February 15, 2016

Dr. Andrew Rawicz

School of Engineering Science

Simon Fraser University

Burnaby, BC V5A 1S6

Re: ENSC 440 Functional Specification for the Smart Baby Cradle

Dear Dr. Rawicz,

The following document is the functional specification report of our Smart Baby Cradle Project. We aim to design and implement a smart baby cradle that can help young parents to take care of the babies with a mobile device application. Our desired product contains four key features such as automatic cradle swing, baby crying detection, webcam monitoring and mobile toy spinning.

The purpose of this document is to provide an overview and high-level functionality description for our proof-of-concept product and the final version producible production. This functional specification report will be used as a reference for the future research and development process.

Our company, BABY ROCK, consists of four talented engineering science students: Fanchao Meng, Yu Liu, Xiaoye Lu and Kiru Sri. If you have any questions or concerns about our proposal, please feel free to contact me by phone at (778) 990-3591 or by e-mail at fanchaom@sfu.ca.

Sincerely,

Fanchao Meng

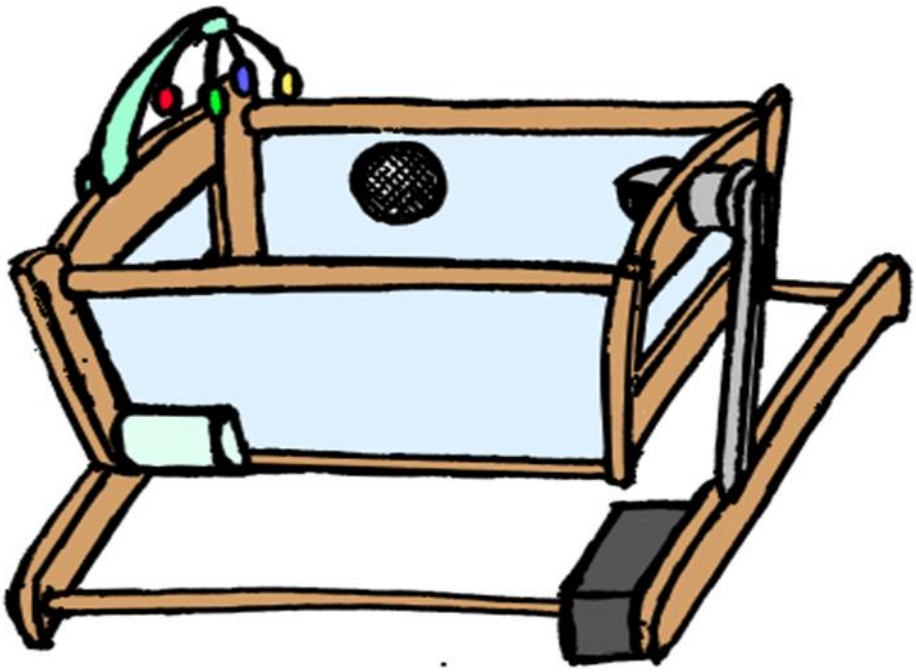
Fanchao Meng

Chief Executive Officer

Baby Rock

Enclosure: Proposal for a Smart Baby Cradle

JANUARY 25, 2016



SMARTY BABY CRADLE

FUNCTIONAL SPECIFICATIONS REV 1.0

FANCHAO MENG, YU LIU, XIAOYE LU, & KIRU SRI
SIMON FRASER UNIVERSITY
School of Engineering

Executive Summary

Many Parents buy a lot of products to help them raise their baby during this time. They buy baby monitors, cribs, cradles, toys, and music player to help calm the baby. These products may end up costing the parent up to $600 depending on what products choose. They are all controlled separately, which may end up being a hassle for the parents. Many of these aren't automated either, it requires the parents to operate the device.

Baby Rock aims to propose a device that will have semi-automated features, as well as manual. The device will combine the features of all the devices mentioned previously, as well as automated to help soothe the baby when the parents are unable to. This will give parents a little more time to do everyday tasks, and reduce the stress on the parent. A happy parent equals a happy baby. The device is called Smart Baby Cradle and it has the following critical features:

1. Smart phone remote control
2. Cradle smoothly swing
3. Mobile toy automated control
4. Sounds detecting
5. Webcam monitoring

Baby Rock Inc. consists of three systems engineers and one computing engineer. Each one has a variety of experience from mechanical to software development, from the use of SolidWorks to the understanding of materials, as well as coding for Arduino and other microcontrollers.

