Safari Scrapbook

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Abstract

A multidisciplinary team of engineering students was formed in an effort to complete the senior design project required by Miami University. The study was conducted in Camden Town, London in May and June of 2014. Students collaborated with a privately owned physical therapy business, Kiki's Clinic, located in Clapham, London. The project focus centers on developing a wear-resistant product for all ages to test grip and pinch strength. The major goal of this product is to develop a functional, safe, interactive product to make the therapist, parent and child's lives easier and positively influenced. This will include an appealing interface for the child, as well as a simple-to-read, accurate display for the monitor.

Research as to what conditions affect grip and pinch strength has been conducted as well as current methods used to assess baseline and progress levels. Safety regulations as determined by the European Union have been established and employed when constructing design ideas. After much prototyping, the final design idea was decided to be a rectangular-shaped camera with pressure sensors on each vertical handle along with a pressure sensor on the upper horizontal part that will serve as the pinch sensor. The child-friendly interface to accompany this design will be a safari scrapbook. This will allow for patient testing, along with the opportunity for the child to practice by adding more pictures to their scrapbook.

This device tests right and left grip strengths individually, simultaneously, and it also tests pinch strength. The data from the various tests will be sent out and converted to an Excel patient file. Each trial will be recorded, and a graph of strength versus time will be generated for the therapist's reference.

Overview

In order to complete the Miami University senior design project, a diverse group of engineering students relocated to London for a month to gain hands on experience with medical devices and cooperating with a client. Each day, teams spent approximately eight hours researching, brainstorming, collaborating and exploring ideas to create a human centered solution for our client. Throughout this course, the team also learned about qualities of good design, project management, and the Agile process through the use of storyboards and TED talks shown during the class.

Kiki's Clinic, a privately owned physical therapy facility located in a small residential building in Clapham, London, opened in 1996 and aims to "help children live their lives fully" [1] by offering pediatric Physiotherapy, Speech and Language Therapy and Osteopathy for newborns to children up to age sixteen. The clinic sees children with a wide variety of conditions and aims to treat each child holistically [1]. To accomplish this, the clinic uses traditional techniques and devices for measuring progress of children with disabilities, while placing an emphasis on playfulness to continually motivate and influence the children. With the constraints of limited space, a fixed budget and the necessity of a clean environment, many creative solutions must be implemented to continually monitor the children's progress.

Research of many conditions that Kiki's Clinic sees on a daily basis was conducted in order to approach the design project in a divergent manner. Students were exposed to a variety of different conditions that could contribute to aspects of future designs. Eventually, after each student shared what they learned, teams were formed based off of similar interests and varying skills.

A team comprised of three Mechanical Engineers and a Biomedical Engineer; Michael Haddad, Nick Truster, Connor Walsh and Lauren Zaucha, actively pursued a project that will test a child's grip strength, pinch strength and provide entertainment to the child. The ability to test grip strength is important in a variety of conditions such as cerebral palsy, juvenile arthritis, quadriplegia, and many more. In all of these conditions, an affected child may experience muscle weakness, muscle rigidity or a loss of motor function; therefore, grip strength is an important variable to consider when diagnosing or tracking the performance of a child.

Once the project was chosen, students worked as a team to come up with the objective of the grip strength test, observations of kids' tendencies and the environment at the clinic, conditions that affected grip strength and basic criteria. From this, "how might we…?" questions were developed, written on a Post-it® and stuck on the glass windows of the classroom. One "how might we…?" from each group was selected and the entire class of seventeen students brainstormed possible solutions.

Each group then clumped possible solutions into self-designated categories. For example, the categories used by this team were virtual reality, ball and cylinder-shaped objects to be squeezed, and motivation techniques. The categories were voted on by the dot-voting system, which helped to show what the popular vote would select; a dot was placed by class members on a Post-it® that was thought to be a good solution to the design problem. The votes were taken into consideration, but were not deciding factors in selecting the final designs.

Upon completing this process, several design ideas were discussed and selected. A couple of ideas stood out above the others, including a ball, glove, or wheel with embedded pressure sensors, a modified dynamometer, an object integrated with a compressible spring, and bicycle handlebars. All of the proposed design ideas would be associated with a child-friendly interface and would reduce the current dangers that are associated with existing methods. Additionally, these ideas would ease the life of the therapist by storing and sorting data automatically so that it did not need to be recorded by hand.

Research

Conditions affecting Grip and Pinch Strength

As a starting point for research, conditions that affect grip strength were researched. One of the more popular diseases that causes muscle stiffness, floppiness or weakness is cerebral palsy. One in 400 people in the United Kingdom is affected by cerebral palsy, and the symptoms normally become apparent during the first three years of a child's life. The severity of cerebral palsy ranges from person to person and can affect different parts of the body. Physiotherapy and occupational therapy are common treatments to relieve muscle stiffness and spasms, in which the grip strength test is usually administered to track progress [3].

Another condition that affects a person’s grip strength is Juvenile Idiopathic Arthritis (JIA). An estimated one in 1,000 children in the United Kingdom is affected by JIA, with the peak age of onset being six years. For unknown reasons, JIA is more common in girls [4]. Joint pain, stiffness and swelling are common along with joint deformities. JIA more commonly affects small joints such as those in the fingers, making this disease a large contributor to a declination in grip strength [5].

Finally, quadriplegia is a condition caused by an injury or a condition such as muscular dystrophy that damages the cervical spinal cord segments. The injury could cause loss of partial or total function in all four limbs. About 40,000 people in the United Kingdom are living with paralysis with the fraction of affected children unknown. Impairment to the arms and the legs is the most obvious symptom of quadriplegia, but impairment and loss of function in the torso is also possible. Therapy is used to strengthen muscles and regain lost function in the limbs [6].

Current Methods

Current methods to assess grip strength exist, but therapists are concerned that they are not extremely kid-friendly. Additionally, there is no one device that measures both grip and pinch strength. One method, and possibly the most popular, is the Jamar Dynamometer. The Jamar Dynamometer is a widely used system to measure handgrip strength in individuals with decreased functionality. The device uses hydraulic pressure with dial-type readout [7]. The cost of this device is around £200. The main problem the team sees with this device is that it is not child friendly. The device contains an opening in which a child’s hand could easily get lodged. The Jamar Dynamometer can be seen below.

Figure 1. The Jamar Dynamometer

Another method used to test grip strength is the Martin Vigorimeter. This device consists of a manometer connected to a compressible balloon [9]. It comes in three different sizes to fit needs of a wide spectrum of people but can tend to be quite boring with little to no positive feedback to motivate the child to want to succeed. A photo of the Martin Vigorimeter can be seen below.

Figure 2. The Martin Vigorimeter

A third method of testing handgrip strength is The Rotterdam Intrinsic Hand Myometer (RIHM). It is designed to measure the forces of the intrinsic hand muscles for research and clinical purposes. Most dynamometers on the market today only measure grip strength or pinch strength, few have the ability to record the strength of the intrinsic muscles of the hand. The RIHM is made of a strong lightweight plastic, which contains the battery, the force sensor and electronics [4]. The digital display on the top of the device shows the peak forces at which the leather band is pulled on shown in the image below.

