19-697

Modern Prototyping Techniques

Lullaby

A smart solution for better sleep!

Final Report

Rachel Gertler, Kero Mikaeil, Neha Sharma,
Jeremie Pocachard, Kelsey Scott

Table of content

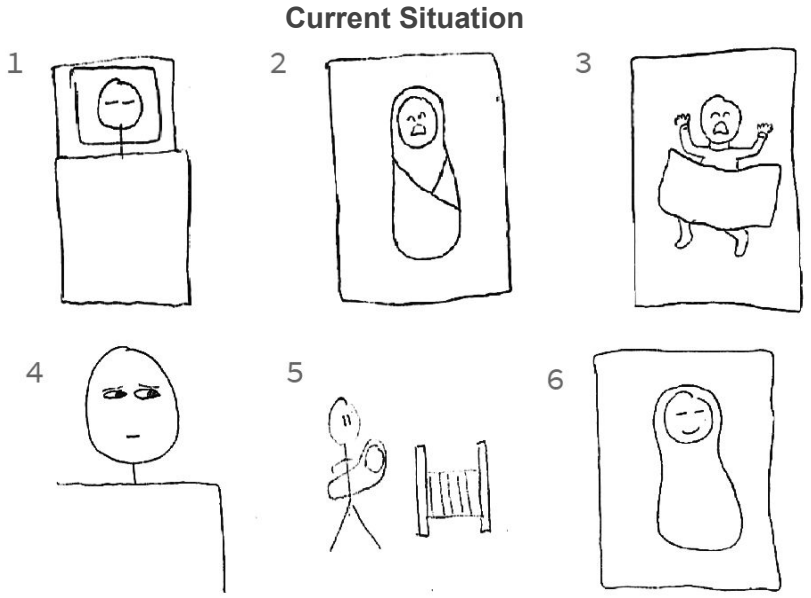
1. Product Proposal

Introducing: Lullaby! Lullaby is a smart monitoring crib insert for children under 3 years old. Our product is composed of three pieces; a plush electronics console, a mattress pad, and a baby mobile. The mobile application interfaces with these pieces integrates IBM's Watson and Bluemix platforms. Lullaby provides a real-time monitoring and customizable automated comforting system to discover, detect, and help parents care for their sleeping child.

Our goal was to ultimately provide parents with a reliable and trustworthy system to give them operational suggestions and remote control to monitor their child in the crib. This is done through video streaming to an application on their phone from which the parents can access anywhere. The crib will also learn how to best put the child to sleep by providing lullabies, music, and white noise patterns so that parents can get to bed sooner, and stay in bed longer. When a baby begins crying during the night, the smart crib monitoring system will log and alert the parents of the most likely cause of discomfort or distress, and it will also decide upon an autonomous response for the crib to help reduce child discomfort.

Babies naturally wake up and cry during the night, soliciting parents to come and comfort them to get their babies to fall back asleep. But some of these comforting mechanisms such as making soft noises, playing music, and rocking their babies can be automated! Lullaby learns what types of comforting mechanisms work best for each individual baby, and puts them back to sleep without the parent having to be woken!

2. Problem Overview



In the above story, you can see a parent happily asleep at 3 am when their child begins to cry. Statistics show that the average newborn wakes up every two to three hours, and as many as 30% of children wake up at least once a night up through age 7[1]. This, of course, can wake the parent up. The parent then goes into the child's room to comfort the baby and put him/her back to sleep. Depending on the child's discomfort, this could take five minutes or could take an hour. Beyond the single instance duration, some children wake up more than two or three times in a given night. Considering this well-known parenting scenario, we were able to identify the following product opportunity gap:

> *There exists an opportunity to improve the quality of sleep of parents by providing them with assistance to reduce the number of times they must attend to a child at night and to reduce the duration of these assistance trips.*

To begin developing a solution to meet this product opportunity gap, we explored a variety of social, economic, and technological (SET) factors that could influence the type of design that would best fit in the current market.

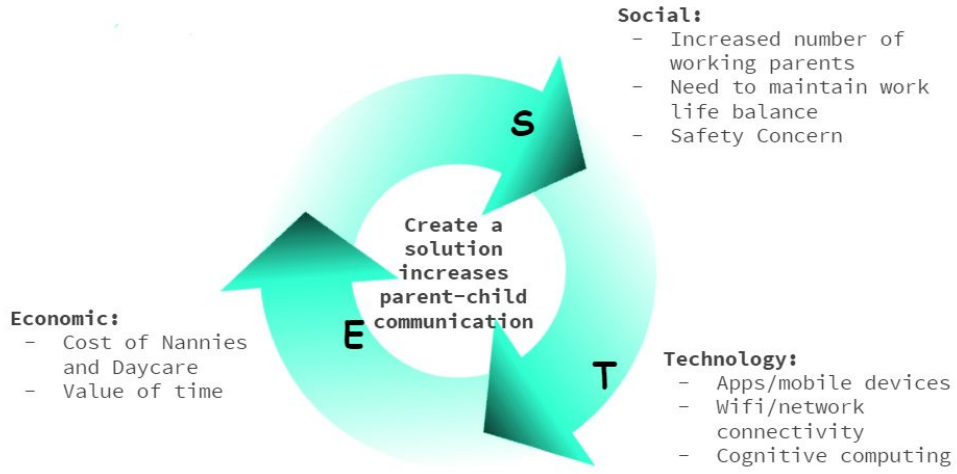


Figure 1: Social, Economic, and Technology Factors for our opportunity gap

3. Target Market

There are approximately 4 million children born in the United States every year[2]. Children generally use cribs from shortly after birth to three years old[3]. Ultimately, there are approximately 12 million children sleeping in cribs at a given time. Around 60% of married US

[1] http://www.parentingscience.com/night-wakings.html
[2] https://www.nichd.nih.gov/health/topics/infantcare/conditioninfo/Pages/born.aspx
[3] http://www.babycenter.com/404_how-and-when-should-i-move-my-child-from-a-crib-to-a-bed_4598.bc

families with children (25 million total [4]) have both parents working full time[5], making getting a restful night of sleep essential for not only their healthy, but also their financial stability.

The Lullaby product will target these 15 million working families, as the product would provide the largest benefit to these families. Due to the vast size of this market, there is a large market opportunity that would likely span the upper millions in revenue annually (15 million families with two working parents, paying $100 would be $1.5 billion in revenue). Given that the solution will require trust between parents and technology to care for their child, hesitation in adoption is anticipated, however the rising trend in available and purchased technology makes Lullaby especially appealing to young parents.

4. Value Opportunity

In order to address parents' needs to get a sound sleep at night but also maintain the health, comfort, and safety of their babies, Lullaby will provide the following advantages:

1. Reduce number of times the baby cries in the night
2. Reduce discomfort to the babies.
3. Reduce the number of times parents have to wake up to comfort their child, ultimately Increasing the time parents sleep during the night
4. Increase the parent's understanding of their child's behavioral cycle

If Lullaby can successfully curb one or two cry incidents a night, parents will likely be able to get 30 minutes to an hour more sleep per night. This equates to 3 to 7 hours per week or 180-365 hours per year of increased sleep. It is estimated that an increase in average sleep by one hour correlates with an increase of 16% in a parents wages[6], making Lullaby not only a convenient, but also a highly economically valuable product.

5. Detailed Description

Lullaby is a system comprised of essentially three parts:The Smart Crib Insert, Intelligent Cloud Platform, and a supporting Mobile Application

Smart Crib Insert: The Crib consist of all the accessories that will help in pacifying the baby in case of any discomfort detected.

[4]http://www.heritage.org/research/reports/2014/11/how-welfare-undermines-marriage-and-what-to-do-about-it
[5] http://www.bls.gov/news.release/famee.nr0.htm
[6] http://online.wsj.com/public/resources/documents/091814sleep.pdf

Intelligent Cloud Platform: A platform that comprises several machine learning tools and services, that will collect child's behavioural data, will perform predictive analytics based on past learning experience and take actions based on the decisions.

Mobile Application: The software mobile application will act as an two-way interface medium between the crib and parents, that will provide all the information regarding the baby's environment, log of the actions taken as well as take the commands from the parents to perform any particular function.

