hosted a teardown webinar. The engineering behind the Kinect is amazing; everything from the placement of the microphone array to the integrated circuits makes the Kinect a highly sophisticated device that's available for $150 versus earlier systems with similar capabilities, priced around $280K.

A. Tear Down Evaluation

The Kinect game sensor is a glossy black device that has integrated in it an I.R. transmitter, 3D Depth Sensors, (RGB) Camera, a multi-array microphone, and a motorized tilt base as shown in Figure 3. The teardown was a hands on procedure to evaluat the physical structure of the Kinect and to learn about the Kinect's components such as integrated circuit IC boards. Each phase is a disassembly of each component of the Kinect from the outside casing to the structural support frame.

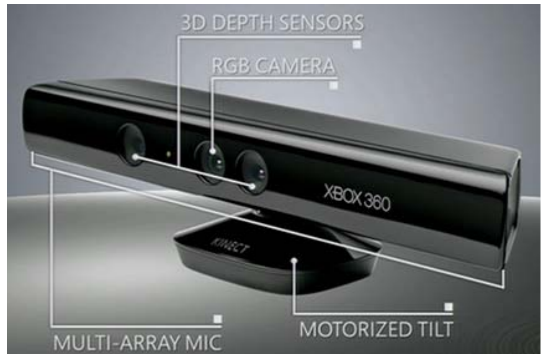

Figure 3. Locations of the various components. Depicted are the locations of the components that make up the Kinect game sensor.

The first step was to disassemble the motorized base. Within step one, a rubber pad had to be removed to get to four T6 Torx screws, one in each corner as indicated by the red circles in Figure 4.

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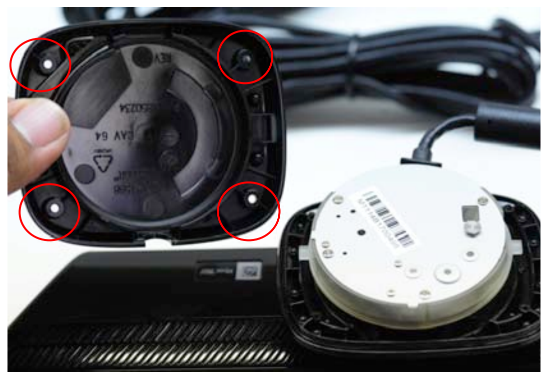

Figure 4. Removal of the Motorized base Cover. The case that houses the motor can then be removed also.

The second step, once the T6 Torx screws to the motor casing were removed, was disconnecting the direct current D.C. power supply cable. The D.C. power cable was the only thing that was holding the motor assembly to the base at this point. The plastic gears in the motorized base are fragile and can easily be warped or stripped if forced into position. This could be considered a design flaw.

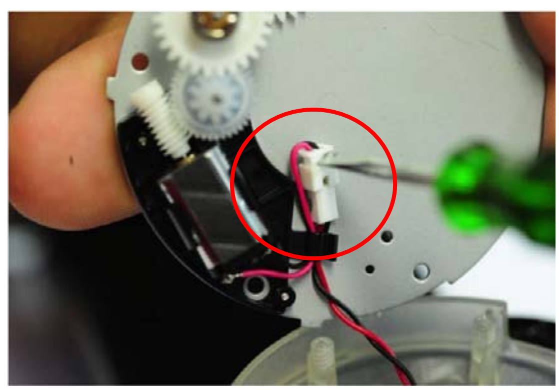

Figure 5. Inside the Motorized Base. The DC power supply had to be disconnected.

Step three included taking apart the Kinect casing. Within step three, the bottom left and right grilles and six T10 Torx security screws were removed. The top and bottom covers, and the side grilles with one fan were also removed from the Kinect by removing the screws.