Figure 3. The Rotterdam Intrinsic Hand Myometer

As for pinch strength, currently, there are three main types of pinch strength that are measured. These various types of pinch strength are obtained by orienting the hand in a different manner. The three types of pinch strength that are measured are tip pinch, key pinch, and palmar pinch. Each one of these measurements should be taken from a standardized position: the elbow at a 90-degree angle and a neutral wrist position preferred. Three trials should be used and averaged to ensure accuracy. The same testing instrument should be used each time. Scores should be compared to appropriate normative age and sex categories. The device must be calibrated or zeroed before each use to prevent error [9]. The three types of pinching are demonstrated below.

Figure 4. Tip Pinch

Figure 5. Key Pinch

Figure 6. Palmar Pinch

Safety Considerations

When considering the possible design options, safety was one of the most important criteria. The European Standard EN-71 has been laid out in order to set a standard for a child's, aged fourteen or less, toys. In this document, it states the requirements and test methods for mechanical and physical properties for children's toys. The goal of the EN-71 is to apply a hazard approach instead of design restrictions for toys [10]. Below are three basic definitions that are important to keep in mind when reviewing over the standards.

Table 1: Safety Definitions

Hazard	A potential source of harm
Risk	The probable rate of occurrence of a hazard causing harm and the degree of severity of the harm;
Harm	Physical injury or any other damage to health, including long-term effects.

A breakdown of series guidelines that should be considered when designing toys is outlined in this document. All toys should be designed and manufactured in such a way as to meet hygiene and cleanliness requirements in order to avoid any risk of infection, sickness or contamination. Also, the materials used are needed to be new, or, if reprocessed, the level of contamination of hazardous substance must not exceed that of a new material. In addition, there should be no infestation from animals or vermin [10]. Below is a list test that the European Standard specifies different forces and/ or loads to be used when testing toys targeted for children of different age groups:

Table 2: European Standard List Test

1. Small Parts Cylinder	15. Geometric Shape of Certain Toys
2. Torque Test	16. Durability of mouth-actuated toys
3. Tension Test	17. Folding or sliding mechanisms
4. Drop Test	18. Electric resistivity of cords
5. Tip Over Test	19. Dynamic Strength
6. Impact Test	20. Stability
7. Compression Test	21. Determination of Kinetic Energy
8. Soaking Test	22. Plastic Sheeting
9. Accessibility of a part or Component	23. Determination of emission sound pressure levels
10. Sharpness of Edges	24. Measurement of Temperature Raise
11. Sharpness of Points	25. Small Balls and Suction Cup Test
12. Flexibility of metallic Wires	26. Perimeter of Cords and Chains
13. Expanding Materials	27. Length of Cords
14. Leaking of Liquid Filled Toys	

The electrical wire that will connect the pressure sensors with the Arduino board and computer will be excluded from the definition of cords, which the European Union declares a hazard, because the cable length might not allow the toy to function properly. TVs and computers on their own are not considered toys and any electrical cables used to connect a toy to a computer/TV is considered an accessory of the computer or TV [10].

Proposals

Criteria

The team considered the criteria that Kiki's clinic required and determined the importance of each of these requirements. First and foremost, the final product must be size conscious because the clinic is very limited on storage space. Therefore, the team decided our final design should not be larger than one square foot and should weigh less than 2.27 kg, to increase portability. To further reduce storage space, the project design would also need to be one universal size and be able to be used ambidextrously to ensure the entire sixteen-year age span could utilize the product. Next, the product must be robust; it must be capable of measuring a high force without failing, withstand wear and frequent cleaning. Additionally, the design needs to be precise, within a margin of five percent of the actual grip force. The group also believed the design should be low-cost, so a requirement of £150.00 maximum for the final project was place on the project. To reduce cost, the group limited designs to entail ten force sensors at most. Safety was also stressed in the design criteria; the product must be large enough so small kids do not swallow it, able to withstand chewing, fire resistant, and a number of other safety criteria as listed on a European website. Finally, the design must be easy to use, entertaining, motivating, and able to provide positive feedback to the child.

The selection matrix was used to aid in narrowing design ideas can be seen below in **Table 1.** Each requirement was given a weight based on the importance of the requirement. When creating this table, the group also considered products based on a need to be used with the wrist in its neutral position, because a neutral position yields the most accurate representation of wrist strength [2].

Table 3: Selection Matrix

Criteria	space/ weight	Robust	Precise Measurement	Cost	Correct Wrist Orientation	Safe	Entertaining	Ease of use	Total
Weight	0.150	0.150	0.150	0.125	0.125	0.10	0.10	0.10	

Using the above criteria and its weighted importance, six design ideas were selected from the larger pool of possibilities. The first design idea, a ball with a pressure sensor incorporated, would include a small ball composed of a malleable material, such as gel or foam, that would be equip with a pressure sensor that would be able to sense the force exerted from a child squeezing the ball. This ball is small, light and robust, and also fairly inexpensive. The ball model would be associated with a kid-friendly and motivational interface such as a lemonade stand with the ball serving as the “lemon”. The harder the ball, or “lemon”, was squeezed, the more lemonade that would appear, thus motivating the child to want to squeeze harder, which is why the ball ranked fairly high. This design is simple, interactive, and motivational, which meets many of the design criteria, allowing the ball to receive high scores in these areas. However, the ability of the force sensor inside the ball to precisely measure grip strength was not as precise as other methods depending on the material chosen. Also, with a ball it would be difficult for a child to keep their wrist in the proper orientation used for testing. A drawing of the ball with an incorporated pressure can be seen below.

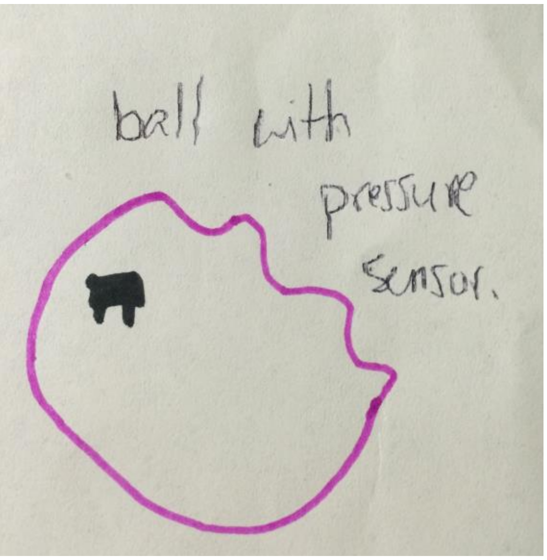


Figure 1. Ball Incorporated Pressure Sensor

The second design idea consists of a glove that has a force sensor integrated in each finger of the glove. The force sensor would read grip strength the same way the ball, but it could be used on a variety of objects. However, the glove model is not very robust; many different sizes of gloves would be needed to cover the range of hand sizes of children from newborns to sixteen years old. Additionally, these gloves would not be easy to sanitize after each use. The glove also would have to have at least five outputs, one for each pressure sensor. The combination of these aspects would make this design less safe, harder to create, and harder to use. A sketch of the glove's design can be seen below.