We plan to finish this project in a 12-week period, and have an extra week if anything deviates from our original plans. This project will require us to research a variety of components usable with a microcontroller, as well as mechanical information which we will use to design and construct the prototype. The project is estimated to cost $400 which is mostly funded by ESSEF and through our own pockets.

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Glossary

AC	Alternating Current
CSA	Canadian Standards Association
CPU	Central Processing Unit
GPIO	General Purpose Input Output
I/O	Input/output
IEEE	Institute of Electrical and Electronics Engineers
RAM	Random Access Memory
User	The parent who are the target audience of this product
Wi-Fi	
WLAN	Wireless Local Area Network
Mic	Microphone
App	Android Application
DAC	Digital to Analog Convertor
ADC	Analog to Digital Convertor

1. Introduction

1.1 Purpose

The Smart Baby Cradle is a baby-care system that will provide a safe cradle for baby and allow wireless remoting to monitoring and comfort the baby. Parents can use a smartphone app (Android application) to control the system, including rocking the bed, speaking to baby, turning on the toy and seeing the baby. This document will introduce the requirements and functional specification which will describe the proof-of-concept system with all critical features.

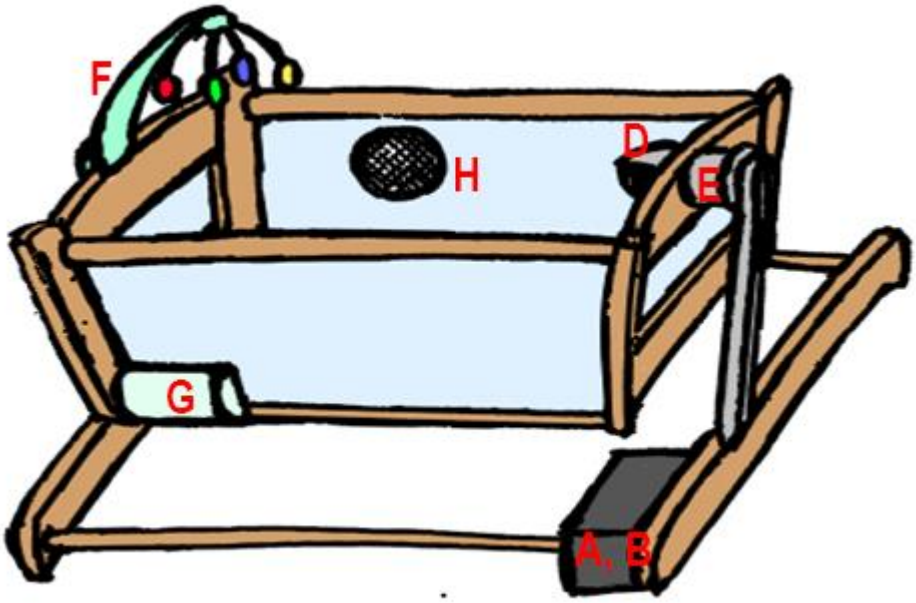

Figure 1 Hand drawing of the high-level design of the Smart Baby Cradle

- **A.** Micro-controller: a mater control that get data from webcam and send control signal to the stepper motor, the speaker and the mobile toy. It also communicates with the Android application to provide remote control.
- **B.** Wi-Fi module shield: allows the micro-controller to deal with the data communication through Wi-Fi network.
- **C.** Router: provides Wi-Fi network environment for the communication between the micro-controller and the phone application.
- **D.** Webcam: monitoring the baby in the cradle and is controlled by micro-controller.
- **E.** Stepper motor: provides required torque to rock the cradle and is controlled by micro-controller.
- **F.** Mobile toy: is used to comfort the baby and is controlled by micro-controller.
- **G.** Mic: collects sound data from the baby to identify if the baby cries and is controlled by micro-controller.
- **H.** Speaker: allows the parent to speak and comfort the baby. It is controlled by the micro-controller.
- **I.** Android application: provides remote control and communicates with the micro-controller.