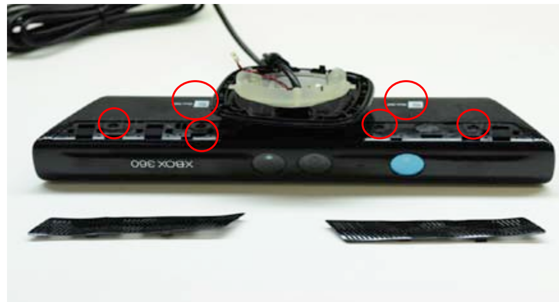

Figure 6. Removal of the Grills. Depicted are the grilles removed and also the locations of the six T10 Torx security screws indicated by the red circles.

Step four essentially was the removal of the large I.C. board that carries the Primesense PS1080 SoC. The microphone array, labled in blue in Figure 7., was the first to be disconnected. The heat sink, labled in green in Figure 7, had to be heated with a heat gun to loosen the adhesive holding it on to the board. Then the seven T10 Torx screws, labeled in red, could be removed..

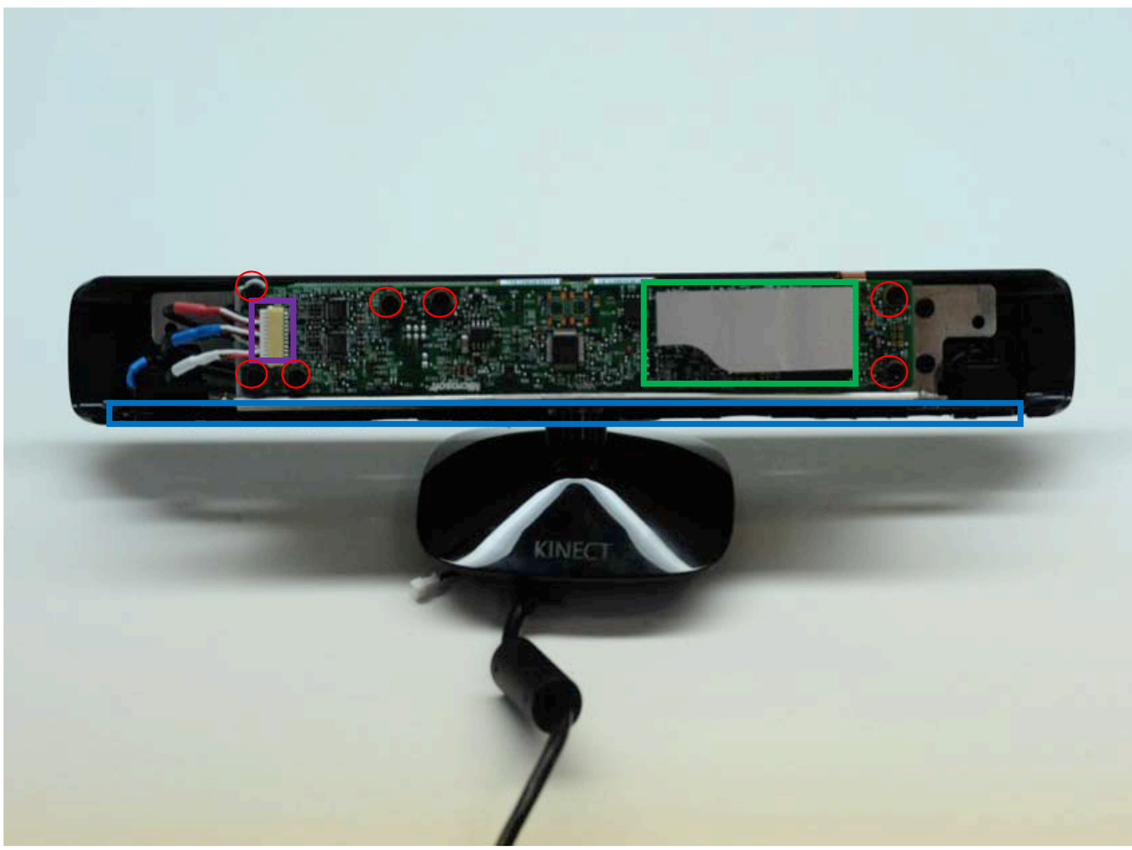

Figure 7. Removal of the microphone array, heat sink, seven T10 Torx security screws and microphone array. Each component is color coded in figure.