Figure 2. Glove with Incorporated Pressure Sensors

The third design idea was modifying a dynamometer, which is the existing instrument used to test grip strength, into a gaming console. This design option would also be associated with a kid-friendly interface, such as the instrument being a drill, where the harder it was squeezed the deeper the hole drilled would be. The main advantage of this design is the tool would be extremely precise and child friendly. Also, this design would be easy to use, since physical therapists understand how to operate the dynamometer. A concern of this existing model is the safety of a child when operating this instrument. Since the dynamometer is being squeezed, the child's hand could easily get stuck or pinched, making this a more unsafe option. Also, a dynamometer could be harder to clean because of the many grooves and intricacy of the design. A sketch of the modified dynamometer can be seen below.

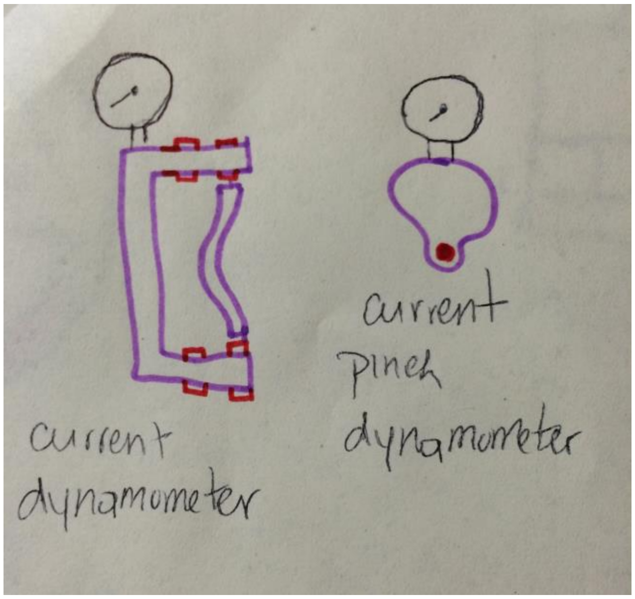


Figure 3. Modified Dynamometer

The fourth design idea is an object that would be equip with a spring. The distance the spring was compressed would correspond to the force exerted on the object. It would include software that would take the displacement of the spring from its original length and generate the force exerted based on Hooke's law. The spring would be compact, lightweight and fairly cheap, but there are also drawbacks. The spring design would not be very precise because different starting lengths would need to be used for different hand sizes, which would make generating a "gold standard" of normative data extremely difficult. Also, there would not be very much motivation present with the action of squeezing a spring, so the child may not try their hardest or get bored relatively easily. A sketch of the spring that would be incorporated into a simple shaped object can be seen below.

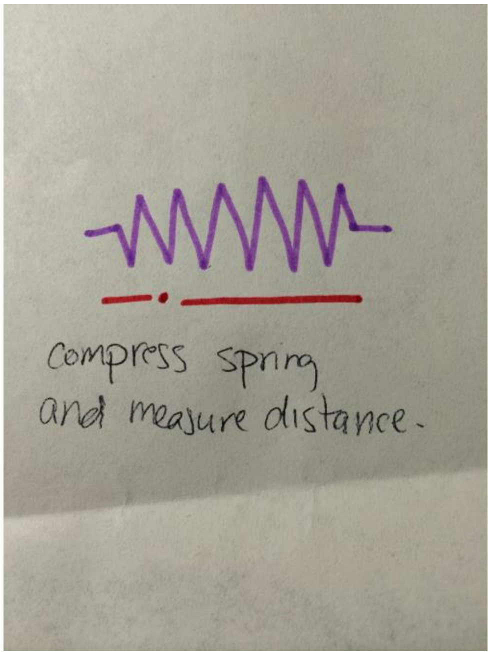


Figure 4. Spring Object

The fifth design idea is a steering wheel with integrated pressure sensors. With this design, the child would act as if they were driving a vehicle. The harder the child squeezed, the faster the vehicle would move, eliciting much positive reinforcement and hopefully more effort in return. Also, the natural way to hold a steering wheel is the preferred orientation for testing grip strength. In contrast to a ball design, the wheel would be stationary, so it would be harder to move it and move away from improper orientation while being tested. The wheel would not be as space-conscious and might end up costing a larger amount of money as some of the other proposed designs due to the intricacy of the design. A sketch of the steering wheel with pressure sensors can be seen below.

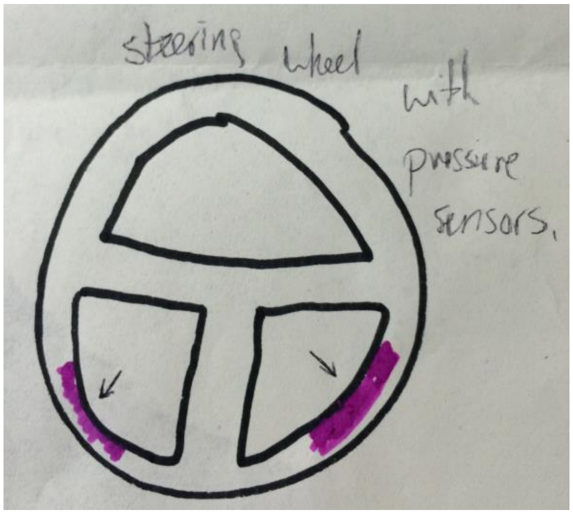


Figure 5. Steering Wheel with Pressure Sensors

The sixth design proposal is bicycle handles in which pressure would be measured with a gauge. In order for proper wrist orientation to be achieved, the handlebars would have to mimic those on a marathon bike: standing straight up. This design would be robust and very easy to maintain while entertaining at the same time. The goal of the associated interface would be to squeeze the handlebars harder to make the bicycle go faster. The biggest problem with the bicycle handlebars is the amount of space they would take up; they are not easily stored or very portable. A drawing of the handlebars can be seen below.

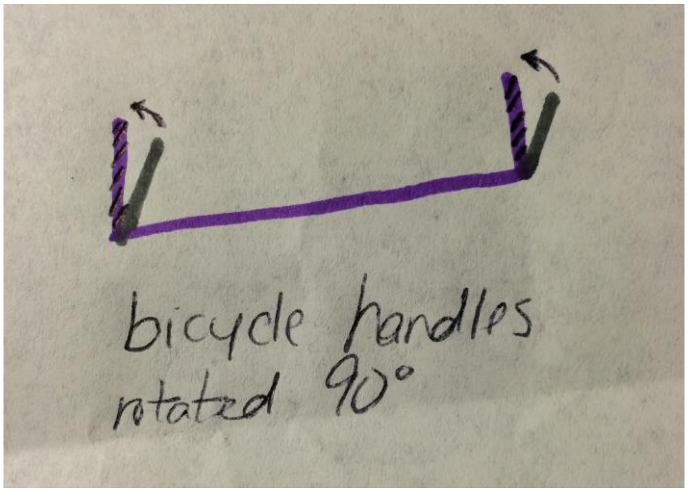


Figure 6. Bicycle Handlebars

When considering the design criteria required by Kiki's clinic, along with the additional requirements of the group, these ideas were selected as the top contenders. These six design ideas based on the needs of the clinic and the given timeframe were determined and ranked upon the specified criteria listed in the matrix. The scored design ideas can be seen in the finalized selection matrix below.