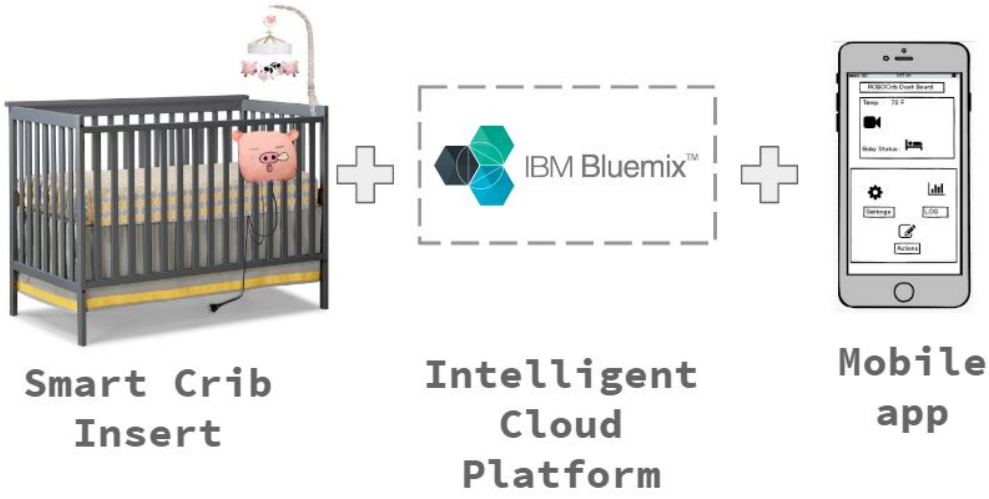


Figure 2: Three piece system that makes up Lullaby

All three parts interact with each other, creating an intelligent monitoring system that is easy to use and also has the ability to learn! Parents interface with the mobile application to monitor their baby through a live streaming video, and they also have the ability to remotely control the comforting mechanisms in the crib. For example, parents can remotely control different music or noise that plays through the speakers on the baby mobile hanging above the crib, or they can control the rocking motion of the mattress pad. All the while, a video camera is also mounted on the baby mobile which gives a clear "birds eye view" of their baby. In the settings feature of the mobile application, the parents or other system administrators can dictate how much autonomy they are willing to designate to the system. We are aware that parents vary greatly in their degree of autonomy they are comfortable with. This means that Lullaby can automatically take control of certain mechanisms (music, rocking, etc.) or give suggestions to the parent of what types of actions the system suspects will help the most at a given time.

6. Prototypes

6.1. Prototype 1: Smart crib concept

The first prototype we created aimed to answer the following question:

What circumstances would surround parents' and babies interactions with the smart monitoring crib?

How will parents engage with the monitoring system? How will the system interact with the baby in the crib? To answer these questions, we brainstormed ideas for certain storyboard situations. We knew discussing these situations with our team and getting feedback from parents would provide a lot of information about the system as a whole. In turn, the information would affect all parts of the design, from the sensors that are used on the physical system, to how the UI will be designed to best serve the parents, and even how the Bluemix AI evaluates and interprets the data. To target this information, we discussed a few different scenarios and created storyboards to present to parents of young children. The scenarios were created to allow us to test parents' willingness to have the crib act autonomously, gain feedback on a variety of different crib reaction methods, discuss the prefered alert type system, and begin discussing potential safety or privacy concerns. These target areas allowed us to create a basis of knowledge from which to continue prototyping and developing a GUI, identify sensors, and create a physical product mockup in the following sprints. The storyboards can be found in Appendix A.

AI Feedback:

One surveyed user was a woman with two kids, one two years old and one four years old. She's in her mid 30's and recommended we explore the learning time for the AI. She noted that each child, in her experience, has a different sleep cycle, and she wanted to know how much time it will take the AI to learn the trends for a particular baby for the system to start responding accordingly. This was extremely important for us to take into account as we developed our pseudo code and AI framework, because if it took 5 months to learn the trends and behaviors, the baby could develop a whole new set of trends and behaviors over that period.

Many users also identified a trust issue that will affect the system: are parents willing to trust the AI to learn how best to address the needs of their children? We are airing conservatively on the side of "not entirely" so we're thinking about ways the AI can make confident-level suggestions and how the app can be customizable to allow parents to feel control in enabling the crib responses. For example, the parents may be able to pre-authorize a certain subset of the autonomous crib responses for the AI to employ without notifying the parent. Alternatively, the parents could set a crying time duration or a frequency or loudness boundary condition that would serve as the threshold for parent notification.

Along the same lines of trust, another point that many parents addressed was that the quality of the product, as parents are highly sensitive to baby product quality. The AI part of our system is exciting and intriguing, but some parents were a little hesitant that it will work as seamlessly as we propose. The concerns brought up were what if the AI causes false alarms? Takes incorrect actions? Or gives incorrect notifications to the parents? There are many cribs and monitoring systems on the market, but what differentiates this product is the ability for our monitoring system to quickly learn and predict babies' rapidly changing behaviors. Thus, in order to create customer confidence with this unique capability, the predictions must be accurate and reliable.

Monitoring Feedback:

Another specific user feedback was from a 24 year old woman who works as a full time nanny to two young children. She currently uses a low-quality video monitoring system, but cannot adjust the audio or control the image quality. The ability to stream video to her phone with a higher resolution is ideal, as it would allow her to see the situation of the napping children while she is working elsewhere in the house or even share the video with parents who could be concerned about their child while at work. She said, "especially for new parents who are leaving their kid at home for the first time it would be a big comfort to be able to check in and get an unfiltered view of 'everything's fine.'"

A suggested additional feature was to add image or video recording capabilities. A surveyed user said proposed that a way to capture and save videos from the feed like if they did something really cute like rolling over or sneaking out of their crib to have for keepsake.

Music and Sound Feedback:

The general reaction to having an auditory component was favorable. In addition to having preset tracks, one user suggested having a way to add your own recorded voice to the system to play when the baby. A simple message like "mommy loves you" or a longer track of the mother's voice reading a book or singing a lullaby would be a great way for the AI to mimic the parent and hopefully sooth the child automatically while still imprinting a positive memory for the child.

Additionally, a few users suggested using a white noise machine to sooth the baby. Many day care centers use these to drown out potentially scary or shocking environmental Some people kept mentioning the use of a white noise machine that they saw was effective in soothing a baby. We think it would be beneficial to have a plethora of sounds, noises, lullabies, and music to choose from, and the AI could learn what works best for the child.

6.2. Prototype 2: User Interface

The second prototype we created aimed to answer the following question:

What will the user experience of the mobile application look like, and what capabilities should it have?

The smartphone app is controlled by the parents, nanny and/or caretaker of the baby and can be accessed anywhere he or she brings her phone. Its main use is to monitor the baby while he/she sleeps, and to receive alerts if the baby is crying with informed guesses as to why the baby is crying. It also provides a parent remote control over sounds, music, rocking motions, and other automated responses to soothe the baby in the crib.

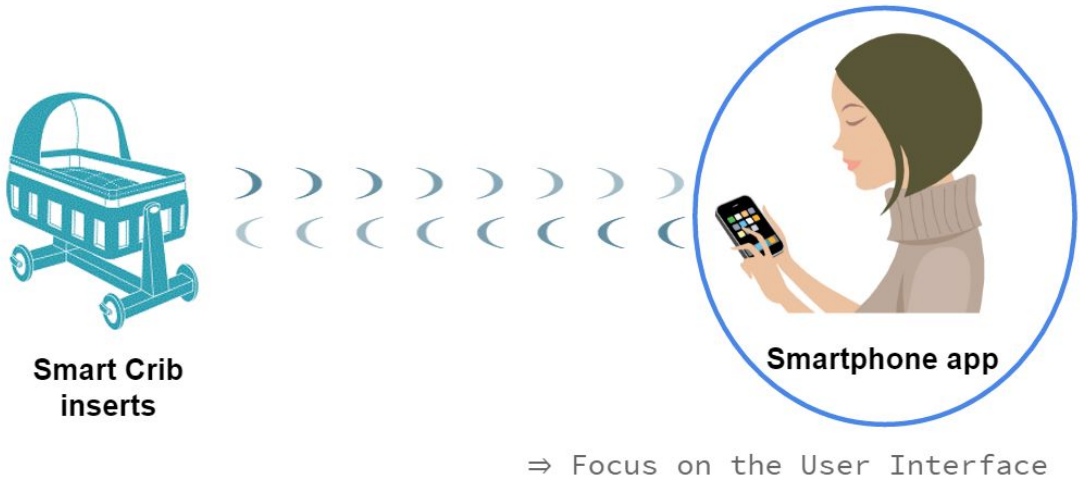
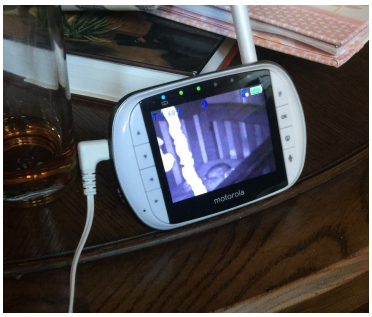


Figure 3: Mobile smartphone application interacting with the smart crib insert

The app should be simple and easy to use. Various features, including the video stream should be quick to access, and the app should provide clear indications of the possible cause of crying with confidence levels and the corresponding best actions to reduce the discomfort causing the distress. We conducted a Sprint in order to prototype what this app might look like and how the parents might interact with the notification system.