1.2 Scope

This document will generally describe what the Smart Baby Cradle can do and what are the requirements for each part of it. The detailed design content will not be stated in this report, but this report will be a reference at our design stage. In order to implement the final production device, this document should be used as a design objective and a quality assurance form in the future design processes.

1.3 Intended Audience

The document is intended for audience with a minimal technical understanding and for BabyRock correspondents. This document will outline the requirements that BabyRock must take to commercialize a final product.

1.4 Background

Parents always feel stressful about baby caring. They have to stay with the baby all the time unless the baby is sleeping. Most of parents face a common problem: when they do something like cooking or reading, they hear the baby is crying or screaming and they have to stop what they are doing. Sometimes, the baby just wants to see or hear the parents or just wants parents to turn on the toys. Parents do need an effective way to check if the baby has serious problem or just wants to play the toy or something.

The Smart Baby Cradle can solve the problem and help parents to find a balance between baby caring and something they really want to do. They can monitor the baby with a phone and comfort the baby by clicking buttons. Our product provides several ways to comfort the baby, such as play sounds, turn on toys and rock the bed.

1.5 Classification

The following convention is used to classify the requirements and the criticality of the requirements for the Smart Baby Cradle to be ready for production:

[**RX. ##-Y**]

Where ## is the requirement number and X is specified as stated below:

- **0** General
- **1** Physical
- **2** Environmental
- **3** Safety
- **4** Sustainability

And **Y** is specified as stated:

- **I** Highest Priority: Core/critical Requirements of the system that must be included in prototype
- **II** Medium Priority: Necessary Requirements for the system to perform essential functions
- **III** Low Priority: Requirements need for Final Product not necessarily the prototype

2. System Requirements

(System overview, requirements, standards, safety)

The system consist of 5 components: Microphone, Motor, Speaker, Mobile Toy and Webcam. These components shall be integrated together using a microcontroller. They shall be used together to help soothe a baby when crying. The microcontroller will detect the baby crying and control the motor, speaker mobile toy and webcam. The user must be able to manually control the 5 components using an Android App. The system will be in initial position when not in operation, where the cradle bed is parallel to the ground.