Table 4. Scored Selection Matrix

Criteria	Space/ Weight	Robust	Precise Measurement	Cost	Correct Wrist Orientation	Safe	Entertaining	Ease of use	Total
Weight	0.150	0.150	0.150	0.125	0.125	0.10	0.10	0.10	

Ball with Pressure sensor	3	3	2	3	1	3	2	3	2.5
Glove With Pressure Sensors	1	1	2	1	1	1	3	1	1.35
Modified Dynamometer	3	3	3	2	3	2	1	1	2.375
Compress Spring	3	2	1	2	2	2	1	2	1.9
Steering Wheel with Pressure Sensors	2	3	3	3	3	3	3	3	2.85
Bicycle Handles	1	3	3	3	3	3	3	2	2.6

Design Deliverable

Design

After reviewing the possible design ideas, a combination of Figure 5 and Figure 6 was selected. The rectangular-shape of the bicycle handlebars provided a guaranteed proper orientation of the arms and wrist. The pressure sensors used to detect grip strength will lie in the two vertical parts of the camera, and the sensor used to determine pinch strength will lie on the upper horizontal part of the camera. The type of pinch this device will be capable of measuring is the key pinch. Since space was a concern with the handlebar design idea, a smaller design was employed to make storage easier. Photos of the final design can be seen below.

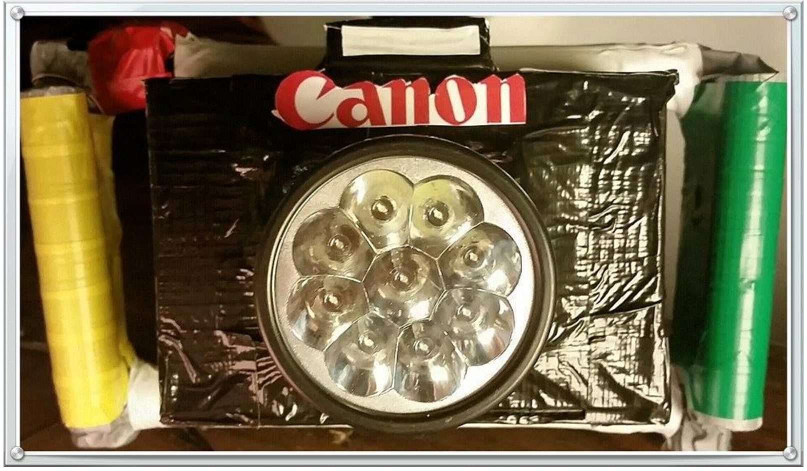


Figure 7. Front of Final Design

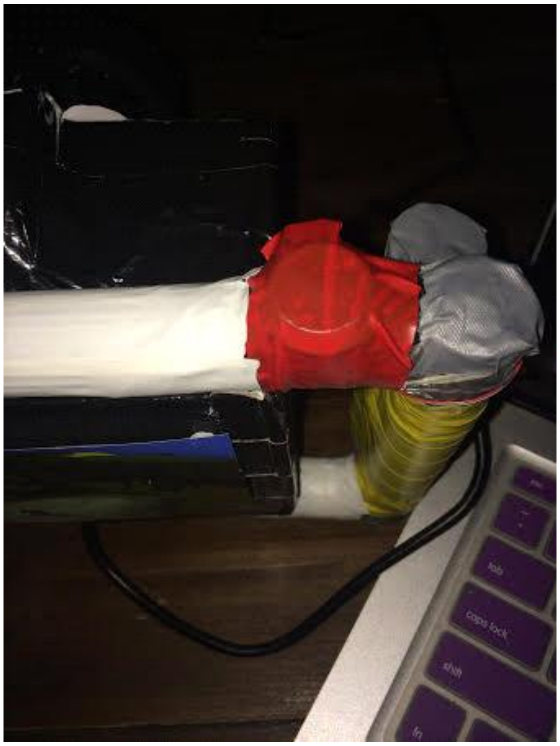


Figure 8. Attached Pinch Sensor as Capture Button

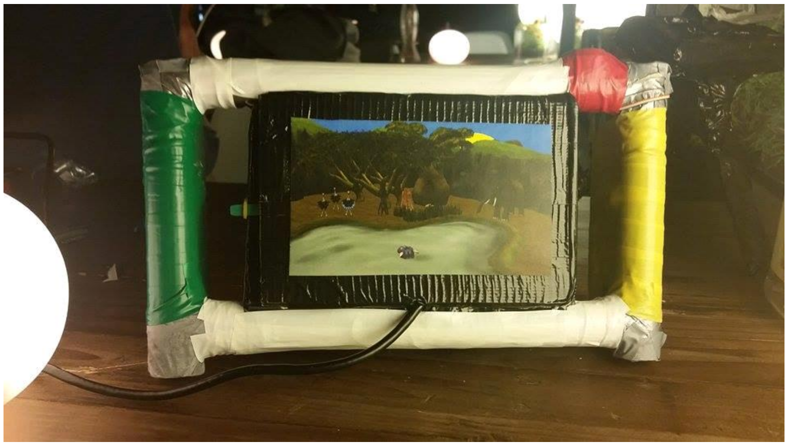


Figure 9. Back View of Camera

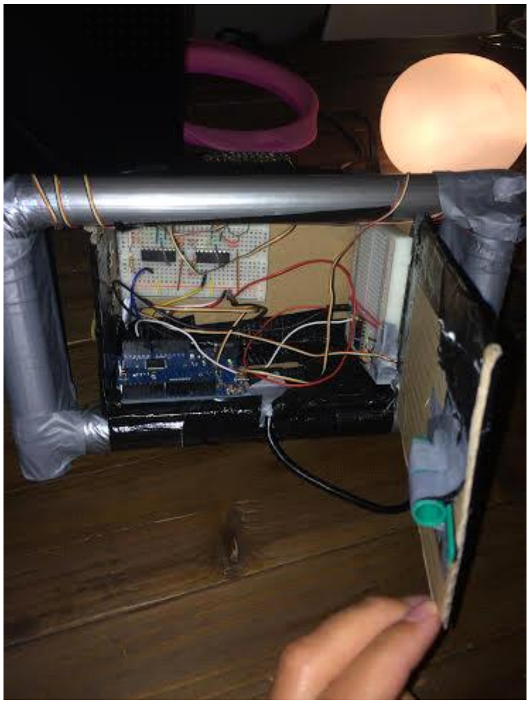
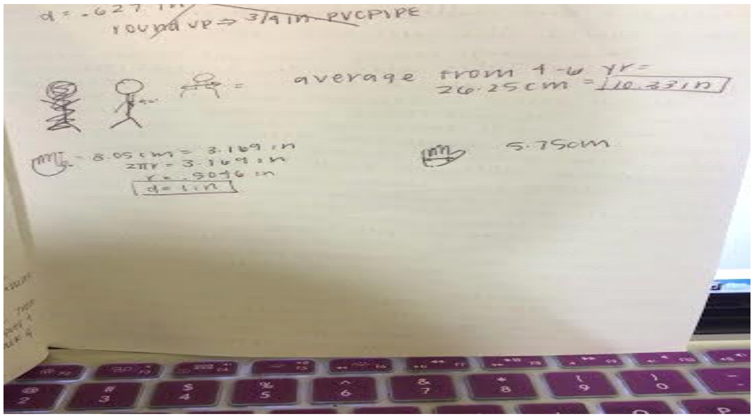