To begin planning, we examined the current solutions to remote baby monitoring and enumerated the information that might be desired by parents, as determined from the previous sprint.



Current Situation

Existing model of a video monitoring system:

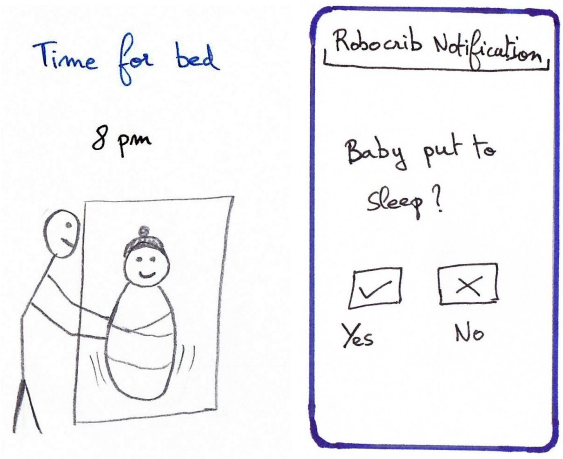
- Very poor video quality
- Cannot adjust audio
- Small battery
- Limited mobility
- Alerts, but does not interpret crying

Low Fidelity UI Sketches

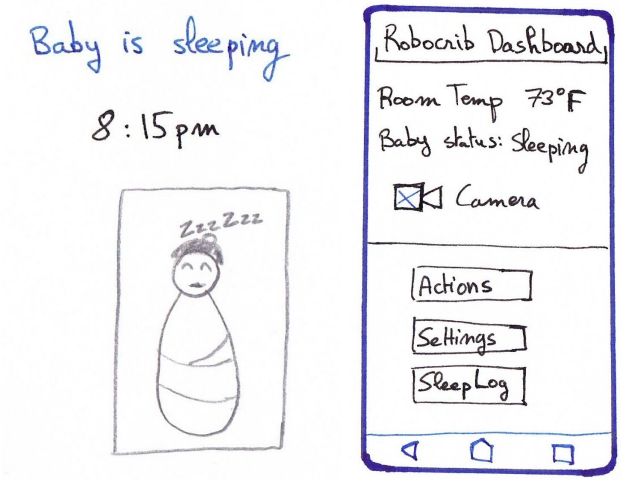
We first developed a low fidelity user interface (UI) using sketches. This initial prototype is the result of our previous brainstorming and heat map. The minimal viable features identified in the

heat map have been integrated into the UI. Our low fidelity sketches follow along with a typical use of the product at night. The left half of the sketch describes what is actually happening in the baby's bedroom, and the right half displays the information displayed on the parents' smartphones through the application.

Time for bed:
Parents put the baby in its crib. Almost immediately, the Lullaby detects the baby's presence in the crib and displays a notification on the parent's smartphone. It asks them to confirm if the baby is going to sleep, this is the starting point of the night.

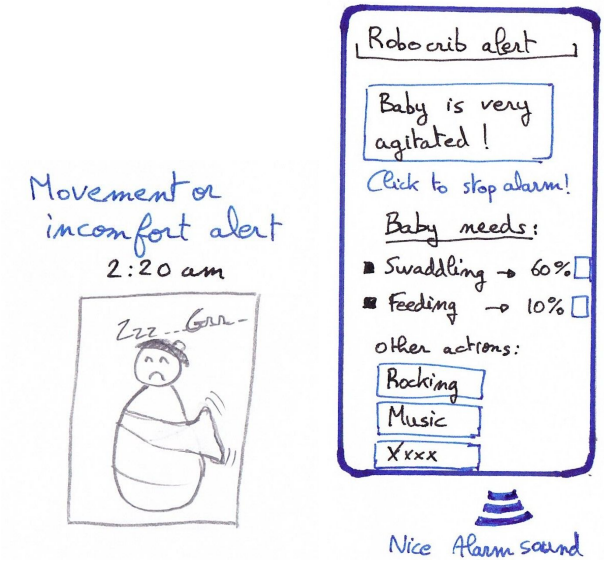


Baby is sleeping: A couple of minutes later, the baby is now sleeping soundly. The parents can consult the app anytime to check the baby status through the app dashboard. It informs them about the room temperature, if the baby is actually sleeping, and also provides the option to watch the baby remotely through a camera. Also from the dashboard, the parents are able to configure the app or consult the sleep log of previous nights.



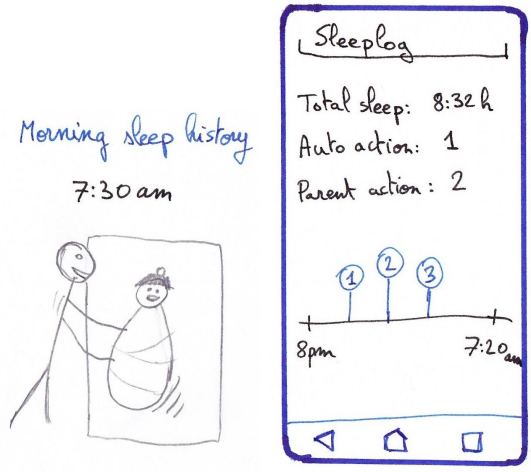
Crying alert: In the bedroom the baby is crying and the Lullaby has detected it. The AI interprets the possible causes of the crying. The app begins sounding a gentle alarm to wake up the parents and displays an alert to shows that the baby is crying. The app displays a list of possible actions to be performed by the parents, according to confidence levels calculated by the AI of the system. Here, the baby very likely needs to be fed.

Agitation alert: The system detects the baby is agitated. The baby is still sleeping but probably not for much longer. The AI decides to plays a nice alarm sound to stir the parents and displays an alert. It proposed a list of different potential upcoming needs based on confidence levels for the baby and a list of actions that can be initiated remotely to preemptively restore comfort to the child.



Discomfort detection: In this case, the baby is still sleeping but begins showing signs of discomfort. No message is actually displayed on the app and the parents are not woken up. The AI decided to launch an automatic action. It knows that rocking the crib gently for 10 minutes generally helps the baby to sleep tight again. A sleep log entry is recorded.

Morning sleep history: After taking the baby out of the crib, the parents can consult the sleep log. It shows them how long the baby slept and shows the different times and types of actions occurred during the night. This includes both the actions and notifications the parents received and the actions the crib took autonomously.

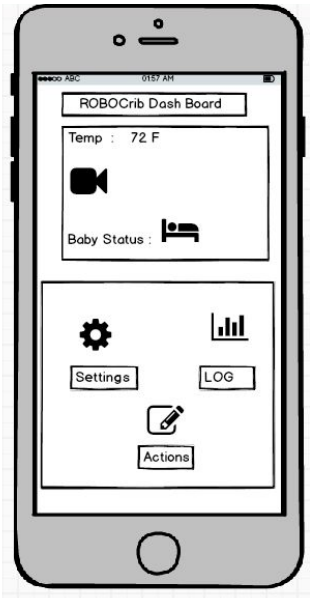


UI prototype - Medium fidelity

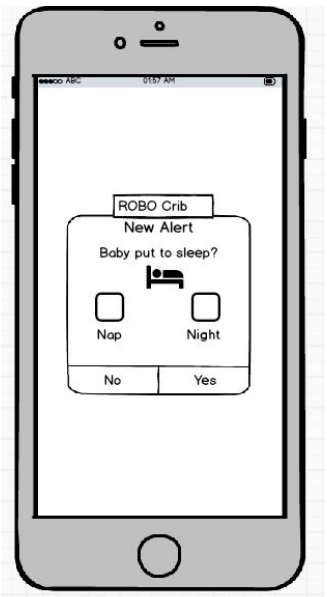
Based on some of the feedback from team members and the initial few potential customers consulted, a medium fidelity mockup was created and used to gather additional feedback. These new mockups represent a slightly more faithful rendering of the application and were well

received by our interviewed potential customers. This new version allowed us to gain further insight on the functionality of the app, the flow of the app and sleep notification process, and to hear more concerns parents may have about the system and application.