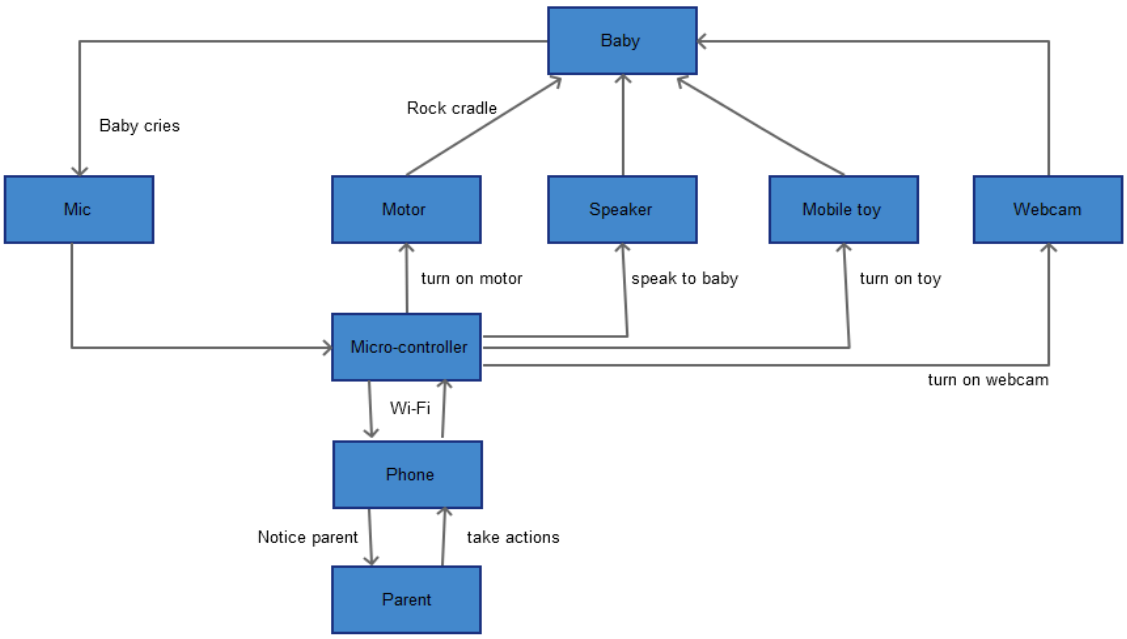

Figure 2 the high-level flow chart of the Smart Baby Cradle system

2.1 General Requirements

[R0.01-I] User must have Wi-Fi connectivity
[R0.02-I] User must have a private home network with WLAN capability.
[R0.03-I] User must have a compatible smartphone (Android or IOS)
[R0.04-I] User must provide AC connection for system.

[R0.05-II] User must not forcefully rock cradle bed.

2.2 Environment Requirement

[R2.01-I] User must provide adequate room
[R2.02-I] User must place system on firm surface (system must not sway)
[R2.03-I] Environment must be an adequate distance away from liquids.

2.3 Safety requirements

[R3.01-I] All electronic components must be kept dry at all time
[R3.02-I] All electrical components shall be in enclosure.
[R3.03-II] All moving components shall be non-accessible by infant.
[R3.04-I] System must move at reasonable speed.
[R3.05-III] Components must be CSA certified.

2.4 Sustainability Requirements

[R4.01-II] Cradle made of recycled material
[R4.02-II] System must last 5 years
[R4.03-II] Mobile toy made of recycled material
[R4.04-II] Most the system has to be recyclable or disposable (disregarding electrical components)

3. Cradle Requirements

The cradle is the base of the system. All other electronic devices are attached to it, including:

1. Stepper motor
2. Speaker and mic
3. Mobile toy
4. Microcontroller

In order to support multiple electronic loads, the cradle has to provide enough space and can handle the weights of those devices and the baby.
In addition, to serve the important function which is to provide option for parent to rock the bed, it has to be able to rock in one dimension.

3.1 General Requirements

[R0.06-III] The height of the cradle shall be at least 1200mm.
[R0.07-I] The cradle shall be able to rock with a shelf covered the body.
[R0.08-I] The structure of the cradle has to be stable to handle all weights of other devices and components.
[R0.09-I] The cradle shall rock in one dimension without exceed 30 degrees.
[R0.10-I] The cradle must provide smooth rocking motion.
[R0.11-I] The cradle feet shall be parallel to each other and stable to the ground.

[R0.12-I] The cradle shall not rock more than 30 rocks in both directions per minute

3.2 Physical Requirements

[R1.01-III] The width of the cradle shall not exceed 800mm.
[R1.02-III] The length of the cradle shall not exceed 1200mm.
[R1.03-II] The total weight of the cradle shall not exceed 10kg.
[R1.04-II] The cradle shall provide comfortable padded support to the baby's body.

3.3 Safety Requirements.

[R3.06-I] The material of the cradle shall be smooth and safe.

4. Stepper Motor Requirements

To rock the cradle in one dimension with required degrees, the motor is the most important and necessary device. We are to use stepper motor. The stepper motor can serve the cradle rotation function for several reasons:

1. It can convert digital signal to shaft rotations
2. Each rotation of the stepper motor is divided into many steps
3. With many steps, it is easy to control the rotation degree
4. It can provide very smooth rotation

In order to describe the requirement for the stepper motor, the definition of torque has to be stated here:

Torque, moment, or moment of force (see the terminology below) is the tendency of a force to rotate an object about an axis, fulcrum, or pivot. Just as a force is a push or a pull, a torque can be thought of as a twist to an object. [1][2][3]

Torque is an important property of the stepper motor because it determines if the motor can provide enough force to rotate or rock the cradle.

4.1 General Requirements

[R0.13-I] The motor shall convert signal to shaft signal.
[R0.14-II] The rotation of the motor shall be divided to different steps.
[R0.15-I] The rotation degree shall be controlled with many steps.
[R0.16-I] The motors shall contain enough torque in a range of 36.8 - 82.1 Oz-in to load the weight of whole cradle system.
[R0.17-II] The voltage to load the motor shall be 24 VDC.
[R0.18-I] The motor shall go back to initial position, when motor not in use.