Figure 10. Flap Door for Storage

The dimensions of the product were determined based off of anthropometric data of children provided by AnthroKids. Hand size and shoulder breadth needed to be considered when generating a model of the mechanism. The length of a child's hand from the tip of the middle finger to the base of the thumb, the portion of the hand capable of making a fist, was determined to be 8.05 cm, or 3.2 in [13]. The formula for the circumference of a circle was used to determine the diameter a child was capable of forming. This diameter was determined to be one inch, which aided in selecting the size of the material outlining the rectangular testing object. The breadth of a child's shoulders was determined to be 26.25 cm, or 10.33 in [13]. This data point was needed when considering how large to make the camera of the safari vehicle. A photo of basic calculations can be seen below in Figure 15.



d = .627 in
~~round up ⇒ 3/4 in PVCPIPE~~

= average from 4-6 yr = 26.25cm = $\boxed{10.33in}$

= 8.05cm = 3.169 in
2πr = 3.169 in
r = .5046 in
$\boxed{d = 1 in}$

5.75cm

Figure 11. Anthropometric Data

Electronics

The team has incorporated 3 sensors into the main structure of the design. These sensors measure the left and right grip strength along with pinch strength. The sensors themselves are produced by Measurement Specialties and are model FX1901 load cells. These sensors are wired to an Arduino board that will convert the voltage output to a useable force value. Due to the low voltage values seen by the load cells, an amplifier has been implemented for each one. These amplifiers up the voltage to a more useable value range, which is recorded in our testing. This voltage will then be converted to a force value.

The first Arduino board that was implemented was the Arduino Uno, which performed well with the components we had. However, it was soon decided that we would use the output values to simulate keystrokes on the computer to run the game interface. This could not be accomplished using the existing Uno board. Therefore, an Arduino Leonardo was ordered, which is similar to the Uno in terms of hardware, but also has the capability to interpret keyboard functions that will be used to run the Alice gaming software on the computer.

Specifically, there will be four outputs that correspond to four different keystrokes. Squeezing both hands, left hand only, right hand only, and pinching will simulate the up, down, left, and right keys, respectively. Using this technique, the user will be able to navigate through the gaming interface without having to take their hands away from the controller.

Once the Arduino board converts the voltage value to a force value, the Arduino program communicates through serial ports with Processing. The Processing program writes the text file and saves the information. The program generates the text file output, which will be complied and visually formatted by the Web Design Team.

The code developed to allow this product to function can be seen in Appendix B. The Circuit Diagram can be seen in Appendix C. Photos of the flow of both the system events and Arduino sequencing can be seen below.

Figure 12. System Flow Chart

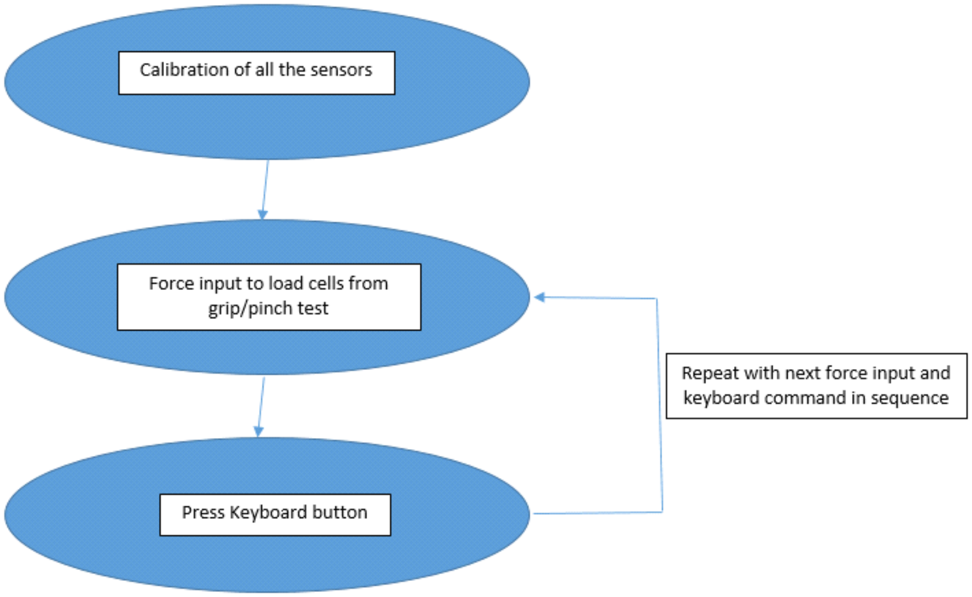


Figure 13. Arduino Logic Flow Chart

Interface

In an effort to make the grip strength task as entertaining as possible, a kid-friendly user interface was developed. The theme of the grip strength mechanism will be a safari photo album. Alice 3.1 will be used to generate the gaming system. The child will be the driver of a jeep on a safari, and their goal will be to build up a photo album.

In order to turn on the Jeep and the camera, the child will need to squeeze both handles as hard as possible; this will assess the child's capabilities of utilizing both hands simultaneously. The computer screen will show an overview of the jungle and then focus in on the various animals. The therapist will instruct the child to take a picture of one of the animals; an elephant, for example. The child will then pinch the sensor on the device as hard as they can to take a picture of the animal.

After the picture is taken, the photo will then appear alongside a blank scrapbook page. The child will squeeze the left handle of the camera as hard as they can to put glue down on the paper, and after they will squeeze the right handle as hard as they can to put a sticker on the picture. Finally, the camera will "shut off" and will not be reactivated until both handles are squeezed once again. Screenshots of various parts of the interface can be seen below.

Figure 14. First Scene Prompt

Figure 15. Safari View

Figure 16. Camera Scope

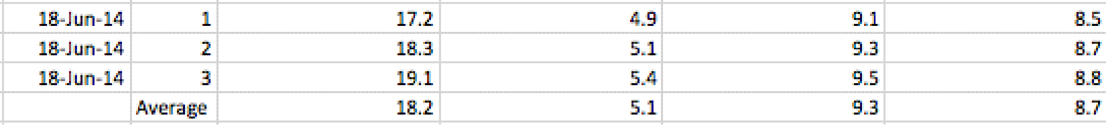
Figure 17. Scrapbook View

INSERT FLOW DIAGRAM   FOR ALICE

Data Output

When a child exerts pressure on the force sensors, the Arduino program communicates through serial ports with Processing. A text file output is generated, which will be complied and visually formatted to look like the figure below. The data is organized in a visually appealing, easy to understand graph so that the therapist can easily compare progress over the span of therapy. Examples of data in a table and chart form can be seen below.