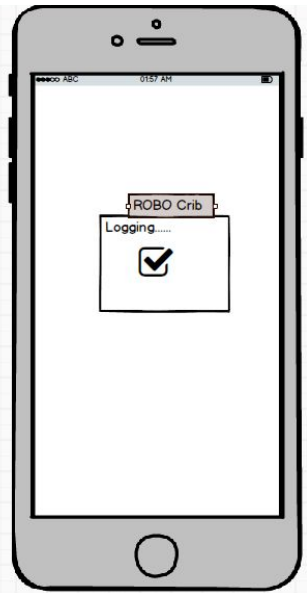
Time for bed



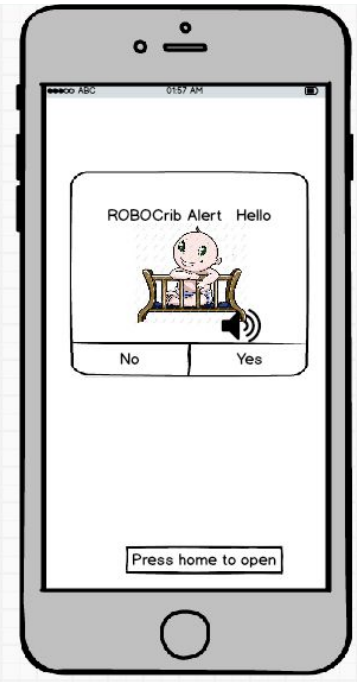
Loading Screen



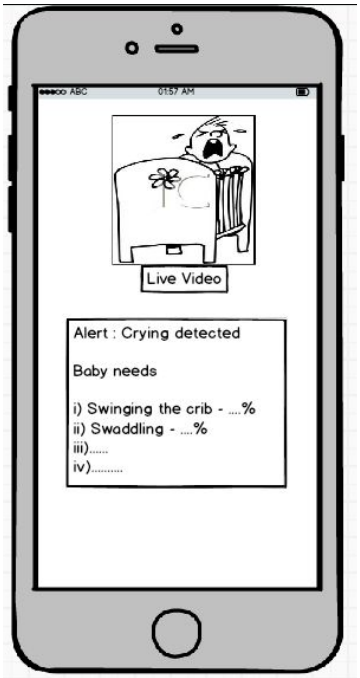
Baby is sleeping



Crying alert



List of actions proposed



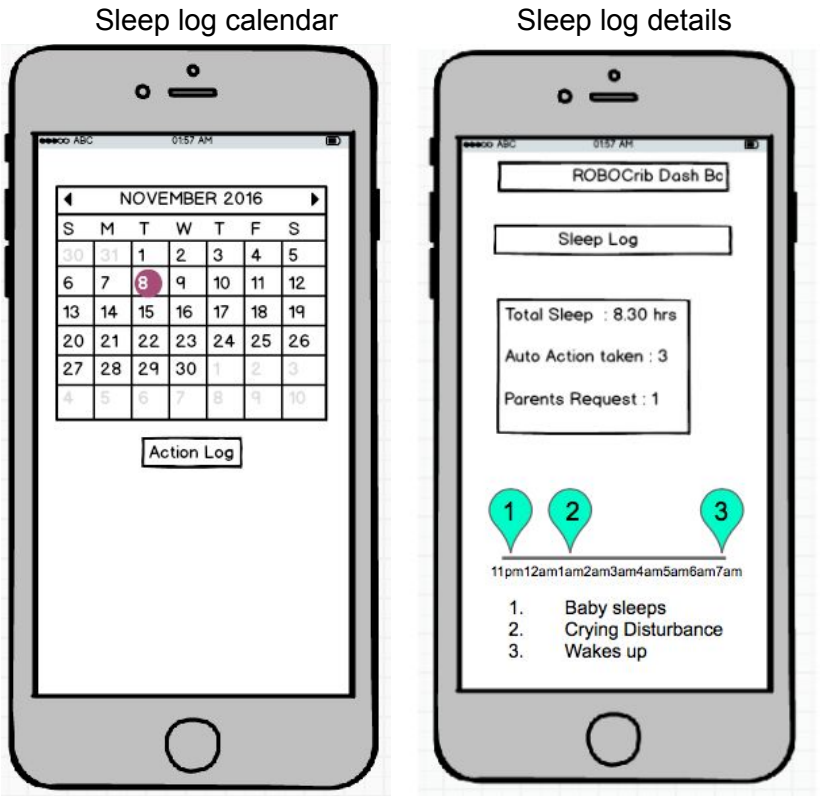


Figure 4: High fidelity user interface mobile application for Lullaby

User Feedback:

The AI abilities and actions that can be automatically engaged should be easily enabled or disabled to allow for customizable levels of autonomy. The app and the system should be able to make the distinction between a nighttime sleep and daytime naps, since the needs of the child are not the same. Some surveyed parents expressed interest in having the sleep log be displayed as a calendar, since this would be the most intuitive way of recording the time data. It should be possible to see the sleep log before the end of the night to track of a child's sleep progress and incidents. The parents can therefore check if the baby will have had enough sleep when it is awaken. This will help the parents to know when to or not to wake the baby. Sometimes the action taken by the parent may not be identical to the AI's best prediction. It would be very constructive for the AI learning process to have to possibility to use the sleep log to manually edit the type of actions taken to calm the baby. Some user feedback shows an interest in having the possibility to consult the app remotely. If a babysitter is taking care of the baby, it is normal that she will have the full control of the Lullaby app, however it would be great

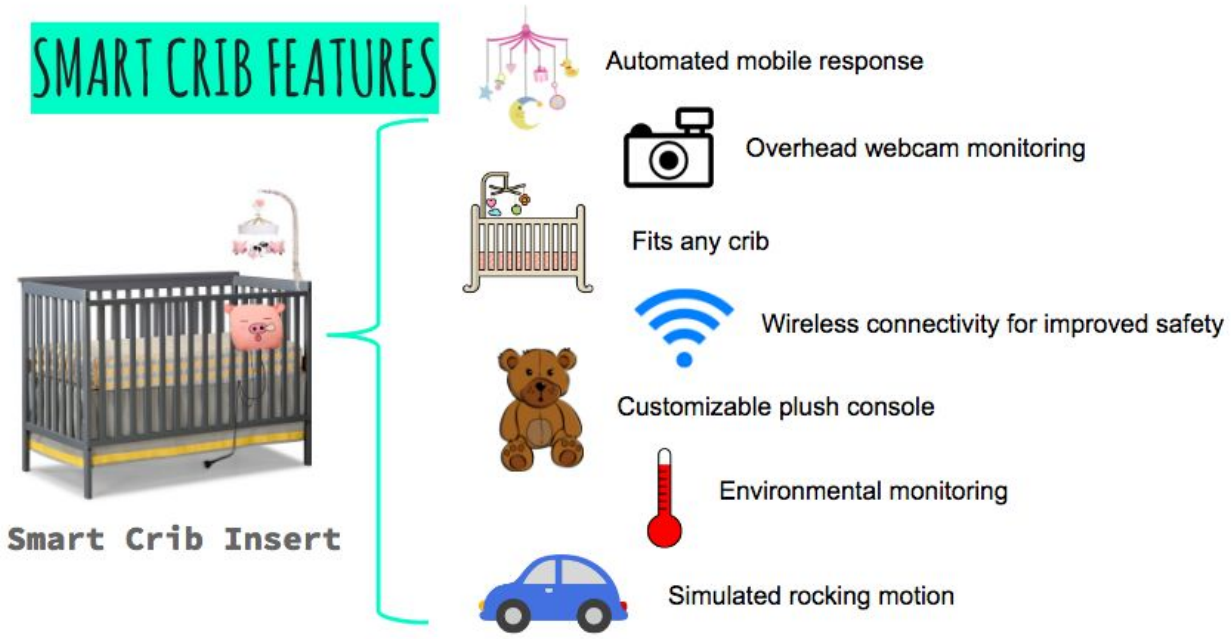
for the parents, who may be having dinner in a restaurant, to have access to the dashboard and the camera for monitoring purposes. The same would also benefit grandparents who would like to see their grandchildren sleeping. The system will be equipped with a camera and multiple sensors. Privacy of the information utilized by the app, especially the video content, must be highly secure in order for parents to consider trusting the application and system.

6.3. Prototype 3: Form factor

The third prototype aimed to answer the following question:

What will the form factor for the product be and how does this fit in the system?