4.2 Physical Requirements

[R1.05-II] The diameter of the motor shall not exceed 80mm.

[R1.06-I] The motor shall be mounted in between of the cradle body and the shelf to create rotation.

4.3 Safety Requirements

[R3.07-I] All wires and motors components shall be covered in case to be isolated from surface.

5. Webcam Requirements

Other than the cradle rotation or rocking function, the monitoring feature is the most important and useful part of the system. The webcam's primary function is to send the video signal to the microcontroller and then forward to the phone application. Two important properties have to be mentioned here:

The display **resolution** or display modes of a digital television, computer monitor or display device is the number of distinct pixels in each dimension that can be displayed.[4][5][6][7] Display **lag** is a phenomenon associated with some types of liquid crystal displays (LCDs), and nearly all types of high-definition televisions (HDTVs).[8][9][10] It refers to latency, or lag measured by the difference between the time there is a signal input, and the time it takes the input to display on the screen.[11][12] The resolution is important because it affect how clear the parents can see the baby through the phone. The lag is important because if the lag gets a serious level, what the parents is seeing might not be the current status.

For the proof-of-concept product, the resolution and lag shall be in an accepted range which can provide smooth clear video signal.

5.1 General Requirements

[R0.19-I] The webcam shall maintain a clear resolution of no less than XXX pixels, with a lag no more than 0.5 seconds.

[R0.20-II] The webcam shall be capable of night vision with the infrared light in order to monitor baby at night in dark environment.

5.2 Physical Requirements

[R1.07-I] The webcam shall be secured at the footboard of the cradle with a full view of the environment of baby cradle.

[R1.08-II] The size of the webcam shall not be greater than a 50mm diameter.

5.3 Safety Requirements

[R3.08-I] The webcam and its electronic components shall be isolated from the surface beyond baby's reach.

6. Speaker Requirements

The speaker supports the function that the parents can talk to the baby, also play music. Whenever the speaker is triggered by the parents, it allows the system to achieve two functions:

1. To talk to the baby directly with parents' original voice in order to smooth the baby's emotion;
2. To play relaxing light music which help baby to relax and distract him / her from anxiety and fear to sleep faster and better.

6.1 General Requirements

[R0.21-I] The operation voltage of the speaker shall be 2.0 - 5.5V.
[R0.22-I] The volume of the speaker shall be adjustable
[R0.23-I] The speaker should be a reasonable distance away from phone

6.2 Physical Requirements

[R1.09-II] The radius of the speaker shall not exceed 50mm.
[R1.10-I] The speaker shall be mounted on the sideboard of the cradle with wires and all electronic components isolated from surface.

6.3 Safety Requirements

[R3.09-I] The speaker must be not reachable by the baby

7. Microphone Requirements

The mic supports the function that the parents can get notice in the phone when the baby is crying or screaming. In the proof-of-concept product, the mic shall be able to detect the sound of baby, which means if the baby makes sound, the mic can detect that and send signal as output.
In the final product, the mic shall be able to detect the frequency of the sound made by baby. Therefore, it can identify if the baby is crying or just snoring.

7.1 General Requirements

[R0.24-II] The mic shall have a range of frequency from 50 Hz to 20 KHz.
[R0.25-III] The voltage to load the mic shall be 3.3 - 5.3V.
[R0.26-I] The mic shall detect the baby's crying frequency.
[R0.27-I] The mic shall send output signal to microcontroller.

7.2 Physical Requirements

[R1.11-III] The size of the mic shall be 39.0 x 21.0 mm.
[R1.12-II] The mic shall be mounted and in a steady and sturdy position.

7.3 Safety Requirements

[R3.10-I] The mic shall be assembled on the cradle where baby could not reach.

8. Mobile Toy Requirements

The mobile toy plays an important role in the system because it is the most effective way to comfort baby. Rotational mechanical motor design with 6 toys hanging on 6 different arms could be triggered to rotate on constant speed to catch the baby's interest.