Table 5. Sample Data



Session Date	Trial	Dual Grip Strength (N)	Pinch Strength(N)	Right Hand Grip (N)	Left Hand Strength (N)
18-Jun-14	1	17.2	4.9	9.1	8.5
18-Jun-14	2	18.3	5.1	9.3	8.7
18-Jun-14	3	19.1	5.4	9.5	8.8
	Average	18.2	5.1	9.3	8.7

Figure 18. Sample Data Chart

Cost Analysis

A list of the materials used in constructing the Safari Scrapbook mechanism can be seen below in Table 6.

Table 6: Material List

Component	Specification	Location/Store	Quantity	Price Per Unit	Total Price
Microcontroller	Arduino Leonardo	Maplin	1	£14.00	£14.00
Amplifier	Texas Instruments INA125P	Maplin	3	£7.00	£21.00
Printer Cable	USB 2.0 High Speed A to B	Maplin	1	£4.00	£4.00
Connecting wires	Red, Black, Yellow	Maplin	N/A	£3.00	£3.00
Resistor	1kOhm	Maplin	3	£0.15	£0.45
Breadboard	Half Sized	Maplin	2	£6.00	£12.00
Load Cell	Measurement Specialties FX1901	Mouser Electronics	3	£19.00	£57.00
Mop Stick	N/A	99 Pence	1	£0.99	£0.99
Camera Lens	N/A	99 Pence	1	£0.99	£0.99

Adding the total prices up, the total comes to around £115.00. A quality dynamometer is on the market for around £200.00. The current models do not provide the entertainment and intrinsic motivation that the Safari Scrapbook Mechanism incorporates. The customer will get more value from a lower cost.

Conclusions

At the end of week two, the team had gained an immense amount of knowledge in many different subject areas. Common conditions that use the strength test to assess and monitor progress of grip strength of the along with current methods of testing grip strength were discovered and none of them were found to be especially kid-friendly or motivating. This sparked ideas and elicited much brainstorming for creating a child-friendly and motivating interface to allow the child to want to excel.

Upon completion of week three, a final design was selected and prototyped. The final design is an expansion on a hybrid of two ideas that were generated in week two. A model design was constructed along code was generated and adjusted to correspond with the microcontroller, A 3D design was sketched on CAD, and the interface on Alice 3.1 was developed, allowing students advance skills regarding multiple technological platforms.

The Safari Scrapbook mechanism was chosen above other design ideas for a multitude of reasons. The product is very cheap to construct, and it is unlike any other strength test on the market. One of the most important aspects of this product is the metaphoric story behind the functional purpose it serves. The story of a child having the ability to go on a safari and create a photo album is a big motivator for the child to want to “add more pictures” to their album. Whilst adding photos, the child is actually practicing the squeezing motion. Practice creates muscle memory and therefore enhances performance.

Added values of safety also accompany the Safari Scrapbook mechanism. The worry of a child’s hand being stuck in the existing dynamometers is eliminated; the criteria distributed by the European Union are exceeded. Additionally, the product was designed in such a way so as to subconsciously force the child to keep their elbows at a ninety-degree angle with their wrists in a neutral position.

The Safari Scrapbook mechanism is also one of very few therapy assessment tools to incorporate both grip and pinch strength testing. This reduces the amount of equipment an office would need to purchase, reducing both the cost and the amount of space the tool takes up.

Working on a project where multiple disciplines were required, such as this, allowed all group members to step outside of their comfort zone. The team developed a finished product that met all criteria of both the customer and the design requirements. The final product is a compact, neat design that only has one cord as an output. The Alice program allowed for a very child-friendly interface, which will allow kids to be motivated to practice and be tested.

The presentation of the device at Kiki’s clinic allowed students to practice professional techniques and exercise communication skills. The process of gathering data and incorporating it into an informative presentation further advanced existing knowledge surrounding interpersonal communication between designers and clients.

If given an opportunity to improve upon this iteration, a few adjustments would be made. First of all, the camera would be constructed out of a material that is more durable than cardboard. If given more time, a camera out of plastic could be created to increase the longevity of the life of the product. Another aspect that could be considered if given more time would be the addition of more levels. An easy, medium and hard level could be created to stimulate the child and encourage progress. A final change that would be made would be to change the Alice code from having twelve inputs to four inputs, so that the Arduino software does not have to run through four iteration each time the game is played.

References

[1] "Kiki's Children's Clinic." *Kikis Clinic CONDITIONS TREATED Comments*. N.p., n.d. Web. 05 June 2014. <http://www.kikisclinic.com/conditions-treated/>.

[2] Stam, H. J., F. Eijskoot, A. Den Ouden, and Ton A.R. Shreuders. *The Rotterdam Intrinsic Hand Myometer (RIHM) A Technical Note* (n.d.): n. pag. Web. 5 June 2014.

[3] "Cerebral Palsy ." *Cerebral Palsy*. N.p., n.d. Web. 05 June 2014. <http://www.nhs.uk/conditions/cerebral-palsy/pages/introduction.aspx>.

[4] Martin, Kate, Dr. "Juvenile Idiopathic Arthritis (JIA) Explained." Childrens Chronic Arthritis Association, n.d. Web. 05 June 2014. <http://www.ccaa.org.uk/index.php?id=3>.

[5] "Juvenile Rheumatoid Arthritis." - *Physiopedia, Universal Access to Physiotherapy Knowledge.* N.p., n.d. Web. 05 June 2014. <http://www.physio-pedia.com/Juvenile_Rheumatoid_Arthritis>.

[6] "Quadriplegia and Quadriplegic." *Quadriplegia : Quadriplegic*. N.p., n.d. Web. 02 June 2014. <http://www.apparelyzed.com/quadriplegia-quadriplegic.html>.

[7] “Jamar Hydraulic Hand Dynamometer." *Jamar Hydraulic Hand Dynamometer*. N.p., n.d. Web. 06 June 2014. <http://www.protherapysupplies.com/Shop-by-Brand/Patterson-Medical/Jamar-Hydraulic-Hand-Dynamometer>.

[8] "Result Filters." *National Center for Biotechnology Information*. U.S. National Library of Medicine, n.d. Web. 06 June 2014. <http://www.ncbi.nlm.nih.gov/pubmed/8602475>

[9] "Baseline Evaluation Instructions." *Fabrication Enterprises, Inc.* (n.d.): n. pag. *Baseline Products*. Fabrication Enterprises, Inc. Web. 3 June 2014.

[10] Malamud, Carl M. *Safety of Toys* (2009): n. pag. AFNOR — French Standard Institute. Web. 5 June 2014. <https://law.resource.org/pub/fr/ibr/nf.en.71.1.e.2011.pdf>.

[11] "Force Sensor - FX1901." *FX1901-Force Sensors-Force Sensor Elements-Measurement Specialties*. Measurement Specialties, n.d. Web. 05 June 2014.