Through discussions with potential customers, we discovered that oftentimes these families invest heavily into the visual appeal of their nurseries. This lead to our third prototype focusing on the form factor specifically. At a high level our goal was to create a visually appealing product that could easily integrate into any existing nursery plan. We realized that each family would purchase different cribs leading us to focus on the crib insert that could integrated opposed to an actual crib as a solution.We then considered that our product required sensors that would need to connect to the internet thus had to make considerations as to wifi connectivity. Another consideration was that the product should be “wireless” meaning to avoid as many wires as we could because parents didn’t want wires near their children. With these considerations we created a Photoshop Mockup of the product with the key features highlighted below.



This prototype was critical in being able to communicate potential form factors to our end customers. By having this prototype, we could then ask specific product feature questions to gauge wants/needs to quickly iterate on the form factor.

We created a mockup of the system to present to parents to gain feedback about the form factor, particularly any related safety concerns they may have. By having a virtual model of the system, we were able to show how the system would fit into a family's nursery. It will also allowed parents to visualize the product and give us further insights about what is and is not desirable to parents with young children. We were able to use interviews with parents to guide our team's system design and iterate to determine a more ideal form factor. We started with a plethora of low fidelity sketches and combined the good features of each to create the "final" virtual prototype to use for feedback collection, however further iterations on the final form factor would be desirable moving forward in system development.

Figure 5: Photoshop rendering of Lullaby three piece crib insert

6.4. Prototype 4: Bluemix and System Interaction

The fourth prototype aimed to answer the following question:

How will Bluemix be utilized for Lullaby ?

IBM Bluemix & System Architecture

We created a network diagram of the required Bluemix and Watson packages and capabilities that will be utilized in the Lullaby AI. This allowed us to consider the input/output requirements for the physical system. A secondary goal of thinking through the various software components is to be able to inform parents of other secure applications of these same modules, if applicable. By comparing to other trusted brands, we may be able to mitigate some of the parent's security concerns. Ultimately, however, the goal is to understand how the app software, the cloud software, and the physical product will all interact.

Ultimately we believe that three main services within IBM Watson will be the most effective in moving forward with our prototype:

1. **Visual Recognition:** understand images and develop patterns and classifications based on these images
2. **Tradeoff Analysis** : leverages pareto optimality when considering what response is best to care for your child
3. **Discovery :** analysis both structured and unstructured data to make smart decisions

Bluemix will interact with both the crib and mobile application ultimately creating a synergistic relationship. Figure below shows this interaction at a high level.

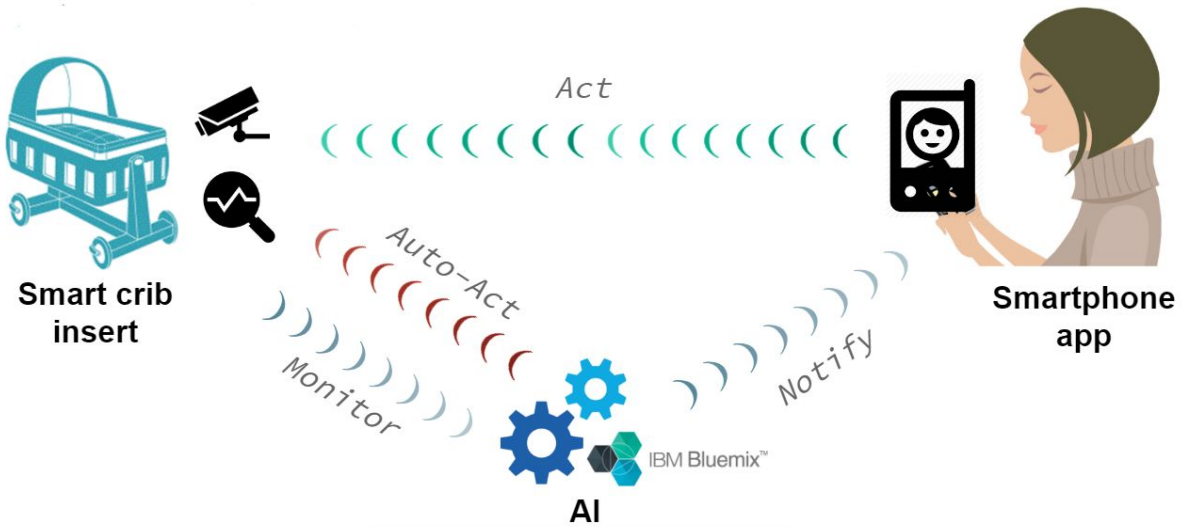


Figure 6: Diagram of how Lullaby works from the big picture: interaction between the user and the mobile application, the crib insert interacting with IBM Bluemix, and IBM bluemix informing the application

The Crib and Bluemix interactions occurs in two ways. The crib sends Bluemix sensor data from its peripherals and receives actions in the form of vibration, spinning, etc. The diagram below shows this interaction at a high level.

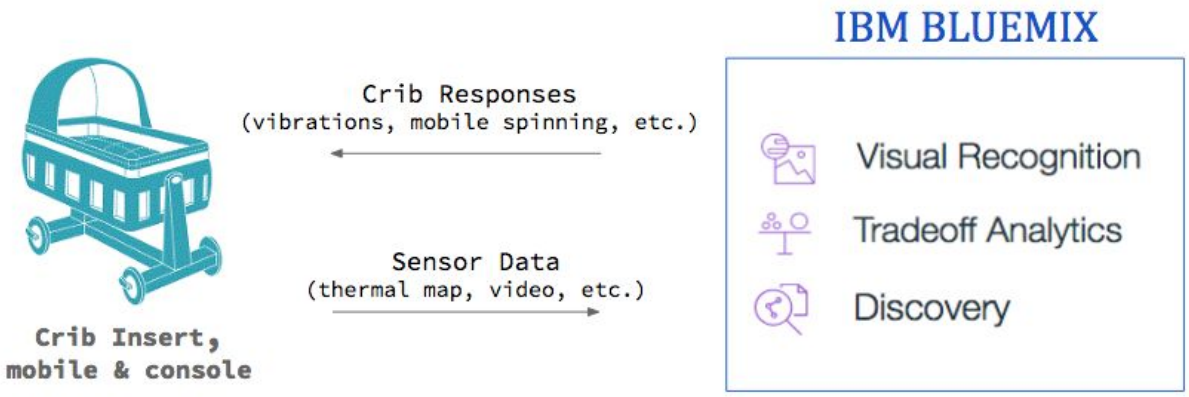


Figure 7: Crib Insert and Bluemix Interaction

Similarly the mobile application interacts with Bluemix in two ways. The user sets preferences to bluemix and the user receives notifications such as video feed when an event occurs. The diagram below shows this interaction at a high level:

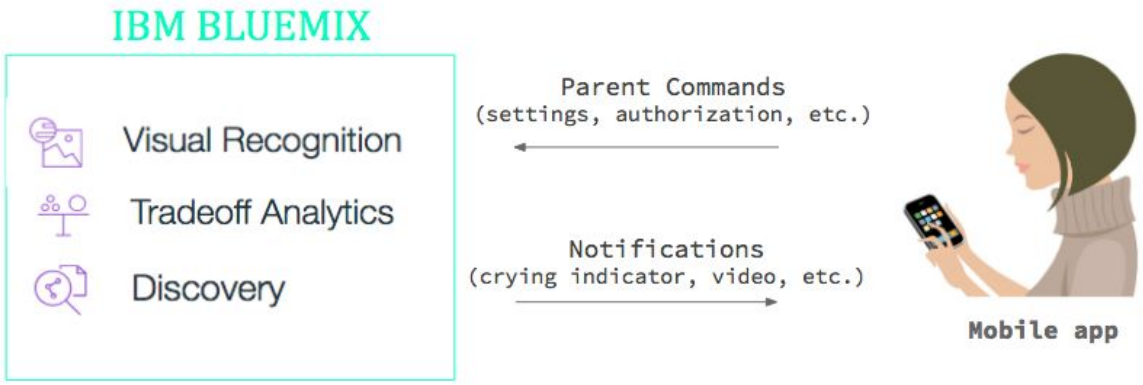


Figure 8: Mobile Application and Bluemix Interaction

7. Final prototype

Lullaby is a customizable nursery monitoring and comforting system. The crib inserts (mattress pad, baby mobile, and electronics console) fits any size and shape crib, and the color schemes and themes can be customized to fit any nursery style. The baby mobile has a video camera to monitor the baby from a bird's eye view, and speakers to play any kind of music or noise. Lullaby learns what types of comfort mechanisms work best for each individual baby, and logs the actions away in a sleep log for parents to access. Lullaby takes action during the night to comfort restless babies so that parents don't have to be woken up as often! The entire family gains in sleep quality and the parents are also less worried by knowing that Lullaby take good care of their baby.