The Mobile toy must be attached on the headboard of the cradle stably with its arms extending in front of baby's face with a safe distance to avoid actually touching the baby.

While the toys rotates in front of baby's face, baby's attention would be greatly attracted.

8.1 General Requirements

[R0.28-III] The material of the mobile toy shall be nontoxic
[R0.29-III] The mobile toy must be able to spin.
[R0.30-III] The mobile toy is attached to secondary motor.
[R0.31-III] The colour of the mobile toy shall be bright and colourful.
[R0.32-III] The toys and arms shall be attached stably with the cradle.
[R0.33-III] The secondary motor is controlled by the microcontroller.

8.2 Physical Requirements

[R1.13-III] The arms of mobile toy shall be at a safety distance from baby's reach.
[R1.14-III] The size of the arms and attached components on the mobile toy shall be greater than 80mm.
[R1.15-III] The total weight of the mobile toy shall not exceed 0.5 KG.

8.3 Safety Requirements

[R3.11-I] The mobile toy must be not be firmly attached to secondary motor.
[R3.12-I] Secondary Motor must be hidden and inaccessible.

9. Microcontroller Requirements and Motor Driver Requirements

The microcontroller is the core device of the system. [13] It is a small computer on a single integrated circuit containing a processor core, memory, and programmable inputs/outputs. It is designed for embedded system that receives signal from other electronic devices and sends commands to them to control their status or turn on the power.

A motor controller is an electronic device that acts as an intermediate device between a microcontroller, a motor and a power supply. [14] Microcontroller works as a brain of the system which controls the direction and speed of the motor. However, motors usually require voltages and currents that exceed the limit of the microcontroller. The motor driver works as an amplifier that provides sufficient power for the motor.

9.1 General Requirements

[R0.34-I] The Microcontroller must have ADC capability
[R0.35-] The Microcontroller must have DAC capability.
[R0.36-I] The Microcontroller must have GPIO pins.
[R0.37-I] The microcontroller should have enough I/O pins both digital and analog in order to fit all the controlled functions of the system.
[R0.38-III] The microcontroller should be compact enough to fit into the circuit box of the cradle.
[R0.39-I] The microcontroller should be an open-source hardware which is easy to program with designated software
[R0.40-I] The motor driver must be compatible with the selected microcontroller model.
[R0.41-II] The motor driver should at least control two DC motors or one stepper motor.
[R0.42-I] The motor driver should have an operating voltage range (5v-12v) that fits the microcontroller's operating voltage or have a separate power supply from the microcontroller.
[R0.43-I] The motor driver should have the functions such as running, breaking, forward and reverse rotating the motor.
[R0.44-II] The microcontroller must have enough RAM and CPU speed to control multiple I/O system features at once.
[R0.45-I] The Microcontroller must be able to distinguish crying sounds from any other sound.
[R0.46-I] The Microcontroller shall have Wi-Fi connectivity.
[R0.47-I] The Microcontroller must be able to process and transmit video from webcam.

9.2 Physical Requirements

[R1.16-III] The size of the microcontroller should not exceed 80mm length * 80mm width.
[R1.17-II] The size of the motor driver should be smaller than the microcontroller and it also needs to be attachable with the microcontroller.
[R1.18-II] The microcontroller shall be mounted in constant steady place.

9.3 Safety Requirements

[R3.13-I] Microcontroller is inaccessible by baby and user.
[R3.14-II] The microcontroller shall be enclosed separately from other components.

10. Android Application Requirements

Android is a mobile operating system which is based on the Linux kernel and designed mostly for smartphones and tablets. Android applications provide user an easy and user friendly interface on mobile devices to directly manipulate the mobile devices or remotely control other electronic devices. [15]

10.1 General Requirements

[R0.48-III] The App needs to be compatible with every smartphone and tablets with android system.
[R0.49-III] The App must be clean and easy on user eye to look at.
[R0.50-III] The App should have a user friendly interface which allows users to easily control every features of the product.
[R0.51-II] The App must provide notification to parents
[R0.52-I] The App must communicate with Microcontroller.
[R0.53-I] The App must have Bluetooth or Wi-Fi connectivity.
[R0.54-III] The App program source code needs to be short and effective in order to increase the operating speed.