[12] "Load Cell with an Arduino." *Load Cell with an Arduino*. The University of Chicago, n.d. Web. 05 June 2014. <http://edg.uchicago.edu/tutorials/load_cell/>

[13] "AnthroKids - Anthropometric Data of Children." *AnthroKids - Anthropometric Data of Children*. N.p., n.d. Web. 13 June 2014. <http://ovrt.nist.gov/projects/anthrokids/>.

Acknowledgements

The team would like to thank Dr. Michael Bailey-Van Kuren for making this project possible and providing insight and lessons surrounding design and the design process.

Additionally, the team would like to thank Kiki’s Clinic for providing open-ended designs that could be studied, researched and developed to complete this project.

About the team

The design team is comprised of four students from Miami University. Michael is a mechanical engineering major who recently graduated; he serves as the Task Manager, where he will keep up with the Kanban system developed to stay on track throughout the project. He has professional experience as an intern at Lear Corporation in the seating systems division. His skills include Arduino coding, Autodesk Inventor and Matlab.

Nick Truster is a senior mechanical engineering major at Miami Univeristy. Nick’s position on the team of four is the Project Manager; he will head up group meetings and take a lead role on making sure guidelines are being adhered to. Previously, he interned at Messer Construction and served as a BSG Engineer/ Project Manager. His skills include project management, CAD and Arduino coding.

Connor Walsh is also a senior mechanical engineering major at Miami Univeristy. Connor is the Risk Manager; he aided in developing a plan to avoid catastrophe in the event plans do not go smoothly, such as ordered parts not being delivered, Wi-Fi going down, a team member falling ill, etc. Connor was a part of the Office Support Staff for Sylvan Lake Family Physicians last summer and is proficient in Microsoft Office, Excel, Outlook, PowerPoint, Matlab, Auto Desk Inventor 10, Abaqus, and MapleSim.

Lauren Zaucha is a senior Biomedical Engineering major at Miami University. She serves as the Chief editor who is in charge of compiling all background information, research and data collected. Lauren was a Research Intern in a Biomedical Engineering lab at The Cleveland Clinic last summer and will return upon the ending of this project. Her skills include physiology knowledge, Matlab, Arduino coding, Abaqus and Microsoft Office programs.

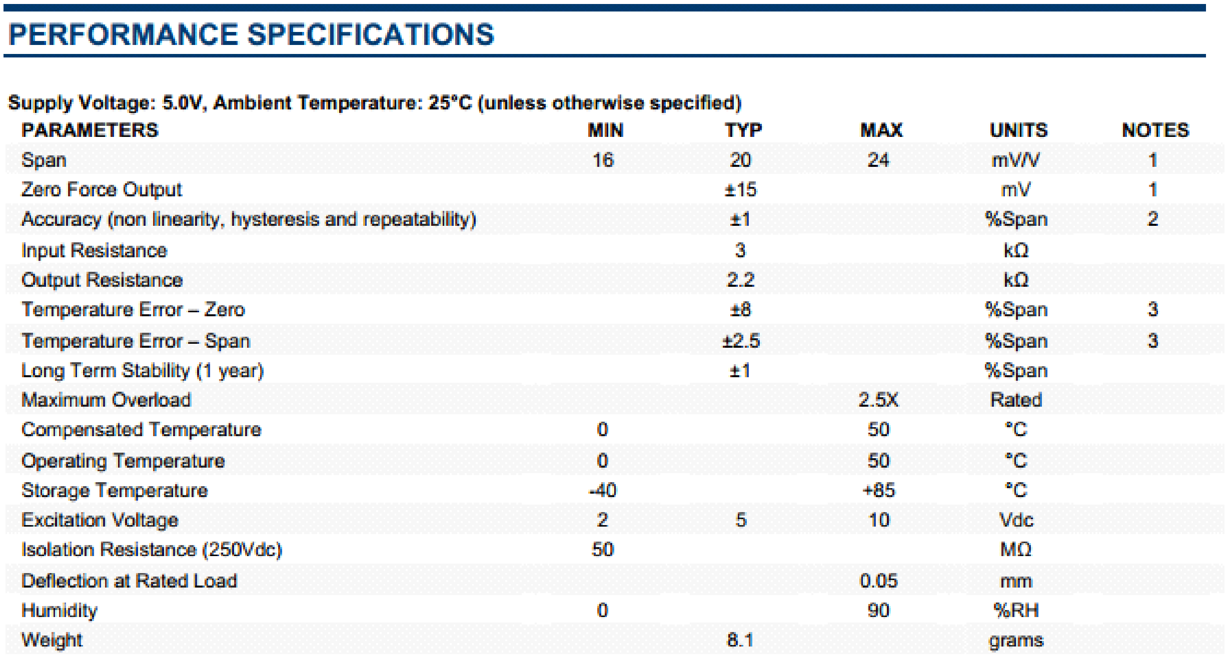
Appendices

Appendix A: Specifications for Measurement Specialties FX1901 Compression Load Cell

Appendix B: Code for the force sensors

Appendix A

Specifications for Measurement Specialties FX1901 Compression Load Cell:

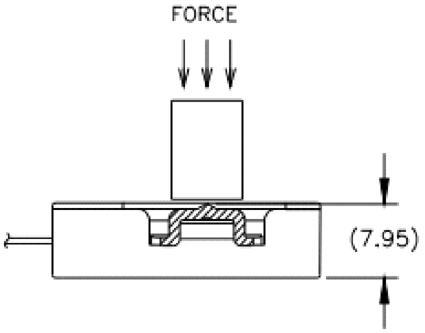


PERFORMANCE SPECIFICATIONS

Supply Voltage: 5.0V, Ambient Temperature: 25°C (unless otherwise specified)

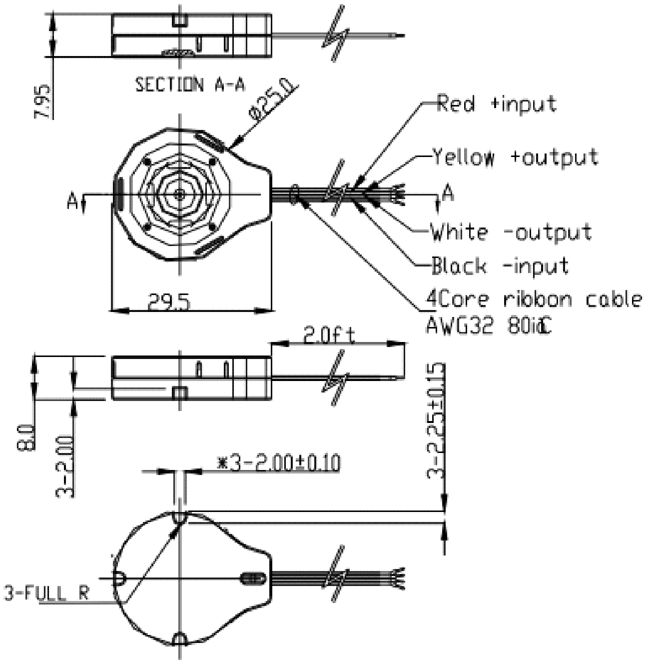
PARAMETERS	MIN	TYP	MAX	UNITS	NOTES
Span	16	20	24	mV/V	1
Zero Force Output		±15		mV	1
Accuracy (non linearity, hysteresis and repeatability)		±1		%Span	2
Input Resistance		3		kΩ	
Output Resistance		2.2		kΩ	
Temperature Error – Zero		±8		%Span	3
Temperature Error – Span		±2.5		%Span	3
Long Term Stability (1 year)		±1		%Span	
Maximum Overload			2.5X	Rated	
Compensated Temperature	0		50	°C	
Operating Temperature	0		50	°C	
Storage Temperature	-40		+85	°C	
Excitation Voltage	2	5	10	Vdc	
Isolation Resistance (250Vdc)	50			MΩ	
Deflection at Rated Load			0.05	mm	
Humidity	0		90	%RH	
Weight		8.1		grams	