Below is a picture of what Lullaby looks like in action! The plush pig console fits the zoo/animal theme of the nursery, and the system is aesthetically pleasing.

Figure 9: Image of Lullaby installed seamlessly into the baby nursery

8. New situation

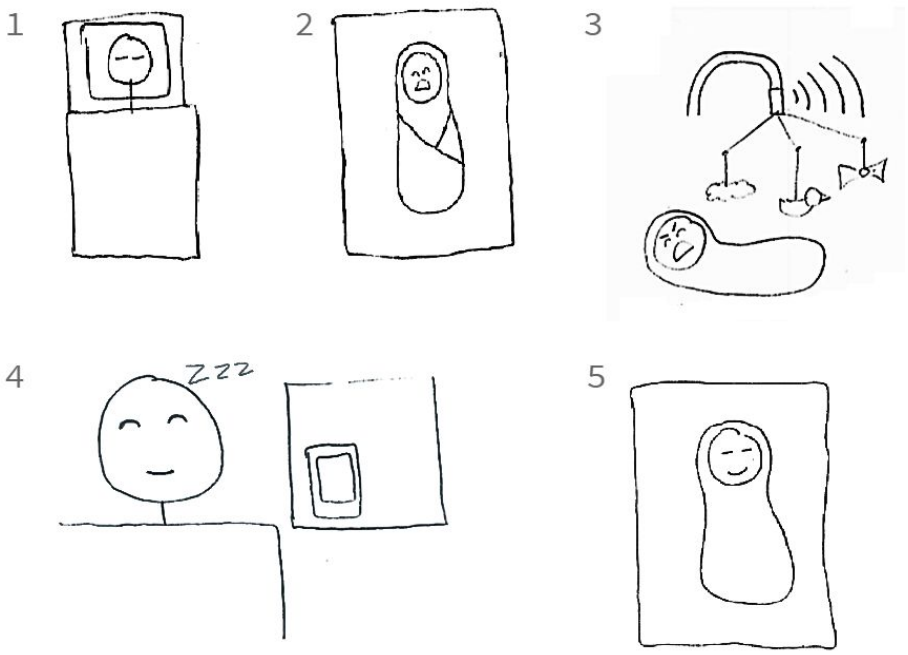


Figure 10: Storyboard depicting a parent sleeping, a child waking up, Lullaby playing some music and spinning the mobile, and falling back asleep without the parent waking up at all

Now imagine the parents of a young infant baby installed Lullaby. The parent is asleep in his/her bed after just putting their baby to sleep. The baby starts getting restless two hours later, and the system has learned that around this time of restlessness, simply playing some white noise helps the baby fall back to sleep. The mobile starts playing the noise, and five minutes later, the baby is back asleep. Lullaby records the time the baby started getting restless and logs the action (playing white noise) in the sleep log in the app. At 3am, the baby starts wiggling around in their swaddle and starts waking up. The mobile plays some white noise, which does not seem to help, but then switches to Mozart and also begins rocking the baby gently. This calms the baby down and the baby goes back to sleep twenty minutes later. Again, the system takes note of all these actions, logs them away in the sleep log, and never needs to alert the parent that their baby needs comforting because the system did it autonomously. The parent wakes up well-rested the following morning and can see that Lullaby took three actions at two different times that night.

The next night, the baby gets restless again at 4am, but this time, Lullaby anticipates that the baby will wake up crying, so the AI makes an informed decision to gently alert the parent that their child will start crying in a few seconds, so the parent can get a quick head start at comforting their child.

All in all, parents are saved from a few times a week they otherwise would have had to get up in the middle of the night, and overall get more sleep!

9. Customer Feedback

After all three prototype pieces were devised, we asked for some customer feedback on the system as a whole. We got a lot of very positive feedback for the three piece crib insert. People mainly said that they were cute, simple pieces that were not intrusive. That was one of our team's main concern, that the console would seem intrusive or intimidating, and that parents would have a difficult time trusting a robotic looking console attached to a baby crib. But the plush pig pillow was "cute" and "welcoming."

We were also concerned about the placement of the camera which is an essential part of one of the Lullaby feature i.e. required for the facial expression recognition of the baby to detect its discomfort. We didn't wanted to place it somewhere that would give the impression that the baby is under some surveillance and so we decided to integrate and position it at the center of the mobile. People really liked the idea of having it camouflaged with the mobile so that it doesn't look too much of a monitoring device and still performs the function.

Another concern we had was the cord that powers the console. Parents could not emphasize enough the importance of keeping the crib absolutely safe with no risk whatsoever of strangling or tangling the baby with the power cord. We took these concerns seriously, and that is why we plan to only have one cord that powers the entire console coming out from the bottom of the plush pig towards the outside of the crib. The mattress pad sides are high enough to completely block the cord from the baby's reach, and the pig console is large enough so that parents have to attach it low enough on the crib itself to have it fit. The lower the pig head attaches, the less amount of cord is really within reach of the baby. If the pig head was smaller, parents could accidentally attach it higher up on the crib and there would be more exposed cord for the baby to potentially grab.

10. Product differentiation

Different solutions on the market exists to help parents with their baby. We identified 3 main groups of ability that can be performed by baby system: monitoring, comforting, intelligence.
Baby monitoring systems are usually equipped of a microphone and a camera. Babies Swings are able to perform rocking and other movement actions. On the overall, none of the options on the market combine these three abilities and particularly the possibility to interpret the data coming from multiples sensors and decide of the appropriate action. This is what makes our solution, Lullaby, so unique on the market.

	Baby monitor	Baby Swing	Lullaby
			
MONITORING	✓		✓
COMFORTING		✓	✓
INTELLIGENCE			✓

Figure 11: chart comparing other baby systems and their capabilities to ours, Lullaby. Lullaby checks off all three parameters of monitoring, comforting, and intelligence.

11. Reflection

This project prototyping provided a lot of insight in terms of our group strengths and dynamics. We thoroughly enjoyed each one of the sprints because it allowed us to free formly flow our ideas together and address each other's concerns immediately. The most helpful step was making the "How Might We" sticky notes because we were able to note where we all had questions in overlapping sections. We chose to concentrate our efforts in the sections where we had the most "How Might We" sticky notes. Our group had tremendous synergy and we all started thinking of many outside the box ideas, and were eager to add more and more features to our crib design. The hard part was taking a step back, realizing that we cannot add all these features to our crib, and we had to choose the most compelling but feasible features we could add. Scope creep, as in many other project procedures, was our biggest challenge. We were able to apply processes such as heat mapping to help guide us and mitigate our scope creep tendencies.

Some of the most obvious characteristics of our group that came out during the sprint sessions were mutual respect, enthusiasm, and creativity. Most conversations were constructive and encouraging, and we didn't shy away from out of the box thinking at the beginning. Every team member was actively writing on the board, generating questions, and thinking critically. This atmosphere will be very helpful as we move forward into professional teams within our various career paths, as it will allow us to continue thinking creatively and critically and will encourage all team members to share his/her insights and ideas without fear of being looked down on. We practiced our presentation skills a lot towards the end and feel like we really nailed the pitch! Overall, we were very happy to have worked with one another and to work on such a fun project!

12. Next Steps

As a team, we thought of several additional steps we can take to continue this project. Some of these next steps are immediate actions to take because they support the most important features of our product, and some are long term steps for down the road.

(1) The first important feature to test is the effectiveness of the crying detection. IBM Bluemix has the ability to distinguish a neutral baby face from one that is crying or distressed, but the tricky part is determining the “tipping point” from when a baby is sleeping to when the baby is crying. While a crying baby in the middle of the night will wake the parent, one of our selling points is being able to detect several moments before the baby starts screaming and crying, so that Lullaby can gently alert the sleeping parent that their child will start crying soon. This way, the parents will not have to be woken by screams, but rather a gentle alarm. Again there was a lot of feedback that encouraged the ability to anticipate the baby to start crying before it actually does.

(2) We crucially need to validate the data collection methods to make sure the inputs information that feed IBM Bluemix with data are properly interpreted. To do so, tests under real conditions will be required to consolidate the machine learning analysis. Also. we need to ensure that IBM Bluemix will be able to make a distinction between the sounds and movements done by the baby and any other environmental events such as an outside noise or light entering the baby room, or even a central air turning on and off.