The Kinect game sensor contains three I.C. boards that are found in Figure 8. The depictions, as well as their color code information, were gathered from ifixit.com.

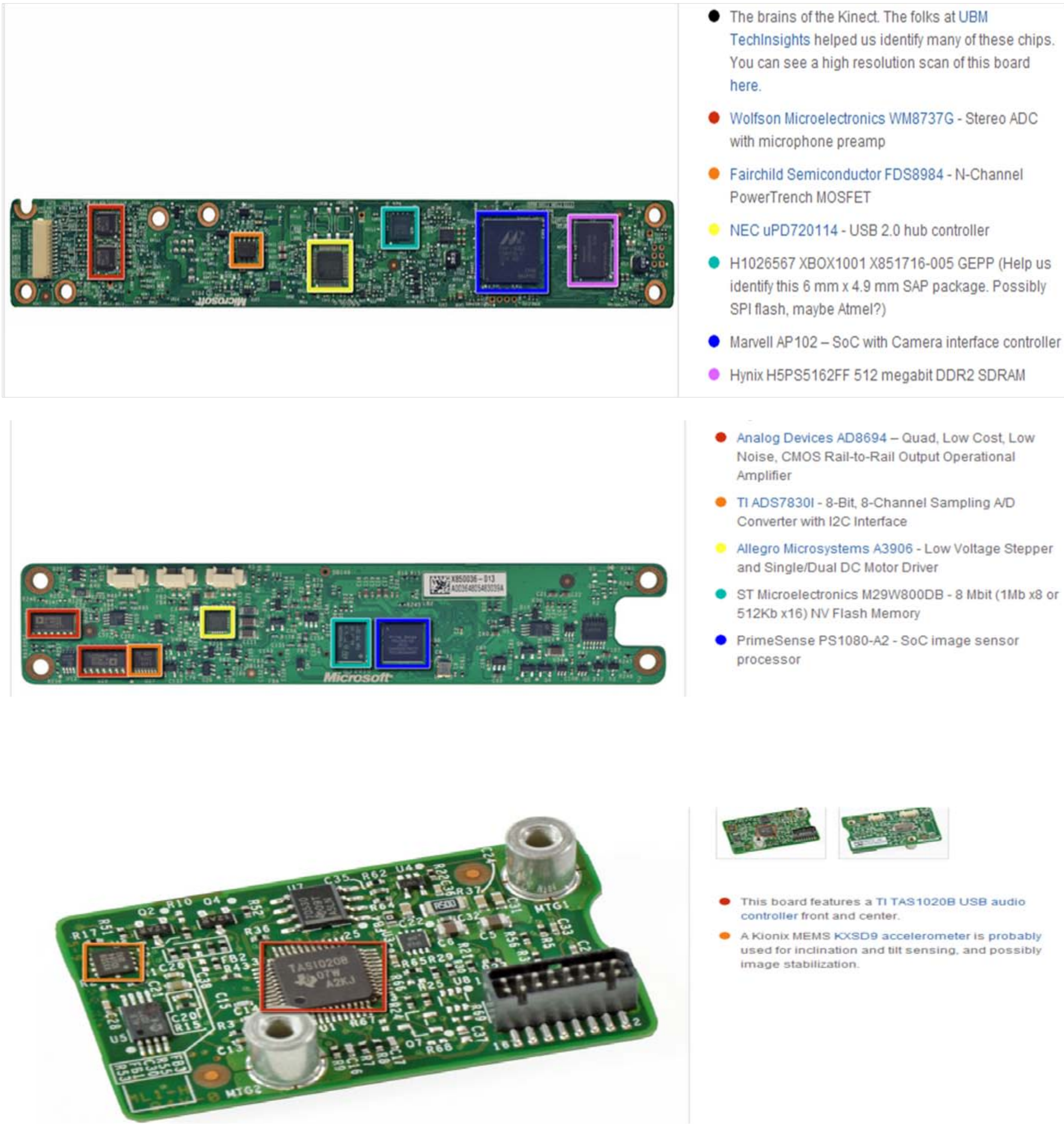

Figure 8. Photo by ifixit from:
http://www.ifixit.com/Teardown/Microsoft-Kinect-Teardown/4066/1