FORCE APPLICATION

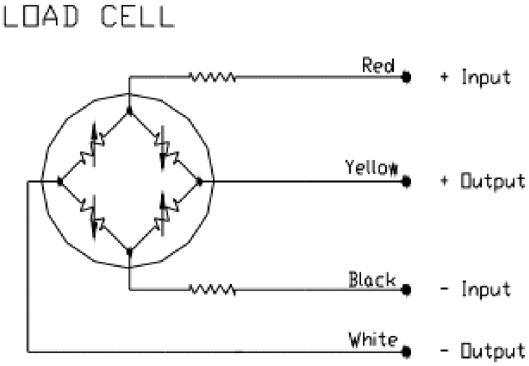


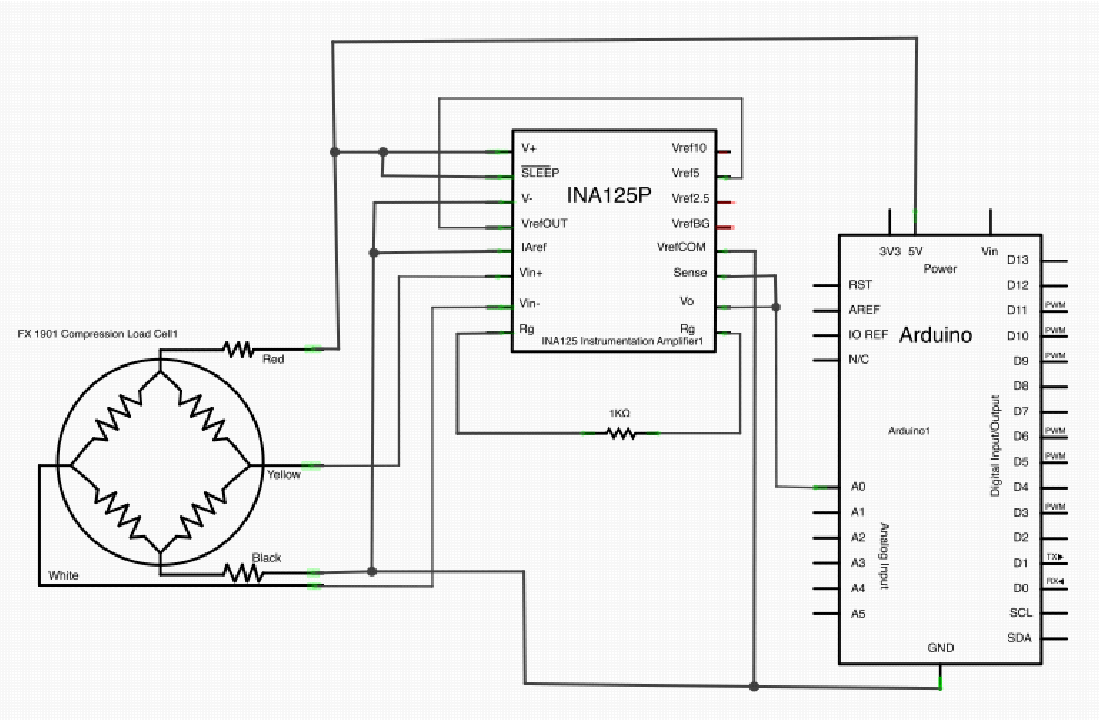
LOAD MUST ONLY BE APPLIED TO THE CONCENTRATOR TIP IN THE CENTER OF THE SENSOR TO MAINTAIN ACCURACY

DIMENSIONS



CONNECTIONS




V+
SLEEP
V-
VrefOUT
IAref
Vin+
Vin-
Rg
INA125P
Vref10
Vref5
Vref2.5
VrefBG
VrefCOM
Sense
Vo
Rg
INA125 Instrumentation Amplifier1
FX 1901 Compression Load Cell1
Red
Yellow
Black
White
1KΩ
3V3
5V
Vin
Power
RST
AREF
IO REF
N/C
Arduino
Arduino1
A0
A1
A2
A3
A4
A5
Analog Input
D13
D12
D11
D10
D9
D8
D7
D6
D5
D4
D3
D2
D1
D0
SCL
SDA
PWM
PWM
PWM
PWM
PWM
PWM
TX▸
RX◂
Digital Input/Output
GND

Appendix B

```
  // Calculate load of right sensor based on A and B readings above
  int loadR = ((bLoad - aLoad)/(bReading - aReading)) * (newReadingR - aReading) + aLoad;
  int loadL = ((dLoad - cLoad)/(dReading - cReading)) * (newReadingL - cReading) + cLoad;
  int loadP = ((fLoad - eLoad)/(fReading - eReading)) * (newReadingP - eReading) + eLoad;


  // millis returns the number of milliseconds since the board started the current program
  if(millis() > time + interval) {


   // squeeze both hands to start the game
  if (loadL >= 10 && loadR >= 10 && d) {
      Keyboard.press(KEY_UP_ARROW);
      Keyboard.releaseAll();
      Serial.print("Right: ");
      Serial.println(loadR);
      Serial.print("Left: ");
      Serial.println(loadL);
      Serial.println();
      delay(2000);
       a = true;
       d = false;
}

   // pinch the sensor to take a picture
  if (loadP >= 15 && a)  {
    Keyboard.press(KEY_DOWN_ARROW);
    Keyboard.releaseAll();
     Serial.print("Pinch: ");
     Serial.println(loadP);
     Serial.println();
     delay(5000);
     b = true;
     a = false;
     d = false;
  }
```

```
// grip of the left hand
 if (loadL - loadR >= 15 && b) {
   Keyboard.press(KEY_LEFT_ARROW);
   Keyboard.releaseAll();
   Serial.print("Left: ");
   Serial.println(loadL);
   Serial.println();
    delay(3000);
    c = true;
    b = false;
    d = false;
 }

// grip of the right hand
 if (loadR - loadL >= 8 && c)  {
     Keyboard.press(KEY_RIGHT_ARROW);
     Keyboard.releaseAll();
     Serial.print("Right: ");
     Serial.println(loadR);
     Serial.println();
     Serial.println("************************************************************************************************");
     Serial.println();
      delay(2000);
      c = false;
      d = true;
   }

  time = millis();
}
```