11. User Documentation

The user documentation shall include the logo of the company, contacts information, potential website with general and technical support information, and a user manual, written in English, French, Spanish, German, Traditional Chinese, Simplified Chinese, Japanese, and Korean to satisfy the international markets.

11.1 General Requirements

[R0.55-III] The user manual shall be written for audience with minimal knowledge of electronic devices.
[R0.56-III] The user manual must be straight forward and simple to understand.
[R0.57-III] The use documentation shall include a detailed installation guide for users.
[R0.58-III] The user manual has to provide adequate pictures when applicable.

12. Conclusion

These requirements are used by Baby Rock as a guide to developing the Smart Baby Cradle. With these requirements, Baby Rock will provide a safe efficient product for the user. It has been split amongst nine requirements:

System: The system as a whole.
Cradle: The Protective Environment for the Baby
Stepper Motor: The mechanism that rocks the Cradle

Webcam: Ability to see the Baby
Speaker: Provides relaxing music as well a vocal communication for the baby.
Microphone: Ability to detect the crying of a Baby
Mobile Toy: A distraction for the Baby
Microcontroller: The heart of the System
Android Application: The user control of the System

These requirements also are split between what the Smart Baby Cradle will have during the prototype and Final product. Some of these Requirements will need to be cleaned up or not essential for the product to function. With the final version of a product, the Smart Baby cradle will provide the User a convenient simple way to monitor their baby.

13. References

[1] “Wikipedia,” Wikipedia. [Online]. Available at: https://en.wikipedia.org/wiki/Torque#Terminology. [Accessed: 14-Feb-2016]

[2] “Wikipedia,” Wikipedia. [Online]. Available at: https://en.wikipedia.org/wiki/Force. [Accessed: 14-Feb-2016]

[3] “Wikipedia,” Wikipedia. [Online]. Available at: https://en.wikipedia.org/wiki/Lever. [Accessed: 14-Feb-2016]

[4] “Wikipedia,” Wikipedia. [Online]. Available at: https://en.wikipedia.org/wiki/Digital_television. [Accessed: 14-Feb-2016]

[5] “Wikipedia,” Wikipedia. [Online]. Available at: https://en.wikipedia.org/wiki/Computer_monitor. [Accessed: 14-Feb-2016]

[6] “Wikipedia,” Wikipedia. [Online]. Available at: https://en.wikipedia.org/wiki/Display_device. [Accessed: 14-Feb-2016]

[7] “Wikipedia,” Wikipedia. [Online]. Available at: https://en.wikipedia.org/wiki/Pixel. [Accessed: 14-Feb-2016]

[8] “Wikipedia,” Wikipedia. [Online]. Available at: https://en.wikipedia.org/wiki/Phenomenon. [Accessed: 14-Feb-2016]

[9] “Wikipedia,” Wikipedia. [Online]. Available at: https://en.wikipedia.org/wiki/Liquid_crystal_display. [Accessed: 14-Feb-2016]

[10] “Wikipedia,” Wikipedia. [Online]. Available at: https://en.wikipedia.org/wiki/High-definition_television. [Accessed: 14-Feb-2016]

[11] “Wikipedia,” Wikipedia. [Online]. Available at: https://en.wikipedia.org/wiki/Latency_(engineering) . [Accessed: 14-Feb-2016]

[12] “Wikipedia,” Wikipedia. [Online]. Available at: https://en.wikipedia.org/wiki/Signal_(electronics) . [Accessed: 14-Feb-2016]

[13] “Wikipedia,” Wikipedia. [Online]. Available at: https://en.wikipedia.org/wiki/Microcontroller. [Accessed: 14-Feb-2016]

[14] C. Benson, “RobotShop,” RobotShop, 10-Nov-2010. [Online]. Available at: http://www.robotshop.com/blog/en/how-to-make-a-robot-lesson-5-motor-controller-3695. [Accessed: 14-Feb-2016]

[15] “Wikipedia,” Wikipedia. [Online]. Available at: https://en.wikipedia.org/wiki/Android_(operating_system) . [Accessed: 14-Feb-2016]