(3) We will eventually explore the system and component aesthetics to make Lullaby more appealing for young parents who are designing their nursery and have great pride in the aesthetics of every piece of furniture. We think that having the option to chose from different animals, color themes, and patterns is ideal. The electronics console could come in a variety of animal faces like the pig as we have here, or a cow, lion, etc.

(5) The mobile interface needs to be worked on further. Right now we have a graphical user interface of medium fidelity, and there is a lot more room to continue designing. We will add color, and work on the user experience. Some of the icons and buttons themselves can be changed and spread out more evenly on the interface too.

(6) Our initial prototype contains core sensors that we believe are most necessary to create a valuable product. In the future, we would like to consider vital sensors and others that may potentially improve the accuracy of our system. We for example thought about the baby's body temperature and breathing rhythm.

(7) Down the road if our sensor capabilities prove to be highly accurate and precise, we could incorporate a health functionality that measures the baby’s vitals. That way, parents can not

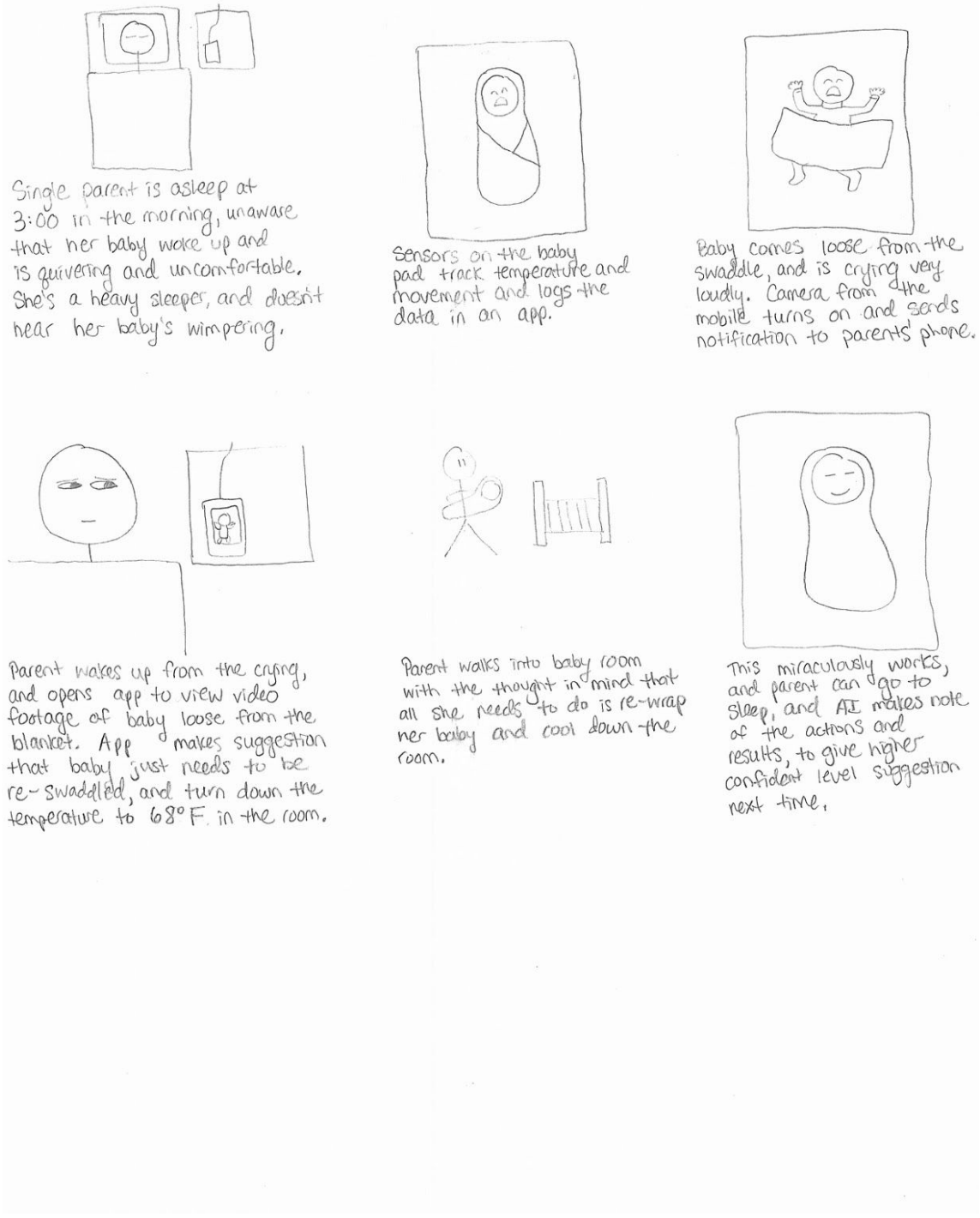
only monitor the baby's sleep and whereabouts, but also keep track of the important vitals such as temperature, heart rate, etc.

(8) In the future, it could also be possible to add a security element too. Our team thought it would be beneficial to detect intruders or warn the parents if a pet like a cat or dog is too close to the crib, or even inside the crib. So not only will this be a monitoring system, but a smart security system as well.

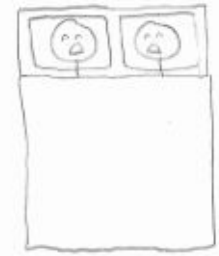
Appendix

Appendix A - Storyboards

Storyboard Prototype Scenario 1:



Storyboard Prototype Scenario 2:



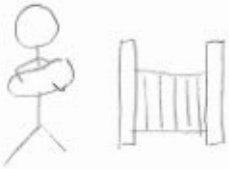
Parents are woken up by screaming and crying from their baby. They've already been woken up three times that night...

They reach over to their phone on the night stand open the app, and see video footage of their baby. They click to option to have the baby pad rock the baby.

The baby pad starts rocking the baby.

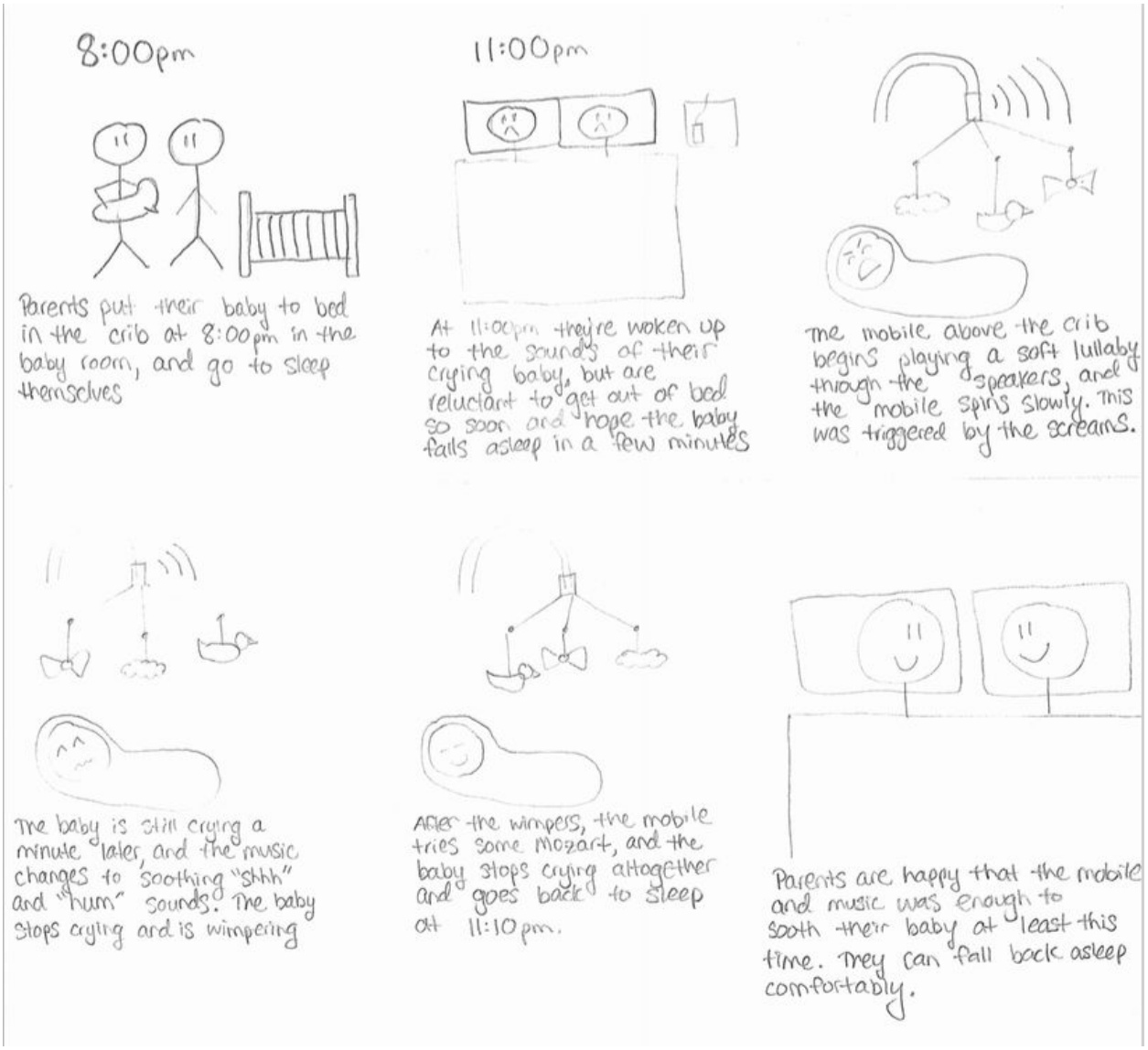
The baby pad, along with the sensors, is designed to provide an automatic rocking system by inflating individual sections at a time. The AI tracks the pace, frequency, intensity, and other features to learn the ideal rocking characteristics.