Step five was to disconnect the depth image CMOS and the color image CMOS cameras and the I.R. transmitter ribbon from the mid size I.C. board. Refer to Figure 9. for color code information

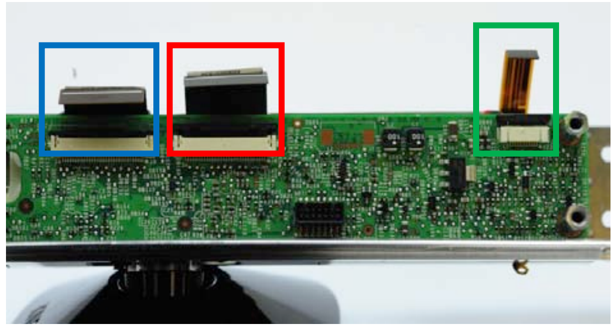

Figure 9. The camera ribbon connectors as well as the I.R. transmitter are disconnected. Depicted are the depth image CMOS ribbon in the blue box, color image ribbon in the red box, and the I.R. transmitter ribbon in the green box.

Step six depicts Figure 10. which shows the bottom view of the Kinect. Once all the components were removed from the frame, the cable that connects the Kinect to the universal serial bus USB device can now be slipped out through the bottom center.

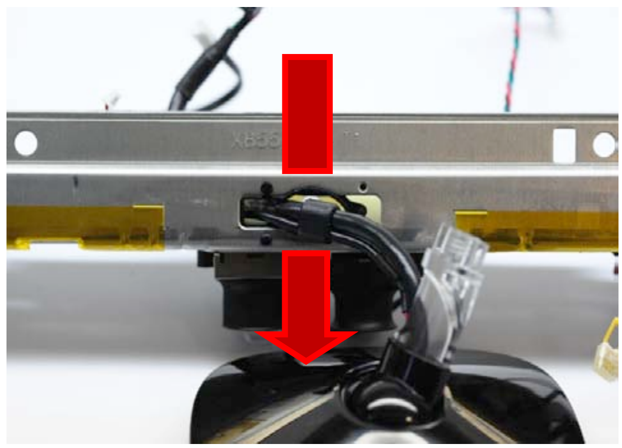

Figure 10. Xbox 360 cables can now be removed. The red arrow indicates the path to which the cable is to be removed.

Steps seven through ten is a simple teardown of the Kinect game sensor's frame. Everything from the IR emitter to the wiring had been removed during the last three phases of the teardown. The Kinect took a total of 10 phases to dismantle that are not all described. As depicted in Figure 11, the subassemblies are bagged and tagged and ready for the next co-op or intern to reassemble.

Figure 11. Subassemblies are bagged and tagged. The kinect took a total of ten phases to dismantle.

V. Kinect Technology

Figure 9. shows a diagram of how the PS1080 SoC functions. The chip includes two optional input capabilities: color (RGB) image and audio while the I.R. light and depth image CMOS are mandatory. Microsoft states that the infrared camera resolution is 320x480 pixels. The lens are relatively large, and have autofocus function. Primesense's PS1080 SoC is the brains behind the Kinect. The PS1080 SoC is a multi-sense system that synchronizes live depth image, color image and audio streaming. The Kinect contains an I.R. transmitter, a color image CMOS, and a depth image CMOS. The infrared is emitted in a matrix of dots that reflect off objects in a given area. The sensor has an angular field of view of 57° horizontally and 43° vertically, while the motorized pivot is capable of tilting the sensor up to 27° up or down. The time that it takes each dot to return to the depth image CMOS is then translated into a depth image internally digitized depth image map.

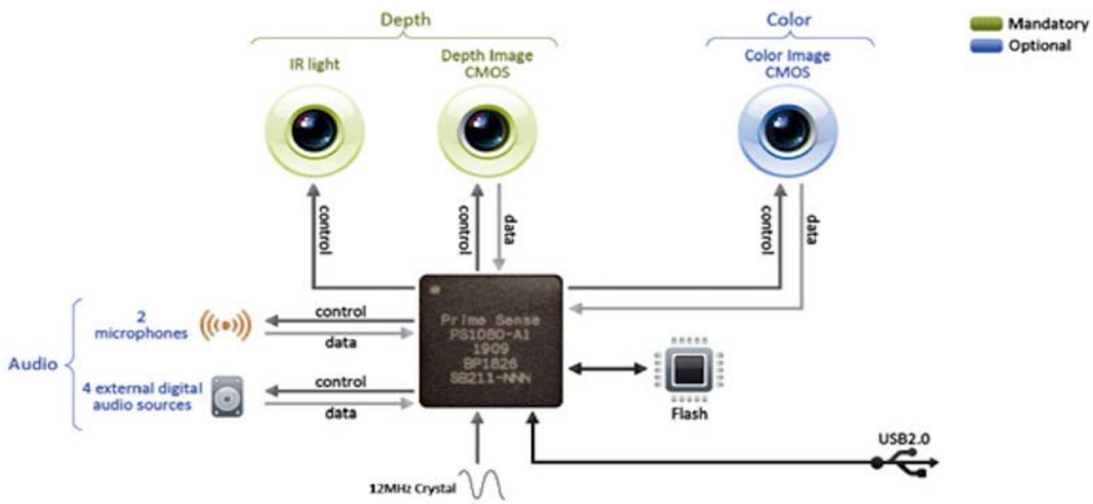

Fig 9. PS1080 SoC Functionality. Photo by ifixit from: http://www.ifixit.com/Teardown/Microsoft-Kinect-Teardown/4066/1

VI. Conclusion

The Kinect project evaluation included an evaluation of the hardware and software development kit. The report gives an insight of the technology and how it functions. The Kinect teardown was a process of ten phases; the complete powerpoint documentation of this process is available upon request. Many websites offer the teardown process; I referenced mainly the ifixit website for information regarding the I.C. board information. Primesense's PS1080 SoC had an innovating influence on this piece of technology, making it the Guinness World Record holder for the fastest selling consumer product of 2010. A little experimentation was also done with the SDK beta. My skills in the programming language C++ were at a novice level. The SDK beta came with source code for its sample applications, and I was able to do some minor code debugging and alterations.

This project will be picked up again by an intern or co-op very soon. My suggestions for the next student would be to get familiar with the development environment, particularly in C++, C#, or Visual Basic in the Visual Studio 2010 program. The Kinect sensor is a promising hands-free device for potential spacecraft applications; another suggestion would be to develop a prototype user interface with the Kinect. The end product, that time did not allow, was to develop a user interface that displays the sensor information relating position and tracking data for the user's head and multiple fingers. Powerpoint slide presentations with teardown details will be readily available for the next intern or co-op as well as a Microsoft Word document containing operations of key components for the Kinect.

VII. Acknowledgments

I would like to thank my fellow interns and colleagues in the EV3 Branch for contributing their time to help me along in my duties for the Kinect evaluation project; interns: Austin Shaver, Shaugnessy Brown, Alsidneo Bell, and Joshua Harris. The mentors of these interns such as, Andy Romero, George Salazar and Oron Schmidt have been key players for side projects aside from the Kinect evaluation. A really big help was Glen Steele in aiding me in the debugging process and helping me understand programming. Big contributions made to the Kinect Evaluation were made by Dave D. Lee, Debbie Buscher, and Mary McCabe. I would like to especially thank my mentor, Helen Neighbors. She had said to me that she's working on being a mentor; she's done a fantastic job! A really big thank you goes out to the individuals who invested their time to get me this NASA Johnson Space Center internship, Mr. Lee Snapp and Dr. Nader Vadiee.

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