Parents can watch on their phone from their bed. The app gives them appropriate updates on how effective this is, and if their baby falls asleep, they can too!

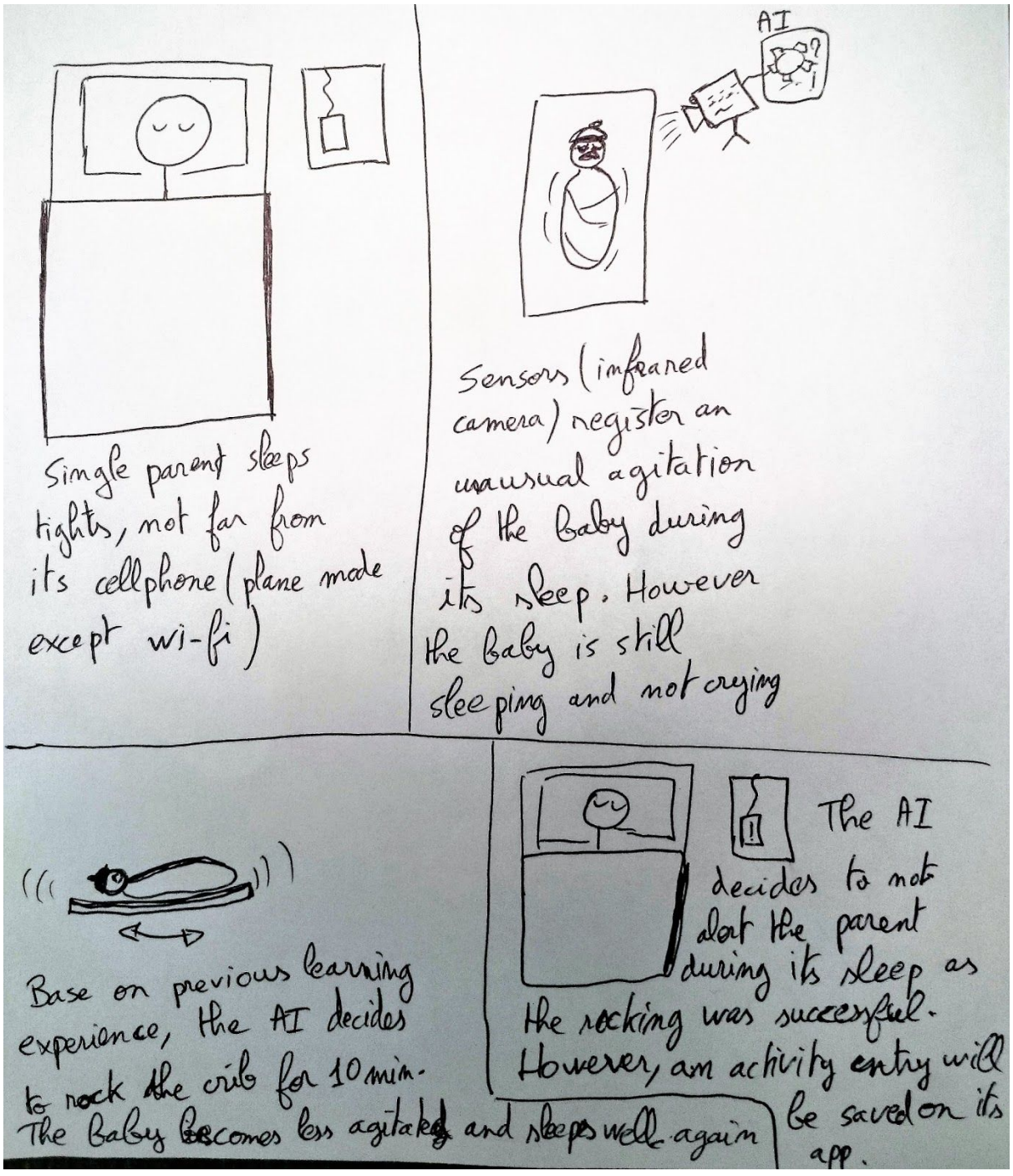


If their baby continues to cry, parents will proceed to help calm the child as normal.

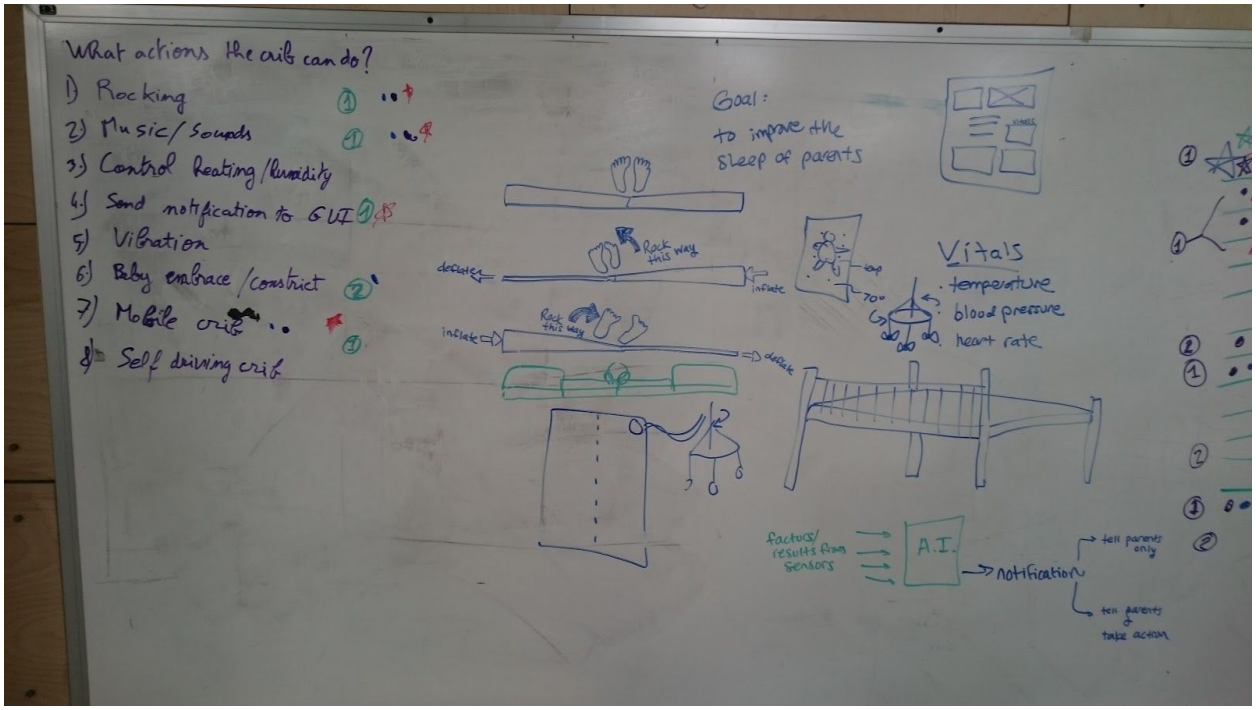
Storyboard Prototype Scenario 3:



Storyboard Prototype Scenario 4:



Whiteboard brainstorming for the Sprint on the form factor:



Whiteboard brainstorming for the Sprint on the mobile app User Interface: